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# The nutritive value of cereals and its relation to processing

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# THE NUTRITIVE VALUE OF CEREALS AND ITS RELATION TO PROCESSING

By

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# PART I

## THE CONTENT OF THE VITAMIN B COMPLEX IN WHEAT AND OATS AND THEIR PRODUCTS PRODUCED IN THE MANUFACTURE OF CERTAIN CEREALS

## INTRODUCTION

The vitamin B complex is composed of at least two essential dietary factors, namely, vitamins B and G. Vitamin B, the antineuritic factor, is heat labile and a deficiency of this substance in the diet causes beriberi in man and polyneuritis in fowls and other animals. Vitamin G, the P. P. factor of Goldberger, is relatively heat stable. A deficiency of this vitamin in the diet produces pellagra. Both vitamins B and G, collectively the vitamin B complex, are essential for normal growth of the organism.

A considerable amount of work has been done in regard to the distribution of the vitamin B complex, and it has been found to be most widely distributed. Cereal grains have been found to be relatively rich sources of the vitamin B complex.

Cereal grains have been thoroughly investigated and some work has been done on the distribution of the vitamin B complex in the different parts of grains, but relatively little consideration has been given to the effect of the processing of the cereal grains in the manufacture of breakfast foods. In this paper a study is made on the effect of the nutritive value of the products produced during different steps of the processing in the manufacture of Kettlejohn's breakfast food, puffed wheat, rolled oats, and puffed rice.

## REVIEW OF LITERATURE

A number of investigators have made a study of the content of the vitamin B complex in the wheat and oat grains but there appears to be a diversity of opinion as to the quantity present. McCollum, Simmonds and Pitz (34) studied the dietary properties of the wheat kernel and found that 15 per cent of whole wheat in the diet supplied sufficient vitamin B for normal growth and the production of a nearly normal number of young. Osborne and Mendel (60) also came to the conclusion that 15 per cent of whole wheat in the diet supplies sufficient vitamin B for normal growth. They state that this is about the minimum. Guest, Nelson, Parks and Fulmer (19) found that 10 per cent of whole wheat contains sufficient vitamin B for normal growth.

Bell and Mendel (2) observed that spring wheat contains a greater amount of vitamin B than winter wheat. They found that 15 per cent of spring wheat or 40 per cent of winter wheat was necessary to supply adequate amounts of vitamin B for normal growth. Bell and Mendel found that the vitamin B in the Minnesota winter wheat was divided among the various milling products as follows: patent flour contains from zero to five per cent, first clear from 10 to 15 per cent, second clear five per cent, low grade 16 per cent, middlings 40 per cent, bran 24 per cent. The minimum amount of each product required in the diet to supply sufficient vitamin B for normal growth was as follows: whole wheat 40 per cent, first clear 40 per cent, second clear 40 per cent, low grade 20 per cent, middlings 10 per cent and bran 20 per cent.

Steenbock, Bell and Nelson (72) attributed this seemingly high content

of vitamin in wheat to the method of keeping the rats on shavings as bedding. These investigators kept their rats in screen bottom cages and found that 60 per cent of corn, wheat or oats must be present in the diet in order to supply sufficient vitamin B for normal growth.

McCollum, Simmonds and Pitz[34] state that the oat kernel contains a liberal supply of vitamin B. Suzuki, Matsuyama and Hashimoto[88] observed that 35 per cent of rolled oats in the diet supplied sufficient vitamin B for normal growth in the rat. Rock and Hetler[68] state that if 50 per cent of the diet of the rat is made up of whole oats the animal grows at a rate slightly below normal. These investigators also observed that vitamin B is present both in the embryo and the endosperm parts of the oat kernel, with a slightly greater concentration in the embryo.

The literature reviewed so far has been in regard to the hitherto so called water-soluble vitamin B. Recently, various investigators have demonstrated that at least two factors constitute the vitamin B complex. Sherman[69] reviews the facts concerning the discoveries of these factors designated as vitamins B, the antineuritic factor, and vitamin G, the P.P. factor.

Smith and Hendrick[71] observed that rats failed to grow normally on a diet containing 40 per cent of rolled oats as the source of the vitamin B complex. Normal growth was obtained on the oat diet when 5 to 6 per cent of autoclaved yeast was added to the ration. These results would indicate that the oat kernel is deficient in the heat stable factor vitamin G.

Hunt[23] states that 15 per cent of wheat in the diet supplies about

the minimum amounts of vitamin B for normal growth provided a sufficient amount of the vitamin G is present. Hunt also states that wheat and corn contain approximately the same amounts of vitamins B and G, but they are richer in vitamin B than in vitamin G.

## SOURCE AND TREATMENT OF MATERIALS USED

Discrepancies in experimental results are often due to a difference in the source and in the treatment of the materials used in the investigations. Therefore, the source and the treatment of the materials used in the investigations of the content of the vitamin B complex of cereal grains and their products are given.

Cleaned puffing wheat. Cleaned puffing wheat is amber durum wheat. It is very hard and contains a high per cent of protein. This wheat is grown primarily in Minnesota and adjacent sections North and South Dakota. It is a spring wheat. The cleaning process removes all foreign grains and seeds.

Pearled puffing wheat. This product is obtained by running the cleaned wheat between revolving stones. As a result of the pearling process approximately three per cent of the total weight of the wheat is pearled off, which is mostly bran.

Puffed wheat. Puffed wheat is obtained by subjecting pearled wheat to a high steam pressure in large cannons for some time and then suddenly releasing the pressure.

"Pettijohn wheat". "Pettijohn wheat"is a soft, white variety of wheat, grown either on the Pacific Coast or in the Rocky Mountain region.

Scoured "Pettijohn wheat". This product is obtained by scouring the "Pettijohn wheat". In the scouring process only a negligible amount of the bran is removed.

Pettijohn's breakfast food. This product is obtained by steaming scoured "Pettijohn wheat" and forcing it between rollers.

Cleaned oats. Cleaned oats are the natural oats that have been through the cleaning process which removes all of the foreign grain and seeds, the double oats, and the small thin oats.

Dry oats. The dry oats are produced by subjecting the cleaned oats to a drying process, which brings the moisture content down to between six and seven per cent and imparts a flavor to the rolled oats.

Oat groats. Oat groats are the kernels of the oats after the hull has been removed.

Rolled oats. Rolled oats are the oat groats rolled into flakes.

Polished rice. Polished rice is the rice kernel with bran removed.

Puffed rice. Puffed rice was prepared from polished rice by the process used in making puffed wheat from pearled puffing wheat.

Scourings from durum wheat. The scourings from durum wheat consist of the bran and other material removed in the pearling process.

All of the grains and grain products were supplied by the Quaker Oats Company.

Butterfat. A high grade of butter obtained from the college creamery was heated just above the melting point and filtered through a soft filter in a hot water funnel. The butterfat was kept in the box before incorporating it in the diet.

Dextrin. Corn starch obtained from Penick and Ford was moistened with 0.5 per cent citric acid and autoclaved for three hours at 15 pounds pressure. This product was then dried in shallow enameled pans over a steam hot plate. When thoroughly dry the product was finely ground.

Casein. Crude casein obtained from Wilkins Anderson and Company was

washed for two weeks with distilled water acidified with acetic acid, the acid solution being changed daily. It was then washed for several days with distilled water. When the washing was completed the product was dried in shallow galvanized pans over a steam hot plate. When dry, the product was finely ground.

Salt mixture. McCallum's salt mixture, number 185, was used in all the experiments.

Animals. Vigorous rats obtained from our own stock colony were used for all the experiments.

Cages. The cages used were 10 x 12 x 24 inches, with removable galvanized iron pans for the bottom. Shavings were used for bedding.

EXPERIMENTAL

## General

Vigorous rats weighing from 50 to 60 grams each were employed on all experiments. The animals before being placed on the experimental diets received the stock growing rations of natural food-stuffs supplemented with whole milk. Usually six rats, three males and three females, were placed together on each diet. The females at the first appearance of pregnancy were removed to an individual cage. The animals were weighed every seven days. The cages were cleaned and new shavings placed in the cages weekly.

The method used in the determination of the amount of the vitamin B complex in oats and wheat and their products obtained by processing in the manufacture of cereals, consisted in determining the amount of these substances required in a diet, adequate in every other respect excepting the vitamin B complex, to produce normal growth in the rat.

The basal ration employed in all of the experiments had the following composition: washed casein 18 to 20 per cent. McCollum's salt mixture, number 185, three and seven-tenths per cent, filtered butter fat five per cent, and dextrin to 100 per cent. This ration was vitamin B free, and animals placed on it failed to grow.

The substances, tested for their content of the vitamin B complex, replaced an equivalent per cent of dextrin in the basal ration. The composition of the diets and the results of the experiments are given in tables on pages 39 to 51.

Vitamin B content of cleaned wheat.

Growth was below normal on ration one, containing 10 per cent of cleaned wheat and no young were produced on this level. Two males died at the end of the sixth month. The time on the ration was nine months. Ration two was the same as ration one with the exception that ration two contained five per cent of agar-agar. Growth was below normal but better than that on ration one. Two of the four females produced one litter of young each, consisting of five and six young. No young were reared. One of the females died just after parturition, while the other mother died within a week after having given birth to the young. Another female died during the fifth month of the experiment. The cause of the death in the latter case was unknown. The animals were kept on the experimental diets for nine months. Growth was very good on diet three, containing 12 per cent of cleaned wheat. Some of the rats grew normally on this diet. The three females produced six litters of 36 young. All of the young died within one week after birth. The experiment continued for a period of seven months.

Growth was normal on ration four containing 15 per cent of cleaned wheat. The nine females on the diet produced 11 litters consisting of 55 young. All of the young died within a few days after birth. Two females died pregnant. One male and two other females died late in the experiment from an unknown cause. The animals were kept on the diet nine months. Ration five was identical with four, with the exception that in the former 5 per cent of yeast replaced 5 per cent of dextrin. Growth was normal on ration five. The added yeast had no noticable effect upon the growth as

compared with results on ration four. Three of the five females produced seven litters consisting of 47 young. Twenty of the young were reared. The percentage of mortality was 57.4. One female died from an unknown cause. The duration of the experiment was nine months. Growth was normal on ration six, containing 20 per cent of cleaned wheat. The five females produced ten litters consisting of 52 young. Six young were reared. The per cent of mortality was 88.5. One male and one female died late in the experiment from an unknown cause. The young died a few days after birth. The experiment was continued through nine months.

Growth was normal on ration seven, containing 25 per cent of cleaned wheat. The three females on the diet produced nine litters consisting of 75 young. Fourteen young were reared. The per cent of mortality was 81.3. Many of the young lived to be two or three weeks of age. One female died during the eighth month of the experiment from an unknown cause. The animals were on ration seven for nine months. Growth was normal on ration eight, containing 40 per cent of cleaned wheat. The three females on the diet produced five litters consisting of 32 young. Four young were reared. The percentage mortality was 87.5. One female died during the sixth month after suckling young for three weeks. The period of the experiment was nine months.

Vitamin B content of pearled clean wheat.

Growth was normal on ration nine, containing 15 per cent of pearled clean wheat. The five females produced seven litters consisting of 42 young. Seven young were reared. The percentage mortality was 83.3. Most of the young died within a week after birth. Two females died pregnant.

and another female died within a week after parturition. The duration of the experiment was ten months. Growth was normal on ration ten, containing 40 per cent of pearled clean wheat. The seven females produced 17 litters consisting of 118 young. Thirty-one young were reared. The percentage mortality was 73.7. Most of the young died within 48 hours after birth. One female died pregnant and another died shortly after parturition. One male died during the fifth month of the experiment from an unknown cause. The duration of the experiment was ten months. Growth was normal on ration eleven, containing 60 per cent of pearled clean wheat and 15 per cent of casein. The three females on the diet produced five litters of 36 young. Nineteen young were reared. The per cent mortality was 47.2. A considerable number of the young died within a few days after birth. The duration of experiment was ten months.

Diet twelve is the same as ration eleven with the exception that the former contains 12 per cent of casein instead of 15. Growth on this diet was slightly better than normal. The three females produced four litters consisting of 28 young. Twenty-one of the young were reared. The per cent of mortality was 25. The duration of the experiment was ten months. Diet thirteen differs from diets eleven and twelve only in the per cent of casein in the ration. Growth was normal on this diet containing 20 per cent of casein and 60 per cent of rolled oats. Three females on the diet produced seven litters of 36 young. Eight young were reared, giving a percentage mortality of 77.7. The majority of the young died within two days after birth. The duration of the experiment was ten months.

Vitamin B content of "Pettijohn wheat".

Diets fourteen, fifteen, and sixteen contained 8, 10, and 11 per cent "Pettijohn wheat." Growth was below normal on these diets. No young were produced. Diet seventeen contained 12 per cent of "Pettijohn wheat". Growth of the rats on this diet was below normal. Three litters of ten young were produced. One female died at parturition. All of the young died within two days after birth. The duration of the experiment was five and one half months. Diet eighteen contained 13 per cent of Pettijohn wheat. The average growth was below the normal on this diet. One litter of five young was produced. All of the young died within 48 hours after birth. The animals were kept on the diet for five months.

Diet nineteen contained 14 per cent of "Pettijohn wheat." On this diet growth was below normal. Three of the five females on the diet produced four litters consisting of 14 young. One female died pregnant. The young died within 48 hours after birth. The animals were kept on the experiment five and one half months. Diet twenty contained 15 per cent of "Pettijohn wheat." Growth on this diet was normal. The 12 females on this diet produced 16 litters consisting of 94 young. All of the young died. Most of the young died within two days after birth. Five females and one male died from an unknown cause. The animals were kept on the experiment for ten months. Diet twenty-one contained 20 per cent of "Pettijohn wheat". Growth was normal on this diet. The two females produced five litters, consisting of 20 young. Sixteen young died within three days after birth. The percentage of mortality was 80. One female died from an unknown cause. The duration of the experiment with diet twenty-one was eight months.

Vitamin B content of scoured "Pettijohn wheat."

Diets twenty-two, twenty-three, and twenty-four contained 8, 10, and 11 per cent of scoured "Pettijohn wheat" respectively. Growth on these diets was below normal. No young were born. The duration of the experiments was four months. Diet twenty-five contained 12 per cent of scoured "Pettijohn wheat". Growth on this diet was below normal. One of the three females produced one litter of two young. The young died within two days after birth. The animals were kept on the experiment five and one half months. Diet twenty-six contained 13 per cent of scoured "Pettijohn wheat". Growth on this diet was below normal. Two of the four females produced one litter each. The eight young born died within two days after birth. One female died from an unknown cause. The animals were kept on the experiment for five months. Diet twenty-seven contained 14 per cent of scoured "Pettijohn wheat". Growth on this diet was slightly below normal. One of the two females on the diet produced one litter, consisting of five young. All of the young died within three days after birth. The duration of the experiment was five and one half months.

Diet twenty-eight contained 15 per cent of scoured "Pettijohn wheat". Growth on this diet was normal. The ten females on the diet produced 22 litters, consisting of 138 young. Ten young were reared. The percentage of mortality was 92.7. Most of the young died within three days after birth. One female died at parturition, and two died shortly after giving birth to young. Two males died from an unknown cause. The duration of the experiment was ten months. Ration twenty-nine contained 20 per cent of scoured "Pettijohn wheat". Growth on this diet was normal. The two

females on the diet produced five litters, consisting of 32 young. Five young were reared. The percentage of mortality was 84.4. Most of the young died within 48 hours after birth. One female died from an unknown cause. The animals were kept on the diet for eight months.

Vitamin B content of Pettijohn's breakfast food.

Diets thirty, thirty-one, and thirty-two contained 8, 10, and 11 per cent Pettijohn's breakfast food respectively. Growth on these diets was below normal. The animals were kept on the diet for four months. Diet thirty-three contained 12 per cent of Pettijohn's breakfast food. The average growth on this diet was below normal. One of the three females on this diet produced two litters, consisting of 10 young. All of the young died within 48 hours after birth. One female died from an unknown cause. The animals were kept on the experiment for a period of five and one half months. Diet thirty-four contained 13 per cent of Pettijohn's breakfast food. One of the four females produced one litter, consisting of five young. All of the young died within 48 hours after birth. The animals were kept on the diet for five and one half months.

Diet thirty-five contained 14 per cent Pettijohn's breakfast food. Growth on this diet was normal. The two females on the diet produced three litters, consisting of 15 young. All of the young died within three days after birth. The duration of the experiment was five and one half months. Diet thirty-six contained 15 per cent of Pettijohn's breakfast food. Growth on this diet was normal. Two of the four females produced three litters, consisting of 11 young. All of the young died within three days after birth. Three of the four females died pregnant.

Vitamin B content of cleaned puffing wheat.

Diet thirty-seven contained 8 per cent of cleaned puffing wheat. Growth was considerably below normal. No young were produced. The experiment covered a period of four months. Diet thirty-eight contained 10 per cent of cleaned puffing wheat. Growth was below normal. One of the four females produced one litter, consisting of seven young. The young died within 48 hours after birth. One female died pregnant and another on the second day after giving birth to young. The duration of the experiment was five months. Diet thirty-nine contained 12 per cent cleaned puffing wheat. Growth was below normal on the diet. Three of the five females produced one litter of young each. A total of 12 young were born. All died within 48 hours after birth. Two females died at parturition. The animals were kept on the diet for five months.

Diet forty contained 13 per cent of cleaned puffing wheat. Growth on this diet was slightly below normal. The two females on the diet produced three litters, consisting of 16 young. All of the young died within 48 hours after birth. One female died pregnant. The duration of the experiment was five months.

Ration forty-one contained 14 per cent of cleaned puffing wheat. Growth on this ration was normal. The four females on the diet produced five litters, consisting of 30 young. All of the young died within three days after birth. The duration of the experiment was five months. Ration forty-two contained 15 per cent of cleaned puffing wheat. Growth on this ration was normal. The three females on the diet produced five litters, consisting of 23 young. All of the young died within two days after birth. The duration of the experiment was seven months.

Diet forty-three contained 16 per cent of cleaned puffing wheat. Growth on this diet was normal. One female produced one litter, consisting of five young. All of the young died within three days after birth. Two females died pregnant and one female died at parturition. The duration of the experiment was five and one half months. Diet forty-four contained 17 per cent cleaned puffing wheat. Growth on this diet was normal. One female died just after giving birth to 10 young. The remaining female died pregnant. The duration of the experiment was five and one half months. Diet forty-five contained 18 per cent of cleaned puffing wheat. Growth was normal or above normal on this diet. The one female on the diet produced two litters, consisting of 13 young, and she later died pregnant. All of the young died within three days after birth. The animals were kept on the diet for a period of five and one half months.

Diet forty-six contained 19 per cent of cleaned puffing wheat. Three of the animals failed to grow normally on this diet. One of the two females on this diet died pregnant, the remaining female produced three litters, consisting of 16 young. One litter of eight young was still born. The other eight young died within 48 hours after birth. The duration of the experiment was five and one half months. Diet forty-seven contained 20 per cent of cleaned puffing wheat. Growth on the diet was normal. The three females on the diet produced five litters, consisting of 20 young. All of the young died within three days after birth. The animals were kept on the diet four months. Diet forty-eight contained 25 per cent of cleaned puffing wheat. Growth was normal on this diet. The four females produced six litters, consisting of 35 young. One litter of nine young

was born dead. The other 26 young died within three days after birth. One female died pregnant and another one died shortly after giving birth to her second litter. The animals were kept on the diet four months.

Vitamin B content of pearled puffing wheat.

Diets forty-nine and fifty contained 8 and 10 per cent of pearled puffing wheat. Growth on these diets was considerably below normal. No young were produced. The duration of the experiments forty-nine and fifty was five months. Ration fifty-one contained 12 per cent pearled puffing wheat. The animals were continued on this diet for five months. Growth on this ration was below normal. Two of the four females on the diet produced one litter of young each. The three young born died within 48 hours after birth. One male died. Diet fifty-two contained 13 per cent of pearled puffing wheat. Growth on this diet was below normal. Three of the five females on the diet produced four litters, consisting of 19 young. Three young were born dead. The remaining 16 young died within 48 hours after birth. One female died from an unknown cause. The animals were on diet fifty-two for nine months.

Ration fifty-three contained 14 per cent of pearled puffing wheat. Some of the rats grew normally on this diet. Of the four females on the ration one produced two litters of seven young. The young died within 48 hours after birth. Two females died pregnant. The duration of the experiment was five months. Ration fifty-four contained 15 per cent of pearled puffing wheat. Growth on the diet was normal. Five of the seven females on the ration produced 11 litters, consisting of 66 young. All of the young died within three days after birth. Two females died from an

unknown cause. The duration of the experiment was seven months. Diets fifty-five and fifty-six contained 16 and 17 per cent pearled puffing wheat respectively. Growth was normal on these diets. No young were produced. The duration of the experiment was five months. Diet fifty-seven contained 18 per cent of pearled puffing wheat. Growth was normal on this diet. One of the two females on the diet produced one litter, consisting of four young. All of the young died within three days after birth. The duration of the experiment was five months.

Ration fifty-nine contained 20 per cent of pearled puffing wheat. Growth on the diet was normal. The four females on the diet produced five litters, consisting of 25 young. All of the young died within three days after birth. The duration of the experiment was four months. Ration sixty contained 25 per cent of pearled puffing wheat. The growth curves were normal on this diet. Two females died, one dying pregnant. The remaining three females produced six litters, consisting of 36 young. One young was reared. The percentage mortality was 97.2. Most of the young died within a week after birth. The duration of the experiment was four months.

Vitamin B content of puffed wheat.

Diets sixty-one to seventy-four inclusive, containing various levels of puffed wheat from 12 to 73.3 per cent, are inadequate for growth. Even on the 73.3 per cent level, growth is considerably below normal. No reproduction was obtained on these levels of puffed wheat. The death rate of the rats on the diets was quite high. The experiments were continued from three to eight months.

Vitamin B content of clean oats.

Rations seventy-five and seventy-six contained 8 and 10 per cent of clean oats respectively. Growth on these diets is below normal. No young were produced. The duration of the experiments was five months. Ration seventy-seven contained 12 per cent of clean oats. Growth was below normal on the diet. One of the three females on the diet produced one litter, consisting of five young. All of the young died within 48 hours after birth. The rats were kept on ration seventy-seven for five months. Ration seventy-eight contained 15 per cent of clean oats. The five females on the diet produced six litters, consisting of 35 young. All of the young died within three days after birth. The duration of the experiment was six months. Growth was below normal for the males but normal for the females. Ration seventy-nine contained 17 per cent of cleaned oats. Growth was below normal. The two females on the diet produced two litters, consisting of 11 young. All of the young died within 48 hours after birth. The animals were on ration seventy-nine for four months. Ration eighty contained 30 per cent of clean oats. Growth was slightly below normal on this ration during the four months period of the experiment. One female died pregnant. The two remaining females produced four litters, consisting of 26 young. All of the young died within three weeks after birth.

Vitamin B content of dry oats.

Rations eighty-one, eighty-two, and eighty-three contained 8, 10, and 12 per cent of dry oats respectively. Growth on these diets was below normal. No young were produced. The animals were kept on the diets five months. Ration eighty-four contained 15 per cent of dry oats. This diet was not adequate for normal growth. One of the five females on the diet produced one litter consisting of three young. All of the young died within 48 hours after birth. The duration of the experiment was four months. Ration eighty-five contained 17 per cent of dry oats. Growth was below normal on this diet. The one female on the diet produced one litter, consisting of three young. All of the young died within 48 hours after birth. The animals were kept on this experiment for four months. Ration eighty-six contained 30 per cent of dry oats. Growth was below normal on the diet. The experiment was continued for six months. One of the two females on the diet produced two litters, consisting of nine young. All of the young died within 48 hours after birth.

Vitamin B content of oat groats.

Diets eighty-seven and eighty-eight contained 8 and 10 per cent of oat groats respectively. These diets were inadequate for normal growth over a period of five months. No young were produced. Diet eighty-nine contained 12 per cent of oat groats. Growth was slightly below normal during the five month's period. The two females on the diet produced two litters, consisting of eight young. All of the young died within 48 hours after birth. Ration ninety contained 15 per cent of oat groats. The growth during the eigh months of the experiment was below normal. Two of the four females on the diet produced three litters, consisting of 17 young. All of the young died within three weeks. Ration ninety-one contained 17 per cent of oat groats. The growth on the diet was below normal, during the four months the rats were on the diet. The two females produced one litter each. The seven young produced died within three days after birth.

Growth on diet ninety-two, containing 20 per cent of oat groats, was below normal. One female died at the end of the fifth month from an unknown cause. The remaining two females produced three litters, consisting of 16 young. All of the young died within three days from birth. The duration of the experiment was eight months. Growth on diet ninety-three, containing 25 per cent of oat groats, was slightly below normal. The three females on the diet produced four litters, consisting of 24 young. All of the young died within four days after birth. The animals were on the ration eight months. Growth on diet ninety-four, containing 30 per cent of oat groats, was slightly below normal. One male died with otitis

media. One female died late in the experiment, the cause of the death being unknown. The two females on the diet produced four litters, consisting of 28 young. All of the young died within one week after birth. The rats were kept on ration ninety-four for eight months.

Vitamin B content of rolled oats.

Diets ninety-five, ninety-six, and ninety-seven contained 8, 10, and 12 per cent of rolled oats respectively. Growth on these diets was below normal, and no young were produced during the five months of the experiment. Growth on diet ninety-eight, containing 15 per cent of rolled oats, was slightly below normal. The three females on the diet produced nine litters, consisting of 55 young. All of the young died within three weeks after birth, and most of the young died within three days after birth. One female died the second day after parturition, and another female died one month after having given birth to young. The time on the ration was eight months. Growth was below normal on diet ninety-nine, containing 17 per cent of rolled oats. Two of the three females on the diet produced one litter each. The 11 young born died within three days after birth.

Vitamin B content of oat hulls.

Diet one hundred contained 40 per cent of oat hulls. Growth on this diet was below normal during the ten months of the experiment. One of the three females on the diet produced three litters consisting of 16 young. All of the young died within three weeks after birth.

Vitamin B content in the scourings of durum wheat.

Diet one hundred one contained 15 per cent of first scourings of durum wheat. Growth on this diet was normal. One of the two females on the diet produced two litters consisting of 10 young. All of the young died within three weeks from birth. One of the females died during the sixth month of the experiment, the cause of her death was unknown. The animals were kept on the experiment for seven months.

Diet one hundred two contained 15 per cent of second scourings of durum wheat. Growth on this level was better than normal for the entire seven months of the experiment. The two females on the diet produced four litters, consisting of 24 young. Fourteen young died. The percentage mortality was 58.3.

Vitamin B content of rice.

Diet one hundred three contained 73.3 per cent of polished rice. Growth on this level of polished rice was considerably below normal. Two of the three females produced one litter of young each. The 11 young born died within three days from birth. The duration of the experiment was eight months.

Diet one hundred four contained 73.3 per cent of puffed rice. There was but little growth on this diet during the seven months of the experiment. No young were produced.

## DISCUSSION OF RESULTS

Oats and wheat and their various products obtained by processing in the manufacture of cereals were investigated in regard to their content of the vitamin B complex.

Diets containing 10, 12, 15, 20, 25, and 40 per cent levels of cleaned wheat were studied. Ten per cent of cleaned wheat in a diet does not supply sufficient amounts of the vitamin B complex for normal growth in the rat. Some of the animals grew normally on the 12 per cent level. Growth was normal on all levels containing as much as 15 per cent of cleaned wheat in the diet. Reproduction was obtained on all levels of cleaned wheat employed. Young were reared on the diets containing 15 per cent or more of cleaned wheat; however, the mortality was high. The majority of the young died within 48 hours after birth. The lowest mortality rate was obtained on diet five, containing 15 per cent of cleaned wheat supplemented with five per cent of dried yeast. The mortality on this diet was 57.4 per cent as compared to 100 per cent on diet four. Diet four was identical with diet five, with the exception that the former did not contain any yeast. The results obtained on diets four and five indicate that a greater amount of the vitamin B complex is required for lactation than for growth and reproduction. No young were reared on the 10 and 12 per cent cleaned wheat levels.

The results obtained on the cleaned wheat diets agree with those of McCollum, Simmonds and Pitz[33] and of Osborne and Mendel[59], who concluded that 15 per cent of whole wheat in the diet supplied sufficient vitamin B for normal growth. Guest, Nelson, Parks and Fulmer[19] found

that 10 per cent of whole wheat in the diet supplied sufficient vitamin B for normal growth.

A relatively large per cent of the females on the cleaned wheat diets died during the period of pregnancy, at parturition, or just after parturition.

Cleaned pearled wheat was investigated at levels of 15,40,and 60 per cent. Growth was normal on all of these diets. All of the diets were adequate for reproduction but inadequate for lactation. The majority of the young died within three days after birth. The percentage mortality on diets 11, 12, and 13, containing 60 per cent of cleaned pearled wheat and 15, 12, and 20 per cent of casein respectively, was 47.2, 25, and 77.7 per cent respectively. These results indicate that a high protein content in a diet is deleterious to suckling young. However, sufficient data was not obtained to absolutely prove that this is the case. Three females on diet 9 and two females on ration 10, containing 15 and 40 per cent respectively of cleaned pearled wheat, died at parturition or shortly afterward. There were no deaths at these periods when the diets contained 60 per cent of cleaned pearled wheat.

Diets 14 to 21 inclusive contained 8, 10, 11, 12, 13, 14, 15, and 20 per cent of "Pettijohn wheat" respectively. Growth on all diets containing less than 15 per cent of "Pettijohn wheat" was below normal. The diet is adequate for normal growth when 15 per cent or more of "Pettijohn wheat" is incorporated in the diet. Young were produced on all of the diets containing 12 or more per cent of "Pettijohn wheat". No young were produced on diets containing 8, 10, and 11 per cent of "Pettijohn wheat". The per-

centage mortaility of the young was 100 with the exception of the 20 per cent level of "Pettijohn wheat". In this case the percentage of mortality was 80. The greater number of the young died within 48 hours after birth. Two females died pregnant.

Diets 22 to 29 inclusive contained 8, 10, 11, 12, 13, 14, 15, and 20 per cent of scoured "Pettijohn wheat" respectively. Growth was below normal on all diets containing less than 14 per cent scoured "Pettijohn wheat". One male and two females on the diet containing 14 per cent of scoured "Pettijohn wheat" grew normally. Growth was normal on the 15 and 20 per cent levels. Growth on the diets containing scoured "Pettijohn wheat" was slightly better than that obtained on the diets containing comparative levels of "Pettijohn wheat". This would indicate that vitamin B is more concentrated in the scoured "Pettijohn wheat" than in the whole grain of "Pettijohn wheat". No young were produced on the 8, 10, and 11 per cent levels. One or more litters were produced on the diets containing 12 per cent or more of scoured "Pettijohn wheat". The percentage of mortality of the young was high, varying from 84.4 to 100. A few young were reared on the 15 and 20 per cent levels. The majority of the young died within 48 hours after birth. On the diet containing 15 per cent of scoured Pettijohn wheat, one female died at parturition and two others died shortly after giving birth to young.

Diets 30 to 36 inclusive contained 8, 10, 11, 12, 13, 14, and 15 per cent of Pettijohn's breakfast food respectively. Growth was below normal on all diets containing less than 14 per cent of Pettijohn's breakfast food. The diets containing 14 per cent or more of Pettijohn's breakfast food were adequate for normal growth. Diets containing 8, 10,

and 11 per cent of Pettijohn breakfast food were inadequate for reproduction; however, young were produced on the higher levels. The percentage of mortality of the young was 100. Generally the young died within 48 hours after birth. Three females on diet 36 died pregnant. Diets 37 to 48 inclusive contained 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 25 per cent of cleaned puffing wheat respectively. Growth was below normal on the 8, 10, 12, and 13 per cent levels, while diets containing 14 or more per cent of cleaned puffing wheat were adequate for normal growth. Reproduction was obtained on all levels with the exception of the eight per cent level. No young were reared on these diets. Most of the young died within 48 hours after birth. On these diets, eight females died pregnant, three died at parturition, and three died shortly after parturition.

Diets 49 to 60 inclusive contained 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 25 per cent of pearled puffing wheat respectively. Growth on the 8, 10, 12, 13, and 14 per cent levels was below normal, while diets containing 15 or more per cent of pearled puffing wheat were adequate for normal growth. There was no reproduction on the 8 and 10 per cent levels; but one or more litters were produced on all of the higher levels of pearled puffing wheat. The percentage of mortality of the young was 100 on all diets with the exception of diet 60, on which one young was reared. Five females on this series of diets died pregnant.

Diets 61 to 74 inclusive contained 12, 13, 14, 15, 16, 17, 18, 19, 20, 25, 35, 50, 60, and 73.3 per cent of puffed wheat respectively. Growth was considerably below normal on all of these diets. No young were born.

The percentage mortality of the adults on these diets was rather large.

Diets 75 to 80 inclusive contained 8, 10, 12, 15, 17, and 30 per cent of clean oats respectively. None of these diets were adequate for normal growth. Growth was slightly below normal on diet 80 containing 30 per cent of cleaned oats.

Diets 81 to 86 inclusive contained 8, 10, 12, 15, 17, and 30 per cent dry oats. Growth was below normal on all of these diets. Young were produced only on diets containing 15, 17, and 30 per cent of dry oats. No young were reared.

Diets 87 to 94 inclusive contained 8, 10, 12, 15, 17, 20, 25, and 30 per cent of oat groats. Growth on all of these diets was below normal. Young were produced only on the diets containing 12 or more per cent of oat groats. No young were reared. Most of the young died within 48 hours after birth.

Diets 95 to 99 inclusive contained 8, 10, 12, 15, and 17 per cent of rolled oats. All of these diets were inadequate for normal growth. Young were produced on the 15 and 17 per cent levels of rolled oats but none were reared. One female died at parturition.

Diet 100 contained 40 per cent of oat hulls. Growth was below normal on this diet; young were produced, but none were reared.

Diets 101 and 102 contained 15 per cent of first and second scourings of durum wheat respectively. Growth was normal on diet 101 and somewhat above normal on diet 102. Young were produced on both diets. The percentage of mortality of the young was 100 on diet 101 and 58.3 for diet 102.

Diet 103 contained 73.3 per cent of polished rice. This diet was inadequate for normal growth. Young were produced, but none were reared.

Diet 104, containing 73.3 per cent of puffed rice was markedly inadequate for growth. No young were produced.

## SUMMARY

Cleaned wheat is a relatively rich source of the vitamin B complex. A diet, containing from 12 to 15 per cent of cleaned wheat, supplies sufficient amounts of the vitamin B complex for normal growth in the rat.

Pearled cleaned wheat does not contain quite as much of the vitamin B complex as the whole grain. At least 15 per cent of the pearled wheat is required to supply an adequate amount of the vitamin B complex for normal growth.

Fifteen per cent of "Pettijohn wheat," a soft winter wheat, supplies adequate amounts of the vitamin B complex for normal growth in the rat.

The vitamin B complex appears to be slightly more concentrated in the scoured "Pettijohn wheat" than in the "Pettijohn wheat," since better growth was obtained on comparative levels of the scoured product.

Sufficient vitamin B complex for normal growth is supplied by 15 per cent of Pettijohn's breakfast food in the diet.

A diet, containing from 14 to 15 per cent of cleaned puffing wheat, supplies adequate amounts of the vitamin B complex for normal growth.

In the pearling process about three per cent of the total weight of the wheat grain is removed, therefore from 15 to 20 per cent of pearled puffing wheat is required to supply adequate amounts of the vitamin B complex for normal growth.

Puffed wheat even when present in the diet to the extent of 75.3 per cent does not contain sufficient of the vitamin B complex for normal growth. The poor quality of the puffed wheat is probably due to the destruction of the anti-neuritic factor in processing.

Normal growth was not obtained on 30 per cent levels of either cleaned oats or dry oats as the source of the vitamin B complex.

Growth was slightly below normal on 30 per cent levels of oat groats.

Seventeen per cent of rolled oats did not supply adequate amounts of the vitamin B complex for normal growth.

Sufficient amounts of the vitamin B complex is furnished by 15 per cent of the scourings of durum wheat in the diet for normal growth.

Forty per cent of oat hulls failed to supply adequate amounts of the vitamin B complex for successful growth.

At levels of 73.3 per cent of either polished or puffed rice the amount of the vitamin B complex is inadequate for successful normal growth.

Diets may contain sufficient amounts of the vitamin B complex for normal growth and reproduction but are inadequate for successful lactation. Increasing the amounts of the vitamin B complex in the diets has beneficial effects on lactation.

A considerable per cent of the females on the various wheat diets died pregnant, at parturition, or just after parturition. This was in marked contrast to the results obtained on the oat diets.

## CONCLUSIONS

1. Fifteen per cent of wheat in the diet supplies sufficient amounts of the vitamin B complex for normal growth.

2. There is no destruction of the vitamin B complex in the process of manufacturing Pettijohn's breakfast food.

3. In the process of manufacturing puffed wheat a considerable amount of the vitamin B complex is destroyed.

4. The oat kernel is inferior to wheat as a source of the vitamin B complex.

5. There is no destruction of the vitamin B complex in the process of manufacturing rolled oats.

6. The wheat grain is deficient in some nutritive factor having a relationship to the wellbeing of the female during the period of pregnancy, at parturition, and the period immediately following parturition.

7. More than three times the amount of the vitamin B complex is required for successful lactation than is required for normal growth and reproduction.

8. An appreciable amount of the vitamin B complex of rice is destroyed in the puffing process.

TABLE I

COMPOSITION OF DIETS

| Ration No. | Cleaned Wheat | Cleaned Wheat Pearled | Pettijohn Wheat | Casein | Butter fat | Salt Mixture | Dextrin | Agar-Agar | Yeast |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | | | 20 | 5 | 3.7 | 61.3 | | |
| 2 | 10 | | | 20 | 5 | 3.7 | 56.5 | 5 | |
| 3 | 12 | | | 20 | 5 | 3.7 | 59.3 | | |
| 4 | 15 | | | 20 | 5 | 3.7 | 56.3 | | |
| 5 | 15 | | | 20 | 5 | 3.7 | 51.3 | | 5 |
| 6 | 20 | | | 20 | 5 | 3.7 | 51.3 | | |
| 7 | 25 | | | 20 | 5 | 3.7 | 46.3 | | |
| 8 | 40 | | | 20 | 5 | 3.7 | 31.3 | | |
| 9 | | 15 | | 20 | 5 | 3.7 | 56.3 | | |
| 10 | | 40 | | 20 | 5 | 3.7 | 31.3 | | |
| 11 | | 60 | | 15 | 5 | 3.7 | 16.3 | | |
| 12 | | 60 | | 12 | 5 | 3.7 | 19.3 | | |
| 13 | | 60 | | 20 | 5 | 3.7 | 11.3 | | |
| 14 | | | 8 | 18 | 5 | 3.7 | 65.3 | | |
| 15 | | | 10 | 18 | 5 | 3.7 | 63.3 | | |
| 16 | | | 11 | 18 | 5 | 3.7 | 62.3 | | |
| 17 | | | 12 | 18 | 5 | 3.7 | 61.3 | | |
| 18 | | | 13 | 18 | 5 | 3.7 | 60.3 | | |
| 19 | | | 14 | 18 | 5 | 3.7 | 59.3 | | |
| 20 | | | 15 | 20 | 5 | 3.7 | 56.3 | | |
| 21 | | | 20 | 20 | 5 | 3.7 | 51.3 | | |

TABLE II

COMPOSITION OF DIET

| Ration No. | Scoured Pettijohn Wheat | Pettijohn Breakfast food | Casein | Butter fat | Salt mixture | Dextrin |
|---|---|---|---|---|---|---|
| 22 | 8 | | 18 | 5 | 3.7 | 65.3 |
| 23 | 10 | | 18 | 5 | 3.7 | 63.3 |
| 24 | 11 | | 18 | 5 | 3.7 | 62.3 |
| 25 | 12 | | 18 | 5 | 3.7 | 61.3 |
| 26 | 13 | | 18 | 5 | 3.7 | 60.3 |
| 27 | 14 | | 18 | 5 | 3.7 | 59.3 |
| 28 | 15 | | 20 | 5 | 3.7 | 56.3 |
| 29 | 20 | | 18 | 5 | 3.7 | 51.3 |
| 30 | | 8 | 18 | 5 | 3.7 | 65.3 |
| 31 | | 10 | 18 | 5 | 3.7 | 63.3 |
| 32 | | 11 | 18 | 5 | 3.7 | 62.3 |
| 33 | | 12 | 18 | 5 | 3.7 | 61.3 |
| 34 | | 13 | 18 | 5 | 3.7 | 60.3 |
| 35 | | 14 | 18 | 5 | 3.7 | 59.3 |
| 36 | | 15 | 20 | 5 | 3.7 | 56.3 |

TABLE III

COMPOSITION OF DIET

| Ration No. | Cleaned Puffing Wheat | Pearled Puffing Wheat | Casein | Butter fat | Salt mixture | Dextrin |
|---|---|---|---|---|---|---|
| 37 | 8 | | 18 | 5 | 3.7 | 65.3 |
| 38 | 10 | | 18 | 5 | 3.7 | 63.3 |
| 39 | 12 | | 18 | 5 | 3.7 | 61.3 |
| 40 | 13 | | 18 | 5 | 3.7 | 60.3 |
| 41 | 14 | | 18 | 5 | 3.7 | 59.3 |
| 42 | 15 | | 18 | 5 | 3.7 | 58.3 |
| 43 | 16 | | 18 | 5 | 3.7 | 57.3 |
| 44 | 17 | | 18 | 5 | 3.7 | 56.3 |
| 45 | 18 | | 18 | 5 | 3.7 | 55.3 |
| 46 | 19 | | 18 | 5 | 3.7 | 54.3 |
| 47 | 20 | | 18 | 5 | 3.7 | 53.3 |
| 48 | 25 | | 18 | 5 | 3.7 | 48.3 |
| 49 | | 8 | 18 | 5 | 3.7 | 65.3 |
| 50 | | 10 | 18 | 5 | 3.7 | 63.3 |
| 51 | | 12 | 18 | 5 | 3.7 | 61.3 |
| 52 | | 13 | 18 | 5 | 3.7 | 60.3 |
| 53 | | 14 | 18 | 5 | 3.7 | 59.3 |
| 54 | | 15 | 18 | 5 | 3.7 | 58.3 |
| 55 | | 16 | 18 | 5 | 3.7 | 57.3 |
| 56 | | 17 | 18 | 5 | 3.7 | 56.3 |
| 57 | | 18 | 18 | 5 | 3.7 | 55.3 |
| 58 | | 19 | 18 | 5 | 3.7 | 54.3 |
| 59 | | 20 | 18 | 5 | 3.7 | 53.3 |
| 60 | | 25 | 18 | 5 | 3.7 | 48.3 |

TABLE IV

COMPOSITION OF DIETS

| Ration No. | Puffed Wheat | Clean Oats | Dry Oats | Casein | Salt mixture | Butter fat | Dextrin |
|---|---|---|---|---|---|---|---|
| 61 | 12 | | | 18 | 3.7 | 5 | 61.3 |
| 62 | 13 | | | 18 | 3.7 | 5 | 60.3 |
| 63 | 14 | | | 18 | 3.7 | 5 | 59.3 |
| 64 | 15 | | | 18 | 3.7 | 5 | 58.3 |
| 65 | 16 | | | 18 | 3.7 | 5 | 57.3 |
| 66 | 17 | | | 18 | 3.7 | 5 | 56.3 |
| 67 | 18 | | | 18 | 3.7 | 5 | 55.3 |
| 68 | 19 | | | 18 | 3.7 | 5 | 54.3 |
| 69 | 20 | | | 18 | 3.7 | 5 | 53.3 |
| 70 | 25 | | | 18 | 3.7 | 5 | 48.3 |
| 71 | 35 | | | 18 | 3.7 | 5 | 38.3 |
| 72 | 50 | | | 18 | 3.7 | 5 | 23.3 |
| 73 | 60 | | | 18 | 3.7 | 5 | 13.3 |
| 74 | 73.3 | | | 18 | 3.7 | 5 | |
| 75 | | 8 | | 18 | 3.7 | 5 | 65.3 |
| 76 | | 10 | | 18 | 3.7 | 5 | 63.3 |
| 77 | | 12 | | 18 | 3.7 | 5 | 61.3 |
| 78 | | 15 | | 18 | 3.7 | 5 | 58.3 |
| 79 | | 17 | | 18 | 3.7 | 5 | 56.3 |
| 80 | | 30 | | 20 | 3.7 | 5 | 41.3 |
| 81 | | | 8 | 18 | 3.7 | 5 | 65.3 |
| 82 | | | 10 | 18 | 3.7 | 5 | 63.3 |
| 83 | | | 12 | 18 | 3.7 | 5 | 61.3 |
| 84 | | | 15 | 18 | 3.7 | 5 | 58.3 |
| 85 | | | 17 | 18 | 3.7 | 5 | 56.3 |
| 86 | | | 30 | 20 | 3.7 | 5 | 41.3 |

TABLE V

COMPOSITION OF DIETS

| Ration No. | Oat Groats | Rolled Oats | Oat Hulls | Casein | Butter fat | Salt mixture | Dextrin |
|---|---|---|---|---|---|---|---|
| 87 | 8 | | | 18 | 5 | 3.7 | 65.3 |
| 88 | 10 | | | 18 | 5 | 3.7 | 63.3 |
| 89 | 12 | | | 18 | 5 | 3.7 | 61.3 |
| 90 | 15 | | | 18 | 5 | 3.7 | 58.3 |
| 91 | 17 | | | 18 | 5 | 3.7 | 56.3 |
| 92 | 20 | | | 20 | 5 | 3.7 | 51.3 |
| 93 | 25 | | | 20 | 5 | 3.7 | 46.3 |
| 94 | 30 | | | 20 | 4 | 3.7 | 41.3 |
| 95 | | 8 | | 18 | 5 | 3.7 | 65.3 |
| 96 | | 10 | | 18 | 5 | 3.7 | 63.3 |
| 97 | | 12 | | 18 | 5 | 3.7 | 61.3 |
| 98 | | 15 | | 18 | 5 | 3.7 | 58.3 |
| 99 | | 17 | | 18 | 5 | 3.7 | 56.3 |
| 100 | | | 40 | 20 | 5 | 3.7 | 31.3 |

TABLE VI

COMPOSITION OF DIETS

| Ration No. | 1st Scourings of Durum Wheat | 2nd Scourings of Durum Wheat | Polished Rice | Puffed Rice | Casein | Butter fat | Salt mixture | Dextrin |
|---|---|---|---|---|---|---|---|---|
| 101 | 15 | | | | 20 | 5 | 3.7 | 56.3 |
| 102 | | 15 | | | 20 | 5 | 3.7 | 56.3 |
| 103 | | | 73.3 | | 18 | 5 | 3.7 | |
| 104 | | | | 73.3 | 18 | 5 | 3.7 | |

TABLE VII

GROWTH AND REPRODUCTION ON DIETS CONTAINING CLEANED WHEAT AND CLEANED WHEAT PEARLED

| Ration No. | No. of males | No. of females | No. of males died | No. of females died | No. of litters | Total No. of young | No. of young died | % Mortality | Growth Curve | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | | - | 9 |
| 2 | 2 | 4 | 0 | 3 | 2 | 11 | 11 | 100 | - | 9 |
| 3 | 3 | 3 | 0 | 0 | 6 | 36 | 36 | 100 | N- | 7 |
| 4 | 9 | 9 | 1 | 4 | 11 | 55 | 55 | 100 | N | 9 |
| 5 | 1 | 5 | 0 | 1 | 7 | 47 | 27 | 57.4 | N | 9 |
| 6 | 1 | 5 | 1 | 1 | 10 | 52 | 46 | 88.5 | N | 9 |
| 7 | 3 | 3 | 0 | 1 | 9 | 75 | 61 | 81.3 | N | 9 |
| 8 | 3 | 3 | 0 | 1 | 5 | 32 | 28 | 87.5 | N | 9 |
| 9 | 1 | 5 | 0 | 3 | 7 | 42 | 35 | 83.3 | N- | 10 |
| 10 | 5 | 7 | 1 | 2 | 17 | 118 | 87 | 73.7 | N | 10 |
| 11 | 3 | 3 | 0 | 0 | 5 | 36 | 17 | 47.2 | N | 10 |
| 12 | 3 | 3 | 0 | 0 | 4 | 28 | 7 | 25. | N | 10 |
| 13 | 3 | 3 | 0 | 0 | 7 | 36 | 28 | 77.7 | N | 10 |

TABLE VIII

GROWTH AND REPRODUCTION ON DIETS CONTAINING PETTIJOHN WHEAT AND SCOURED PETTIJOHN WHEAT

| Ration No. | No. of males | No. of females | No. of males died | No. of females died | No. of litters | Total no. of young | No. of young died | % mortality | Growth curve | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | | - | 4 |
| 15 | 4 | 3 | 0 | 1 | 0 | 0 | 0 | | - | 4 |
| 16 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 17 | 2 | 5 | 0 | 1 | 3 | 10 | 10 | 100 | - | 5½ |
| 18 | 3 | 3 | 0 | 0 | 1 | 5 | 5 | 100 | - | 5 |
| 19 | 2 | 5 | 0 | 1 | 4 | 14 | 14 | 100 | - | 5½ |
| 20 | 6 | 12 | 1 | 5 | 16 | 94 | 94 | 100 | N | 10 |
| 21 | 2 | 2 | 0 | 1 | 5 | 20 | 16 | 80 | N | 8 |
| 22 | 4 | 2 | 0 | 1 | 0 | 0 | 0 | | - | 4 |
| 23 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 24 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 25 | 3 | 3 | 0 | 0 | 1 | 2 | 2 | 100 | - | 5½ |
| 26 | 3 | 4 | 0 | 1 | 2 | 8 | 8 | 100 | - | 5 |
| 27 | 4 | 2 | 0 | 0 | 1 | 5 | 5 | 100 | - | 5½ |
| 28 | 8 | 10 | 2 | 3 | 22 | 138 | 126 | 92.7 | N | 10 |
| 29 | 2 | 2 | 0 | 1 | 5 | 32 | 27 | 84.4 | N | 8 |

TABLE IX

GROWTH AND REPRODUCTION ON DIETS CONTAINING PETTIJOHN BREAKFAST FOOD AND CLEANED PUFFING WHEAT

| Ration No. | No. of males | No. of females | No. of males died | No. of females died | No. of litters | Total no. of young | No. of young died | % mortality | Growth curve | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 31 | 4 | 2 | 0 | 1 | 0 | 0 | 0 | | - | 4 |
| 32 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 33 | 4 | 2 | 0 | 1 | 2 | 10 | 10 | 100 | - | 5½ |
| 34 | 2 | 4 | 0 | 0 | 1 | 5 | 5 | 100 | - | 5½ |
| 35 | 4 | 2 | 0 | 0 | 3 | 15 | 15 | 100 | N | 5½ |
| 36 | 2 | 4 | 0 | 3 | 3 | 11 | 11 | 100 | N | 8 |
| 37 | 2 | 4 | 0 | 1 | 0 | 0 | 0 | | - | 4½ |
| 38 | 3 | 3 | 0 | 2 | 1 | 7 | 7 | 100 | - | 5 |
| 39 | 3 | 5 | 0 | 3 | 3 | 12 | 12 | 100 | - | 5 |
| 40 | 4 | 2 | 0 | 1 | 3 | 16 | 16 | 100 | - | 5 |
| 41 | 2 | 4 | 0 | 0 | 5 | 30 | 30 | 100 | N- | 5 |
| 42 | 3 | 3 | 0 | 0 | 5 | 25 | 23 | 100 | N | 7 |
| 43 | 3 | 4 | 0 | 3 | 1 | 5 | 5 | 100 | N | 5½ |
| 44 | 4 | 3 | 0 | 2 | 1 | 10 | 10 | 100 | N | 5½ |
| 45 | 5 | 1 | 0 | 0 | 2 | 13 | 13 | 100 | N | 5½ |
| 46 | 4 | 2 | 0 | 1 | 3 | 16 | 16 | 100 | N | 5½ |
| 47 | 2 | 4 | 0 | 0 | 5 | 20 | 20 | 100 | N | 4 |
| 48 | 2 | 4 | 0 | 2 | 6 | 35 | 35 | 100 | N | 4 |

TABLE X

GROWTH AND REPRODUCTION ON DIETS CONTAINING PEARLED PUFFING WHEAT

| Ration No | No. of males | No. of females | No. of males died | No. of females died | No. of litters | Total no. of young | No. of young died | % mortality | Growth curve | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 49 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 4½ |
| 50 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 51 | 10 | 4 | 1 | 0 | 2 | 3 | 3 | 100 | - | 5 |
| 52 | 2 | 5 | 0 | 1 | 4 | 19 | 19 | 100 | - | 5 |
| 53 | 2 | 4 | 0 | 2 | 2 | 7 | 7 | 100 | - | 5 |
| 54 | 5 | 7 | 0 | 2 | 11 | 66 | 64 | | N- | 7 |
| 55 | 5 | 2 | 0 | 1 | 0 | 0 | 0 | | N | 5 |
| 56 | 5 | 2 | 0 | 1 | 0 | 0 | 0 | | N | 5 |
| 57 | 4 | 2 | 0 | 0 | 1 | 4 | 4 | 100 | N | 5 |
| 58 | 3 | 3 | 0 | 1 | 5 | 23 | 23 | 100 | N | 5 |
| 59 | 2 | 4 | 0 | 0 | 5 | 25 | 25 | 100 | N | 4 |
| 60 | 2 | 5 | 0 | 2 | 6 | 36 | 35 | 97.2 | N | 4 |

TABLE XI

GROWTH AND REPRODUCTION ON DIETS CONTAINING PUFFED WHEAT

| Ration No. | No. of males | No. of females | No. of males died | No. of females died | No. of litters | Total no. of young | No. of young died | % mortality | Growth curve | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 8 | 5 | 3 | 0 | 0 | 0 | 0 | | - | 4 |
| 62 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 63 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 64 | 5 | 8 | 0 | 1 | 0 | 0 | 0 | | - | 8 |
| 65 | 5 | 2; | 0 | 1 | 0 | 0 | 0 | | - | 5 |
| 66 | 3 | 4 | 1 | 2 | 0 | 0 | 0 | | - | 5 |
| 67 | 4 | 5 | 0 | 1 | 0 | 0 | 0 | | - | 5 |
| 68 | 4 | 3 | 2 | 2 | 0 | 0 | 0 | | - | 5 |
| 69 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | | - | 6 |
| 70 | 4 | 5 | 1 | 1 | 0 | 0 | 0 | | - | 5 |
| 71 | 3 | 4 | 1 | 1 | 0 | 0 | 0 | | - | 4 |
| 72 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | | - | 4 |
| 73 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 4 |
| 74 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | | - | 3 |

TABLE XII

GROWTH AND REPRODUCTION ON DIETS CONTAINING CLEAN OATS, DRY OATS, AND OAT GROATS

| Ration No. | No. of males | No. of females | No. of males died | No. of females died | No. of litters | Total no. of young | No. of young died | % mortality | Growth curve | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 75 | 3 | 4 | 1 | 0 | 0 | 0 | 0 | | - | 4½ |
| 76 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 77 | 3 | 3 | 0 | 0 | 1 | 5 | 5 | 100 | - | 5 |
| 78 | 7 | 5 | 0 | 0 | 6 | 35 | 35 | 100 | N- | 6 |
| 79 | 4 | 2 | 0 | 0 | 2 | 11 | 11 | 100 | - | 4 |
| 80 | 3 | 3 | 1 | 1 | 4 | 26 | 26 | 100 | N- | 6 |
| 81 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | | - | 4½ |
| 82 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 83 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 84 | 7 | 5 | 0 | 0 | 1 | 3 | 3 | 100 | - | 6 |
| 85 | 5 | 1 | 0 | 0 | 1 | 3 | 3 | 100 | - | 4 |
| 86 | 4 | 2 | 0 | 0 | 2 | 9 | 9 | 100 | - | 6 |
| 87 | 3 | 3 | 1 | 1 | 0 | 0 | 0 | | - | 4½ |
| 88 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 89 | 4 | 2 | 0 | 0 | 2 | 8 | 8 | 100 | - | 5 |
| 90 | 8 | 4 | 0 | 0 | 3 | 17 | 17 | 100 | N- | 8 |
| 91a | 4 | 2 | 0 | 0 | 2 | 7 | 7 | 100 | N- | 4 |
| 92 | 3 | 3 | 0 | 1 | 3 | 16 | 16 | 100 | N- | 8 |
| 93 | 3 | 3 | 0 | 0 | 4 | 24 | 24 | 100 | N- | 8 |
| 94 | 4 | 2 | 1 | 1 | 4 | 28 | 28 | 100 | N- | 8 |

TABLE XIII

GROWTH AND REPRODUCTION ON DIETS CONTAINING ROLLED OATS, OAT HULLS, FIRST SCOURINGS OF DURUM WHEAT, SECOND SCOURINGS OF DURUM WHEAT, POLISHED RICE AND PUFFED RICE

| Ration No. | No. of males | No. of females | No. males died | No. females died | No. of litters | Total no. of young | No. of young died | % mortality | Growth curve | Months on Ration |
|---|---|---|---|---|---|---|---|---|---|---|
| 95 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 4½ |
| 96 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 97 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | | - | 5 |
| 98 | 6 | 6 | 0 | 2 | 9 | 55 | 55 | 100 | N- | 8 |
| 99 | 3 | 3 | 0 | 0 | 3 | 19 | 19 | 100 | N- | 4 |
| 100 | 3 | 3 | 0 | 1 | 3 | 16 | 16 | 100 | - | 10 |
| 101 | 4 | 2 | 0 | 0 | 2 | 10 | 10 | 100 | N | 7 |
| 102 | 4 | 2 | 0 | 0 | 4 | 24 | 14 | 58.3 | N | 7 |
| 103 | 3 | 3 | 0 | 0 | 2 | 11 | 11 | 100 | - | 8 |
| 104 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | | - | 7 |

# PART II

## A COMPARISON OF THE PROTEINS OF ROLLED OATS WITH THE PROTEINS OF WHOLE MILK POWDER, AND CASEIN SUPPLEMENTED WITH YEAST, TOGETHER WITH A STUDY OF THE NUTRITIVE VALUE OF ROLLED OATS FROM THE STANDPOINTS OF REPRODUCTION AND LACTATION

# INTRODUCTION

Analysis of official statistics shows that grains, meats, and dairy products constitute the most important groups of food commodities consumed by mankind. Pearl[65] has shown by calculations based on government statistics for the years 1911-1918, that cereal grains and their products lead all other classes of food-stuffs by supplying 36 per cent of the protein eaten and approximately 35 per cent of the calories consumed by the American people. Meats and dairy products furnished 26 and 20 per cent of the protein respectively. Mitchell[51] stated that, on the average, some 43 per cent of the protein of the American diet is derived from milled cereals, wheat being the principal source.

The amount of the immense annual oat crop consumed directly by the human being is relatively small. But indirectly, a considerable proportion of the oat crop contributes in a great degree to human nutrition. Oats are of particular interest, since they are relatively, a rich source of protein of vegetable origin. The nutritive value of the oat proteins is not well established. A review of the literature shows conflicting views on the subject. Therefore, in this paper, two questions concerned with the nutritive value of rolled oats are considered:

1. How do oat proteins compare in nutritive value for growth with the proteins of whole milk powder and casein supplemented with yeast?
2. What is the nutritive value of rolled oats with respect to reproduction and rearing of young?

## REVIEW OF THE LITERATURE

Proteins of vegetable origin are regarded as being inferior to those of animal sources from the standpoint of biological value. Research on oat protein has a varied history. The earlier investigations showed oat proteins to be of markedly inferior quality as compared with those from animal sources and of poorer quality than those of other cereals. Later investigation has modified this opinion.

Osborne and Mendel[58] fed rats on protein concentrates from different cereals and found that the young animals failed to grow adequately on the oat diet. In later investigations of these observers[59], using the entire cereal grains at protein levels of 5.8 and 10 per cent with the addition of salt mixture, some of the animals grew to a large size, a result which indicated that the oat protein was adequate for growth in the rat.

McCollum, Simmonds, and Pitz[35] observed that when rats were fed a diet containing 9 per cent of oat proteins, and considered adequate in every other respect, they failed to grow after about one month. They also found that the oat kernel appeared to cause injury to the animals, when the diet was of such a nature as to lower their vitality; and that oats produce feces of a pasty character which make their elimination difficult and in all probability tend to debilitate the animal. But further work has altered this opinion for McCollum and Simmonds[28] state, "The oat kernel is comparable with wheat or maize in its dietary properties in nearly all respects". The lack of the necessary inorganic

constituents in the diet was probably the cause of the failure of the earlier investigations.

Sherman, Winter, and Phillips[70] conducted short experiments on human beings. Two subjects were fed a diet composed of "scones" made from oatmeal, starch, and butter, and eaten with apple and sugar. In the main experiment a small amount of milk was added to the diet. On this diet the nitrogen balances were $\pm$ 0.0 and + 0.2 gram per day although the calorific value was just sufficient to meet the energy requirement and supply 0.57 or 0.55 gram of protein per kilogram of body weight. In another experiment of the same duration in which no milk was added to the diet, the nitrogen balances were - 0.7 and - 0.6 grams of nitrogen per day respectively. Since the nitrogen equilibrium was maintained with such a low protein intake in the first series, and so closely approximated in the second, these investigators conclude that oatmeal proteins are efficiently utilized in the maintenance metabolism of normal adults.

Hartwell[20] concluded that oatmeal proteins when fed at a 10 per cent level provide for growth in the rat, but the rate of growth is slower than that of animals on a mixed diet such as kitchen scraps, bread and milk. She stated that a diet of oatmeal, butter, and salt mixture is not adequate for successful gestation and lactation. This is attributed not to the quality but to the quantity of the proteins in the diet. Growth of the young rats was found to be better when the mother was fed on a diet of 10 per cent oatmeal protein than when 10 per cent caseinogen was employed. Better growth in the suckling young was obtained by supplementing oatmeal protein with casein, gluten, gelatin, or egg albumin.

Suzuki, Matsuyama and Hashimoto[88] observed that growth was normal with diets containing 8 and 10 per cent respectively of rolled oat proteins. The efficiency of any given protein cannot be evaluated by chemical analysis alone. The presence in the food of indigestible carbohydrates, such as cellulose, hemicellulose and pentosans - and probably other substances - have considerable effect upon the digestibility of food proteins. Mendel and Fine[41, 42, 43, 44, 45, 46] have shown that these differences largely disappear when vegetable proteins are fed in a nearly pure state.

Thomas[89], conducting experiments upon himself, assigned the biological values of approximately 100 to the proteins of milk, meat, and fish - indicating complete utilization of the absorbed nitrogen. To corn and wheat he assigned the values 30 and 40 respectively. According to Thomas, the animal proteins are two or three times more valuable in adult nutrition than are the cereal proteins. McCollum, Simmonds, and Parsons[29,30,31,32,33] have made an extensive study of the biological value of the proteins of various foods by the use of rats. According to these experiments, the foods studied arrange themselves in decreasing order of the biological value of their proteins according to the following scheme: 1. beef kidney; 2. wheat; 3. milk, beef liver; 4. beef muscle, barley, rye; 5. corn, oats; 6. soy beans, navy beans, peas. In these experiments consideration was not given to the amount of protein consumed by the experimental animals. Mitchell[20,21,22,23,24], using a modified Thomas method for the determination of the biological value of proteins, found that when proteins are fed at such a level as to permit little or no growth the utilization of the absorbed nitrogen is usually good regardless of the type of protein fed.

TABLE XIV

PROTEIN VALUES OF FOODS FOR MAINTENANCE AND GROWTH

LEVEL OF PROTEIN FEEDING 8 TO 10%

| Food | Protein Content: On Fresh basis | Protein Content: On Dry basis | Quality of Protein: Digestibility (corrected) | Quality of Protein: Biological value | Protein Value of Food: On Fresh | Protein Value of Food: On Dry |
|---|---|---|---|---|---|---|
| Whole egg (cooked) | 15.2 | 49.3 | 100 | 94 | 12.0 | 44.9 |
| Milk | 3.3 | 25.4 | 100 | 85 | 2.6 | 20.2 |
| Egg white (cooked) | 12.3 | 89.1 | 100 | 83 | 10.0 | 72.6 |
| Beef liver | 20.4 | 70.8 | 90 | 77 | 14.9 | 51.1 |
| Beef kidney | 16.6 | 71.3 | 99 | 77 | 12.3 | 52.8 |
| Beef heart | 16.0 | 42.8 | 100 | 74 | 11.3 | 30.3 |
| Beef round | 21.3 | 71.0 | 96 | 69 | 13.7 | 45.7 |
| Pork ham | 25.0 | 62.5 | 100 | 74 | 17.9 | 44.8 |
| Veal | 20.7 | 78.0 | 100 | 62 | 12.4 | 47.0 |
| Rolled oats | 16.7 | 18.1 | 90 | 65 | 9.8 | 10.6 |
| Whole wheat | 13.8 | 15.6 | 91 | 67 | 7.1 | 8.1 |
| White flour | 10.8 | 12.4 | 100 | 52 | 4.3 | 5.0 |
| Whole corn | 7.5 | 8.4 | 95 | 60 | 3.0 | 3.5 |
| Potato | 2.2 | 10.1 | 78 | 67 | 0.8 | 3.9 |
| Navy beans (cooked) | 22.5 | 25.7 | 76 | 38 | 4.2 | 6.0 |
| Cocoa | 21.6 | 22.6 | 38 | 57 | 1.6 | 1.8 |
| Chocolate | 12.9 | 13.7 | 38 | 37 | 0.4 | 0.6 |
| Yeast | | | 76 | | | |
| Casein (15%) | | | 90 | | | |

The following values are given as representing the biological value of some proteins fed at a level of 5 per cent:

| | | | |
|---|---|---|---|
| Veal | 97 | Cocoanut | 77 |
| Milk | 94 | Corn | 73 |
| Beef | 92 | Soybean | 73 |
| Rice | 88 | Casein | 71 |
| Oat | 82 | Potato | 69 |
| Yeast | 77 | Navybean | 29 |

These figures represent the values of the digestible nitrogen from the given foods in repairing the depleted body tissues that result from endogenous catabolism. The relative inferiority of casein is due to the low content of cystine. When the proteins are fed at a higher level, which will permit more or less rapid growth, values different from the above are obtained. The table on "Protein Values of Foods for Maintenance and Growth" gives the evaluation of foods with respect to the nutritive value of their protein (nitrogen), from the standpoint of both quality and quantity where fed at 8 to 10 per cent levels of protein intake. The protein values summarized in the last two columns of the table show the superiority of animal foods over vegetable foods as sources of protein in the diet. Whole oats are distinctly superior to whole wheat and whole corn as sources of protein. The variation in the biological values of protein when fed at different levels of intake is due to the relative protein-sparing effect of the non-nitrogenous constituents of such diets.

Mattill[37], using the technique perfected by Mitchell[49], observed that the proteins of milk powder, precooked oats, and whole wheat had bio-

logical values of 89, 82 and 72 respectively, when fed at five per cent protein levels. These results are similar to those obtained by Mitchell.

The nutritive properties of casein are well known. Therefore, only a small amount of the literature on the subject will be reviewed. Osborne and Mendel [57], in a study of the comparative nutritive value of certain proteins to growth, found that from 15 to 18 per cent of casein was sufficient for normal growth in the rat. Osborne and Mendel [62], in a study of the quantitative comparison of casein, lactalbuain, and edestin for growth or maintenance, observed that cystine was the limiting amino acid of casein. Mitchell [52], in his review of the nutritive properties of casein, states that the biological value is somewhat higher than that of cereal grain proteins.

Osborne and Mendel [61] fed rats a diet containing 50-60 per cent of yeast as the source of proteins. Normal growth was obtained on less than 18 per cent of yeast proteins. Hawk, Smith, and Holder [21] in determining the nutritive properties of yeast protein for man, found that baker's yeast can replace from nine to 29 per cent of the protein in the diet without detriment to the best interests of the individual. The yeast food was well utilized. This was demonstrated by the retention of the protein, maintenance of body weight, and the general conditions of health. Mitchell [48] states that the corrected digestibility of yeast proteins for rats was 76 on a 10 per cent level and 78 on a five per cent level. Stitt and Koch [73], using rats as the experimental animals, observed that raw dried yeast as the only source of proteins in the diet had a digestibility of 72 per cent. Meisenheimer [40] gives the following as the analysis of

yeast proteins:

| | |
|---|---|
| Guanine | 4 % |
| Adenine | 4 % |
| Cytosine | 1.6% |
| Histidine and arginine | 10 % |
| Lysine | 10 % |
| Glycocoll | 5 % |
| Alanine | 10-15% |
| Valine | 10-15% |
| Leucine | 5-10% |
| Proline | 2 % |
| Phenylalanine | 8 % |
| Asparaginic acid | 3.5% |
| Glutaminic acid | 6 % |
| Tyrosine | 2 % |
| Tryptophane | .5% |
| Cystine and other sulphur compounds | 2 % |
| Oxyproline | 4.5% |
| Choline | .5% |
| Glucosamine | .5% |

The fact that rats failed to reproduce normally when fed purified diets was observed by numerous investigators before a specific reproductive vitamin was proposed. The failure of normal reproduction was attributed to the insufficiency of the known essential dietary factors of that period.

McCollum and Davis (26) using a diet of whole milk powder 10, casein 15, butterfat five, agar-agar two, dextrin 53, sucrose 15, and various additions of inorganic materials, failed to obtain normal reproduction. They concluded that the failure of normal reproduction was not due to the inorganic material. Mattill and Conklin (58) in a study of whole milk diets concluded that the milk proteins were not adequate for normal reproduction. But, after obtaining much better results upon the addition of yeast, ascribed the failure in reproduction to the lack of vitamin E. They were not, however, satisfied with either of these explanations. Mattill (36) obtained a fourth generation on a diet of dried whole milk 93, salt mixture two, and yeast five; the animals on this diet without the yeast produced young that were small and died within three or four days. Therefore the increase of vitamin B in the diet appeared beneficial for rearing of young. Reynolds and Macomber (67,68) concluded that the amount of vitamin A, protein, and calcium had marked effect upon fertility in rats.

Evans and Bishop (8,9,10,11,12,13,14) proved the existence of a specific dietary factor for reproduction. They found that increasing the amount or quality of protein, carbohydrate, and vitamins A, B, C and D did not improve reproduction on a basal synthetic diet. Mattill and Stone (39), employing milk rations, found that such diets were insufficient in protein and vitamins for reproduction. After the announcement of the existence of vitamin E, they stated that the failure in their experiments was due to the lack of this vitamin.

Sure (60,61) obtained normal growth on diets containing nine and six-tenths per cent milk powder proteins; young were produced but the rearing of the young was not successful. He concluded that normal reproduction

was not due to proteins nor to vitamins A, B, C or D, but to some other factor found in Georgia velvet bran pod meal, yellow corn, and rolled oats. Anderegg (1) observed that a diet containing 50 per cent of whole milk powder furnished sufficient proteins and vitamins for normal growth and reproduction, but the mortality of the young was high. Daniels and Hutton (3,4), working on the nutritive properties of milk and milk powders, obtained good reproduction by supplementing whole milk with ferric citrate, iodine, and ash of soy beans, lettuce, or yeast. The ash contained aluminum and silicon. They obtained good reproduction when the diet was supplemented with equal amounts of NaF, $KAl(SO_4)_2 \cdot 12\ H_2O$, $Mn\ SO_4 \cdot 5\ H_2O$, and $Na_2SiO_3$ so that each rat received 1.5 mg. of each salt per day. They concluded that the deficiency in milk diets was strictly inorganic. Kennedy (25) demonstrated that the ether extract of rolled oats contained the reproductive factor. She also observed that a deficiency of calcium or an excessively high per cent of protein in the diet would induce sterility even though vitamin E were present. Nelson and co-workers (56) investigated the effect of vitamin B upon growth and reproduction. Their work indicated that a much greater amount of vitamin B was required for reproduction than for growth. Later work by Guest, Nelson, and associates (19) demonstrated that the amount of vitamin B required for growth and reproduction was about the same. These observations were confirmed by Miller (47) who conducted investigations along the same line.

A diet may be sufficient for reproduction but not adequate for successful lactation; therefore the existence of a lactation promoting factor

has been suggested. Evans[7] observed that on many synthetic diets lactation was not successful. Lactation was improved by the addition of such substances as fresh leaves, wheat germ, egg yolk and meat, and vegetable oils. Sure[82,83] found that the oils of wheat, cottonseed, yellow corn, and the palm permitted normal lactation and prevented sterility. The oils of the peach kernel, the soy bean, the peanut, and the olive appeared to promote lactation but did not prevent sterility. Grijns[17,18] thought that there were at least two reproductive vitamins, one of which affected lactation only. Sure[84] observed that the reproductive factor of cottonseed oil was concentrated in the unsaponifiable material. When incorporated in a skimmed milk powder diet to the extent of 0.0175 per cent the concentrate produced good reproduction. Lactation was benefitted when twice this amount was used in the diet. In a more recent paper, Sure[79] was not certain as to the part wheat oil played in lactation. The wheat oil might prevent the oxidation of vitamin A and supply additional vitamin A. However, there was still a possibility that wheat oil contained a fat soluble lactation factor.

Guest, Nelson, and associates[19] studied various grains as sources of vitamin B for growth, reproduction, and lactation. As a result of obtaining good growth and reproduction - but a low per cent of young reared - they concluded that the amount of vitamin B necessary for lactation was considerably greater than that required for growth and reproduction.

Hartwell[20] employing Piebald rats on a diet prepared by heating 100 gm. of oatmeal, 2.88 gm. of salt mixture; and 14 gm. of butter with 500 gm. of water, observed that the litters produced were of small size

and the percentage of mortality was high. The weight of the young both at birth and at the weaning period was below normal. There was a noticable failure to rear the young even when bread and milk were given to the doe after the birth of the litter. The conclusion was that the oatmeal diet was not satisfactory for gestation on account of the low per cent of proteins present. In order to observe lactation the doe was placed on the experimental ration after the birth of the litter. The young failed to grow normally. In some instances the young developed symptoms indicating the lack of vitamin B. Therefore, this was considered as the cause of the inefficiency of the lactating mothers on the oatmeal diets and that it was not due to the quality of the oatmeal proteins.

Some investigations of the requirements of vitamin B for lactation have been made. Guest, Nelson and associates[19] observed that considerably more vitamin B is required for successful lactation than is required for growth and reproduction. Miller[47] concluded that the amount of vitamin B required for lactation was no greater than that required for growth and reproduction. Sure[85] observed that the lactating mother used the vitamin B complex quite inefficiently and, therefore, a large excess of the complex must be furnished in the diet of the mother, in order that the young may secure sufficient amounts in the milk. In regard to vitamins A and D, Sure[74] found that only minimum amounts were required by the mother as they were very economically utilized.

Vogt[90] observed that the vitamin requirements for the nursing young are very great. The young are fortified by a vitamin reserve when born. Sure[75,76] again demonstrated that the nursing young require large amounts

of the vitamin B complex, and that it is inefficiently secreted by the lactating mother. The growth of the young could be greatly stimulated by directly feeding vitamin B concentrates. Sure(86) ascribed much infant mortality to the lack of sufficient vitamin B complex.

Recently much work has been done in the study of the complex nature of the hitherto so-called water-soluble vitamin B. Most of the work in the past on reproduction and lactation has been concerned with the vitamin B complex and not with the individual vitamins B and G. At least two factors are recognized in the old vitamin B complex. One is heat labile and the other is relatively heat stable. The heat labile factor prevents polyneuritis or beri-beri and the heat stable factor prevents pellagra. Both factors are growth promoting. Sherman(69) reviews the facts concerning the discoveries of these factors designated in this paper as vitamins B and G. Evans and Burr(16) observed that approximately five times as much vitamin B was required for lactation as for growth. Vitamin G was found to be of little importance. On the other hand Sure(78), using rice polishings which contain more vitamin B than G, found that in order to secure normal lactation the polishings must be supplemented with autoclaved yeast. About three times as much of both vitamins B and G were required for lactation as were necessary for growth. Sure(77), using "vitavose", a commercial concentrate rich in vitamin B, found it to be inadequate for lactation. It was greatly improved by the addition of autoclaved yeast. Daniels, Jordan, and Hutton(6) studying milk diets, concluded that the poor growth of the suckling young was due to the low calorific value of the diets, or to the distaste for food resulting in too little of the diet being eaten, and not to a deficiency of vitamin B secretion in the milk.

In a more recent paper, Daniels, Hutton, and Marks[5] again stated that food consumption by the lactating mother on a milk diet played an essential role in the well being of the suckling young. The antineuritic vitamin was not the limiting factor.

Evans and Burr[15] noted a paralytic effect upon young when the mother was on a diet deficient in vitamin E. The young grew well until two or three days before weaning. At this time the young suddenly became paralyzed, and most of them died.

Waltner[91] studied the effects of iron on blood, growth, fertility, and lactation. He observed that reduced iron produced a harmful effect upon fertility and lactation, but the effects might be cured by vitamin D. Sure[87] observed in studies on lactation that copper has no supplementary value to a vitamin B concentrate.

## SOURCE AND PREPARATION OF MATERIALS USED

There are many cases of discrepancies in experimental results which are due to the different sources of the materials used and to the different methods of treatment in their preparation. Hence, the source and treatment of the materials used in the experiments discussed in this paper will be described.

Rolled oats. Rolled oats obtained from the Quaker Oats Company were used in all the experiments. The rolled oats were fed in three different ways: 1. Ordinary ground rolled oats, 2. rolled oats cooked and fed moist, 3. rolled oats cooked and dried.

(1) Rolled oats, fed raw, were finely ground and incorporated in the diets.

(2) Rolled oats, cooked and fed moist, were finely ground and mixed with the other ingredients of the diet; they were thoroughly moistened with distilled water and cooked in a double boiler for five minutes at 200° F.

(3) Rolled oats, cooked and dried, were thoroughly moistened with distilled water and cooked in a double boiler for five minutes at 200° F. They were then dried in a partial vacuum of 23 inches and at a temperature of 70° C. The dried material was finely ground and incorporated in the ration. The rolled oats used in (1) and (2) above had the following composition: moisture 8.50, protein 16.00, fat 6.80, ash 1.75, fibre 1.45, starch 62.10, and pentosans 3.80 per cent. The composition of the cooked and dried rolled oats as used in (3) was as follows: moisture 3.87, protein 16.78, fat 7.13, ash 1.83, fibre 1.53, starch 65.11 and pentosans 3.98 per cent.

Whole milk powder. The whole milk powder was obtained from the Merrell-Soule Company and contained protein 26.10, fat 27.15, sugar 38.00, ash 5.90, and moisture 2.85 per cent.

Casein. Commercial casein, obtained from Wilkens-Anderson Company, was washed for two weeks with distilled water acidified with acetic acid, the acidified solution being changed daily. After two weeks only distilled water was used for a period of several days. After the washing was complete, the casein was dried in shallow galvanized iron pans over steam hot plates and then finely ground. The dried product had the following composition: moisture 4.45, ash 0.40, and protein 95.15 per cent. The product was vitamin free.

Dextrin. Cornstarch secured from the Penick and Ford Company was moistened with 0.5 per cent citric acid solution and autoclaved for three hours at a pressure of 15 pounds. The resulting product was dried in shallow enameled pans over a steam hot plate and then finely ground.

Mineral mixture. McCollum's salt mixture 185 was used. However, in the whole milk powder diets 0.2 per cent of ferric citrate was added in addition to the salt mixture.

Yeast. The yeast used in the experiments was dried baker's yeast from the Fleischmann Company. The composition of the dried yeast was as follows: 45.73 per cent of protein, 1.50 per cent of fat, 30.99 per cent of starch, 6.01 per cent of cellulose and gums, 7.62 per cent of ash, and 8.15 per cent of moisture.

Butterfat. A high grade of butter, obtained from the College Creamery, was melted at a low temperature and then filtered through a soft filter

average gain in weight per gram of food and of protein consumed was 0.17 and 1.72 respectively. The six rats during the 11 week period consumed 3,833 grams of ration 107, containing 11.69 per cent of whole milk powder proteins, and made a total gain of 76 grams. The food consumed had a calorific value of 16,329 and contained 448 grams of protein. The average gain in weight per gram of food and of protein consumed was 0.20 and 1.70 grams respectively. The consumption of 3,645 grams of ration 108, containing 13.36 per cent whole milk powder proteins, produced a total gain in weight for 766 grams for six rats over a period of 11 weeks. The food consumed contained 487 grams of protein and had a calorific value 15,674. The average gain in weight per gram of food and of protein consumed was 0.21 and 1.58 grams respectively.

Growth on diets in which casein and yeast constituted the sole source of proteins.

Ration 109 contained 12.01 per cent of proteins, casein constituting eight and thirty-five hundredths and yeast three and sixty-six hundredths per cent of the diet. Over a period of 11 weeks the six rats made a total gain of 552 grams. The rats consumed 3,862 grams of food, containing 334 grams casein protein, and 146.4 grams of yeast protein, making a total of 480.4 grams of protein. The food eaten had a calorific value of 16,189. Each gram of food consumed produced an average gain of 0.14 grams. The average gain in weight per gram of protein consumed was 1.18 grams. The six rats on ration 110, containing 10.02 per cent of protein from casein and three and sixty-six hundredths per cent from yeast, consumed 3,750 grams food and made a total gain of 587 grams over a period of 11 weeks.

The food consumed had a calorific value of 15,788 and contained 376 grams of protein from casein and 137 grams from yeast, making a total of 513 grams of protein consumed. The average gain in weight produced per gram of food and of protein consumed was 0.16 and 1.14 grams respectively. Over a period of 11 weeks, six rats ate 3,895 grams of ration 111, containing a total of 15.35 per cent proteins, casein constituting 11.69 per cent and yeast three and sixty-six hundredths per cent of the diet. The food consumed had a calorific value of 16,592 and contained a total of 598 grams of protein. The total gain in weight was 734 grams. The average gain in weight per gram of food and of protein consumed was 0.18 and 1.23 grams respectively. Ration 112 contained 17.02 per cent of proteins, casein constituting 13.36 per cent and yeast three and sixty-six hundredths per cent of the diet. Over a period of 11 weeks the six rats made a total gain of 742 grams. The animals consumed 4,250 grams of food containing 567 grams of casein and 156 grams of yeast proteins. The food eaten had a calorific value of 18,275. The average gain in weight per gram of food and of protein consumed was 0.17 and 1.02 grams respectively.

Growth on diets in which rolled oats, cooked and dried, constituted the sole source of proteins.

Diets 113, 114, 115 and 116, containing eight and thirty-five hundredths, 10.02, 11.69 and 13.36 per cent respectively of cooked and dried rolled oat proteins were employed. It was impossible to secure accurate food consumption records on diets 113 to 115 inclusive. The rats scratched the food out of the cages. No food was wasted by the

rats on diet 116. Therefore, the results obtained on diet 116 only of this series are comparable in the comparative biological study of proteins.

The six rats on ration 116, containing 13.36 per cent of cooked and dried rolled oat proteins, consumed 3,136 grams of food containing 419 grams of protein and having a calorific value of 13,485. The total gain for the 11 weeks period was 521 grams. The average gain in weight per gram of food and of protein consumed was 0.13 and 1.21 grams respectively.

Growth on diets in which rolled oats, cooked and fed moist, constituted the sole source of proteins.

The consumption of 3,553 grams of diet 117, containing eight and thirty-five hundredths per cent of cooked rolled oat proteins produced a total gain of 431 grams in six rats. This amount of food contained 295 grams of protein. The calorific consumption for the 11 weeks period was 17,733. The average gain in weight per gram of food and protein consumed was 0.12 and 1.46 grams respectively. The six rats during the 11 week period consumed 4,281 grams of diet 118, containing 10.02 per cent of cooked rolled oat proteins. This amount of food contained 18,022 calories and 429 grams of protein. The average gain in weight per gram of food and of protein consumed was 0.13 and 1.34 grams respectively. On ration 119, containing 11.69 per cent of cooked rolled oat proteins, the consumption of 4,457 grams of food, which contained 521 grams of protein, produced a total gain of 693 grams in six rats during a period of 11 weeks. The calorific intake was 18,987. The average gain in

weight per gram of food consumed was 0.15 grams and for protein was 1.33 grams. On ration 120, containing 13.36 per cent of cooked rolled oat proteins, the total food and protein consumption for the 11 week period was 4,139 and 553 grams respectively. The calorific value of the food consumed was 17,798. The total gain in weight for the six rats was 730 grams. The average gain in weight per gram of food consumed was 0.18 and for protein was 1.32 grams.

Growth on diets in which uncooked rolled oats constituted the sole source of proteins.

The six rats on ration 121, containing eight and thirty-five hundredths per cent rolled oat proteins, consumed 3,136 grams of food containing 262 grams of protein in 11 weeks. The calorific consumption was 13,077. The total gain was 383 grams. Therefore, the average gain per gram of protein consumed was 1.46 grams. The gain per gram of food eaten was 0.12 gram. The six rats on ration 122, containing 10.02 per cent of rolled oat proteins, consumed 3,087 grams of the food containigg 314 grams of protein. The experimental animals made a total gain of 346 grams in 11 weeks. The calorific value of the food consumed was 12,996. The average gain in weight per gram of protein eaten was 1.33 grams. The gain per gram of food was 0.13 gram.

Ration 123 contained 11.69 per cent of rolled oat proteins. Over a period of 11 weeks the total gain for six rats was 355 grams. In order to make this gain 3,580 grams of food containing 415 grams of protein were consumed. The intake was 15,123 calories. The average gain in

weight was 0.16 gram per gram of food and 1.33 grams per gram of protein consumed. The total gain in weight for six rats on ration 124, containing 13.36 per cent of rolled oat proteins, was 612 grams. Three thousand four hundred and seventy-six grams of ration containing 464 grams of protein were eaten during a period of 11 weeks. The calorific value of the food consumed was 14,947. On this diet the average gain in weight per gram of protein consumed was 1.32. For each gram of food consumed gain in weight of 0.18 grams was obtained.

Experiments on Reproduction and Rearing of Young

In the experiments on reproduction and rearing of young, a further study was made on the diets investigated for growth. And in addition, other diets were employed, consisting of various levels of rolled oats from 35 per cent up to and including 91.3 per cent, fiver per cent of filtered butterfat, McCollum's salt mixture 185 (1914)[25], 3.7 per cent, and the remainder dextrin to 100 per cent. The rations were fed ad libitum and no food consumption records were kept in this series of diets. The results obtained are given in Tables XVIII and XIV on pages 107-108, and the composition of the diets is shown in Tables XV and XVI on pages 103-104.

Reproduction and rearing of young on diets containing whole milk powder.

Ration 105 contained 31.99 per cent of whole milk powder as the sole source of proteins and vitamins. This amount of milk powder contained 8.35 per cent of proteins. One female produced one litter of three young; another produced two litters of two and nine young. The third female died pregnant. Of the 14 young born seven were reared. The mortality was 50 per cent. The average age of the mothers at the birth of the first litter was 126 days. The time on the ration was five months. Growth on this diet was below normal. The amount of the ration consumed was 6,685 grams in 20 weeks. Ration 106 contained 38.39 per cent of whole milk powder as the sole source of proteins and vitamins. This amount of milk powder contained 10.02 per cent of protein. During the five-month period each of the three females on the diet produced one litter each eight and ten, young. The young from the litters containing eight and ten rats died within one week after birth. Of the 74 young born

,six were reared, the percentage mortality being 75. The average weight of the young at birth was 4.3 grams and at four weeks of age 33 grams. The average age of the mothers at the birth of the first litter was 112 days. Growth on thediet was normal. Eighty-five hundred grams of food were consumed in 20 weeks. Ration 107 contained 44.79 per cent of whole milk powder as the only source of proteins and vitamins. The milk powder furnished 11.69 per cent of proteins. During the five-month period three females produced two litters of young each. One female died at the end of the second month. The cause of death was unknown. Of the 40 young born only 15 were reared. The 25 young died within one week after birth. The mortality on the diet was 62.5 per cent. The average weight of the young at birth was 4.5 grams and at 28 days of age was 29 grams. The average age of the mothers when the first litters were born was 107 days. Growth on the diet was normal. Seven thousand five hundred grams of ration were consumed in 20 weeks. Ration 108 contained 15.19 per cent of whole milk powder as the sole source of proteins and vitamins. There were 13.36 per cent of proteins in the diet. The three females on the diet produced four litters of 20 young. Of the 20 young born 17 were reared, making the percentage mortality 15. The three young which died constituted one litter. They died during the first week after birth. The average weight of the young just after birth was 4.5 grams and at four weeks of age 36 grams. One litter of two weighed 50 grams each at the end of 28 days. The mother's age when the first litters were produced was 133 days. Growth on the diet was normal. Seven thousand seven hundred eighty-seven grams of food were consumed in 20 weeks.

Reproduction and rearing of young on diets containing casein and yeast.

The rations 109, 110, 111, 112, coming under this head, contained agar-agar for roughage, butterfat for the fat soluble vitamins, and yeast for the vitamin B complex.

Diet 109 contained 8.78 per cent casein, supplying 8.35 per cent protein, and eight per cent of dried yeast, furnishing 3.66 per cent of protein. During the five-month period two of the three females produced one litter each of two and three young. All of the young died during the week after birth, making the percentage mortality 100. The average weight of the young shortly after birth was four grams. The average age of the two mothers when the first young were born was 135 days. Growth on the diet was slightly below normal. During the 21 week period 8,335 grams of food were consumed. Ration 100 contained a total of 13.68 per cent of proteins, supplied by the 10.53 per cent casein and eight per cent yeast in the diet. Three females produced four litters of 26 young, only seven of which were reared. The mortality was 73.1 per cent. The young died within a few days after birth. The average weight of the young shortly after birth was 4.3 grams and at the age of 28 days was 28 grams. The average age of the mothers when the first litters were born was 133 days. Growth on the diet was normal. The six animals consumed nine kilograms of ration in 21 weeks. Ration 111 contained a total of 15.35 per cent of protein, supplied by 12.29 per cent casein and eight per cent of yeast in the diet. The three females on the diet produced four litters of 30 young. One young was born dead, and 22 died within one week after birth. Seven young were reared. The percentage mortality was 76.7. The average weight of the young shortly after birth was 4.3 grams

and at 28 days of age was 26 grams. The average age of the mothers when the first litters were born was 98 days. The time on the ration was five months. The growth curves were normal. Eight thousand two hundred five grams of ration were consumed in 21 weeks.

Ration 112 contained a total of 17.02 per cent of proteins, supplied by the 14.04 per cent of casein and the eight per cent of yeast in the diet. The four females on the diet produced seven litters of 40 young. One female died just after giving birth to a litter of seven young, and, as a result, the young died. One young was born dead. The remainder of the young with the exception of the six which were reared, died within one week after birth. The percentage of mortality was 85. The average weight of the young shortly after birth was 4.5 grams and at 28 days of age was 42 grams. The average age of the mothers when the first litters were born was 105 days. The time on the ration was five months. The growth curves were normal. In 11 weeks the animals consumed 8,468 grams of the diet.

Reproduction and rearing of young on diets containing rolled oats cooked and fed moist.

The rolled oats in the diets were the source of the proteins and of the vitamin B complex. Butterfat supplied vitamin A and D. The rolled oats and butterfat furnished vitamin E.

Ration 117 contained 52.20 per cent of cooked rooled oats which supplied 8.35 per cent of proteins in the diet. Two of the three females produced one litter each of five and six young, all of which were reared. The average weight of the young shortly after birth was 4.3 grams and the average weight was 36 grams at 28 days of age. The average age of the two mothers when their

first young were produced was 140 days. The time on the ration was five months. The growth curves were slightly below normal.

Ration 118 contained 62.63 per cent of cooked rolled oats, which supplied 0.07 per cent of proteins in the diet. The three females produced four litters of 34 young, all of which were reared. The average weight of the young shortly after birth was 4.4 grams and at 28 days of age was 30 grams. The average age of the mothers when the first litters were born was 145 days. The time on the ration was five months. Growth curves were normal. Ration 119 contained 73.06 per cent cooked rolled oats, which supplied 11.69 per cent of protein in the ration. The three females produced one litter of young each. All of the 17 young were reared. The average weight of the young shortly after birth was 4.5 grams and averaged 36 grams at the end of the fourth week. The average age of the mothers when they produced the young was 140 days. The time on the ration was five months. The growth curves were normal. Ration 120 contained 83.50 per cent of cooked rolled oats, which supplied 13.36 per cent of proteins in the diet. Of the four females on the ration, one died at parturition during the middle of the third month. The remaining three females produced four litters of 33 young; two of the young died during the first week after birth. The remaining 31 young were reared. The average weight of the young shortly after birth was 4.6 grams and at the end of 28 days 44 grams. The average age of the mothers when their first litters were born was 140 days. The time on the ration was five months. The growth curves were above normal.

Reproduction and rearing of young on diets containing uncooked rolled oats.

In the following diets the rolled oats were the sole source of protein. The vitamins were supplied by the oatmeal and the five percent of butterfat incorporated in the diets.

Ration 121 contained 52.20 per cent rolled oats, which supplied 8.35 per cent of proteins. Two of the three females produced one litter each of five and six young. The litter of six died in four days because of lack of care by the mother. All of the litter of five were reared. The percentage of mortality was 54.5. The average weight of the young shortly after birth was 4.4 grams and at 28 days of age was 22 grams. The average age of the mothers when the litters were produced was 123 days. The time on the ration was five months. The growth curves were below normal. Six thousand seven hundred thirty grams of ration were consumed within 21 weeks. Ration 122 contained 62.63 per cent of rolled oats, supplying 10.02 per cent of protein in the diet. Each of the three females on the diet produced one litter of young. Of the 16 young born 12 were reared. The six young which died constituted one litter. They died with 10 days after birth. The mortality was 33.3 per cent. The average weight of the young at birth, or shortly after, was 4.5 grams and 30 grams at the age of four weeks. The average age of the mothers when the litters were produced was 140 days. The duration of the experiment was five months. The growth curves were slightly below normal. During 21 weeks 7,000 grams of ration were consumed. Ration 123 contained 73.06 per cent rolled oats, supplying the diet 11.69 per cent of proteins. The three females on the diet produced four litters of 24 young. One young was born dead and 10 young died within four days after birth.

One female, for some unknown reason, died during the fifth month of the experiment. The average weight of the young shortly after birth was 4.5 grams and 28 grams at the end of four weeks. Two litters were reared. The average age of the mothers when the first litters were born was 120 days. The rats were kept on experiment for five months. The growth curves were normal. Seven thousand four hundred and ninety grams of ration were consumed in 21 weeks.

Ration 124 contained 83.50 per cent of rolled oats, supplying 13.36 per cent of proteins. The three females produced five litters of 35 young. Since only one young died, the percentage of mortality was but 2.9. The average weight of the young shortly after birth was 4.5 grams and 42 grams at the age of 28 days. The average age of the mothers when the first litters were produced was 84 days. The duration of the experiment was five months. The growth curves were normal. Eight thousand three hundred and six grams of ration were consumed.

On ration 125, containing 35 per cent of rolled oats and supplying 5.6 per cent of proteins, no young were produced. The duration of the experiment was seven months. One female died during the first month of the experiment and another died at the end of the fourth month. The growth curves were considerably below normal.

On ration 126, containing 40 per cent of rolled oats and supplying 6.4 per cent of proteins, one of the three females produced one litter of six young. Five young were reared. The average weight of the young shortly after birth was 3.5 grams and 10 grams at 28 days of age. These young were then placed with a lactating female on the growing ration.

The young grew normally and reproduced normally on the growing ration. The mortality on ration 126 and 16.7 per cent. The duration of the experiment was seven months. The growth curves were considerably below normal.

Ration 127 contained 45 per cent rolled oats, supplying 7.2 per cent proteins in the diet. Of the four females, one female died at the end of the third month from an unknown cause; another died at the end of the fifth month with otitis media; and one of the two remaining females produced two litters of 12 young, four of which were reared. The remainder of the young died within the first week after birth. The average weight of the young shortly after birth was 3.5 grams and 10 grams at 28 days of age. The percentage mortality was 66.6. The age of the mothers when the first litter was produced was 137 days. The duration of the experiment was seven months. The growth curves were considerably below normal.

The four young reared were placed on the growing ration. They grew, reproduced, and reared young normally.

Ration 128 contained 50 per cent of rolled oats supplying eight per cent of protein in the diet. Three males and five females were placed on the diet. One male died at the end of the first month with otitis media. Three females died; one died at the end of the second month with otitis media; another died pregnant during the fifth month; and one died at parturition in the sixth month. Four litters of 21 young were born and eight were reared. The percentage mortality was 62. The 13 young died within four days after birth. The average weight of the young shortly after birth was four grams and at the end of four weeks, 20 grams. The average age of the mothers

when the first litters were produced was 98 days. The first generation animals were kept on the diet 7.5 months. The growth curves were below normal.

Three of the young reared were placed on the growing ration. They grew, reproduced, and reared young normally. Five of the young were continued on the experimental ration for five months. The three females produced one litter each. A total of 19 young were born, two being born dead. Eight died when two weeks of age and three young died four days after birth. Six young, constituting one of the litters, were reared. The average weight of the young shortly after birth was 4.5 grams and at one month of age 20 grams. The age of the mothers when the first litters were produced was 124 days. The growth curves were below normal. The experiment was not continued with the third generation.

Ration 129 contained 56 per cent rolled oats, supplying 8.96 per cent proteins in the diet. Four males and two females were employed on the diet. One female produced one litter of five young and the other three litters of five, five, and eight young respectively. All of the young died within the first week after birth. The average weight of the young at birth was 3.5 grams. The average age of the mothers when the first litters were produced was 153 days. The time on the ration was 7.5 months. The growth curves were below normal.

Ration 130 contained 60 per cent of rolled oats, supplying 9.6 per cent protein in the diet. The three females produced seven litters of 44 young, 12 of which were reared. The percentage mortality was 72.8. One young was born dead and the remainder died within a week after birth. The

average weight of the young shortly after birth was 4.5 grams and 25 grams at 28 days of age. The average age of the mothers when their first litters were produced was 94 days. The first generation was kept on the ration 7.5 months. The growth curves were normal.

The second generation was carried over a period of four months. Three females produced four litters of 22 young; 18 young were reared, giving a percentage mortality of 13.7. One young was born dead and three young died 10 days after birth. The growth curves were below normal.

The third generation was continued on the ration three months after rearing. Three females produced five litters of 24 young, 13 of which were reared. The percentage mortality was 45.9. Eleven young died within 48 hours after birth. The average weight of the young shortly after birth was five grams and at 28 days of age 27 grams. The mothers reproduced at an average age of 100 days. The growth curves were normal. The fourth generation was not continued.

Ration 131 contained 65 per cent rolled oats, supplying 10.40 per cent of protein in the diet. One male died during the eighth month of the experiment, the reason being unknown. One female died during the sixth month on the second day after giving birth to her third litter. The litter of six young were born dead. In addition to the litter born dead seven other litters were produced. Most of the 28 young which died did so within 48 hours after birth. The percentage mortality was 75.7. The average weight of the young was 4.5 grams shortly after birth and 37 grams at 28 days of age. The average age of the mothers when their first litter was produced was 81 days. The time on the ration was 7.5 months

for the first generation. The growth curves were normal. One of the three females of the second generation on this diet died during the third month. One of the remaining two females produced one litter of 14 young and reared 11. The other females produced two litters of one and eight young. Four young died within one week. Nineteen of the 23 young born were reared. The average weight shortly after birth was 4.5 grams and at four weeks of age 27 grams. The per cent mortality was 17.4. The time on the ration was five months. The growth curves were slightly below normal.

Three males and three females of the third generation were continued on the diet three and one-half months. In this time two litters of 12 young were born and all were reared. The average weight of the young shortly after birth was four grams and 28 days of age was 27 grams. The growth curves were normal. The fourth generation was not continued.

Ration 132 contained 70 per cent of rolled oats, supplying 11.20 per cent of proteins in the diet. Of the three females on the diet one died at parturition, after having previously given birth to two litters of young. Ten litters of 44 young were born and 13 reared. The remainder of the young died within one week after birth. The average weight of the young shortly after birth was 4.5 grams and 31 grams at 28 days of age. The first generation was kept on the diet seven and one-half months. The growth curves were normal.

From the three females of the second generation kept on the diet three litters of young were produced. Of the 15 young born, 14 were reared. The percentage of mortality was 6.7. The time on the ration was

five months. Growth curves were below normal.

Ration 133 contained 75 per cent of rolled oats, supplying 12 per cent of proteins in the diet. One male and all three females on the diet died. Two of the females died shortly after having given birth to their third litter of young. The cause of the death of the other female and the male was unknown. Therefore 12 young died, account of the fact that their mothers died and nine young died within a week after birth. The percentage mortality was 38.2. The average weight of the young shortly after birth was 4.5 grams and 30 grams at 28 days of age. The average age of the mothers when their first litters were produced was 85 days. The first generation was kept on the diet eight and one-half months. The growth curves were normal.

Three females of the second generation produced one litter each. Three young from a litter of four died within one week after birth. The percentage mortality was 17.6. The average weight of the young shortly after birth was five grams and 34 grams at the age of 28 days. The second generation was discarded at the end of four months. The growth curves were below normal.

Three males and three females from the second generation were continued on the diet for three and one-half months. Each female produced a litter of young, a total of 30 young. All of the young were reared. The average weight of the young shortly after birth was 4.5 grams and 36 grams at 28 days of age. The growth curves were normal. The fourth generation was not continued.

Ration 134 contained 80 per cent of rolled oats, supplying 12.80

per cent of proteins in the diet. Of the three females on the diet one died at parturition, after having previously given birth to two litters of young. Ten litters of 58 young were born. One litter of four young were born dead. Six young died within 48 yours after birth. The percentage mortality was 17.8. The average weight of young shortly after birth was 4.5 grams and 30 grams at 28 days of age. The average age of the mothers when their first litter was produced was 66 days. The first generation was discarded after nine months. The growth curves were above normal.

The three females of the second generation produced three litters of 20 young. One young was born dead, nine young died within 42 hour after birth. Ten young were reared, making the percentage of mortality 50. The average weight of young shortly after birth was 4.5 grams and 23 grams at 28 days of age. The time on experiment was four months. The growth curves were below normal.

One male and five females of the third generation were continued on the diet for a period of four months. Each female produced one litter of young. Of the 38 young born 25 were reared. Every one died within one week after birth. The percentage mortality was 29.9. The average weight of the young shortly after birth was five grams and at 28 days of age was 32 grams. The growth curves were normal. The fourth generation was not continued.

Ration 135 contained 85 per cent of rolled oats, supplying 13.60 per cent of proteins in the diet. One of the three females died pregnant during the fifth month after having previously given birth to one litter.

## DISCUSSION OF RESULTS

### Comparative Growth on Oat Proteins, Milk Powder Proteins, and Casein

In the study of the comparative value of the proteins of rolled oats, whole milk powder, and casein supplemented with yeast, the average gain in weight of the experimental animals per gram of protein consumed, in the 11 week period, is taken as the basis of comparison. Table XVII shows the result of the experiments and Table XV gives the composition of the diets.

When the ration contained 8.35 per cent of whole milk powder proteins the average gain in weight for six rats was 1.64 grams. When the diets contained 10.02, 11.69, and 13.36 per cent of whole milk powder proteins the average gain in weight per gram of protein consumed was 1.72, 1.70, and 1.58 grams respectively. The greatest gain in weight per gram of whole milk powder protein consumed was on the 10.02 per cent protein level. This probably represents approximately the maximum growth promoting capacity of whole milk powder proteins when fed to albino rats under the conditions of the experiment.

The whole milk powder in each of the four levels contained sufficient vitamins for normal growth. Normal growth was obtained on diets with purified casein and 8.35 per cent of milk powder proteins, equivalent to 31.99 per cent of whole milk powder, as the only sources of vitamins A, B, C, and D. The growth curves were normal on the diets containing 10.02 or more per cent of whole milk powder proteins. Sure (80) observed that 9.6 per cent of milk proteins was adequate for good growth.

The casein diets, 109, 110, 111, and 112, contained 8.35, 10.02 11.69, and 13.56 per cent casein respectively--supplemented in each case with 3.66 per cent yeast protein. The average gain in weight per gram of total protein consumed over the period of the experiment was, for diet 109, 1.18 grams; for diet 110, 1.14 grams; for diet 111, 1.23 grams; and for diet 112, 1.02 grams. The maximum gain per gram of protein consumed was on the diet containing casein and yeast proteins at levels of 11.69 and 3.66 per cent respectively. Osborne, Mendel, and Ferry (63), in estimating the nutritive value of casein at levels of 17.4 per cent, 14.7 per cent, 12.0 per cent, and 9.3 per cent, obtained maximum growth promoting properties on the 9.3 per cent level.

It is unknown to what extent yeast protein supplements casein. Osborne and Mendel (61) observed that rats grew normally on less than 18 per cent yeast protein. Smith and Holder (71) found that yeast protein was well utilized by human beings. Nelson, Heller, and Fulmer (55) using the albino rat, secured good growth and rearing of young on yeast proteins. Mitchell (48) and Stitt and Koch (73) observed that the digestibility of yeast proteins was above 70 per cent. Meisenheimer (40) states that yeast protein contains two per cent of cystine and other sulphur-containing compounds in addition to other essential amino acids. Yeast proteins should greatly supplement casein since cystine is the limiting amino acid of casein according to Osborne and Mendel (57). The growth curves were normal on the diets which contained as much as 10.02 per cent of casein and 3.66 per cent of yeast protein. Since 12 per cent of casein, according to Osborn and Mendel (57), is not adequate for normal growth in the rat, it is evident that yeast proteins sup lement casein to a considerable

extent.

A diet of rolled oats, cooked in a double boiler for five minutes at 93.3° C. and dried in a partial vacuum of 23 inches at 70° C., contained 13.36 per cent of rolled oat proteins. During the period of experiment, the average gain in weight per gram of protein consumed on this diet was 1.21 grams. Growth was below normal on this protein level. The food consumption was low on this diet.

The diets of rolled oats cooked in a double boiler for five minutes at a temperature of 200° F. and fed moist contained oat proteins at the levels of 8.35, 10.02, 11.69, and 13.36 per cent. The average gains in weight on these respective levels of protein, per gram of protein consumed, were 1.46, 1.34, 1.33, and 1.32 grams. The maximum growth efficiency was exhibited on the 8.35 per cent level of oat proteins. Only on the 8.35 per cent level of the oat protein was the growth below normal.

The average gains in weight per gram of protein consumed on the 8.35, 10.02, 11.69, and 13.36 per cent uncooked rolled oat proteins were 1.46, 1.33, 1.33 and 1.32 grams respectively. The maximum efficiency of the oatmeal proteins, for promoting growth, was obtained on the 8.35 percent level. Growth was normal on 11.69 and 13.36 per cent levels of rolled oats proteins, but below normal on the other two levels.

The results on the diets of rolled oats, cooked and dried, are considerably lower than those obtained on the uncooked and the cooked fed moist. This appears to be due to the failure of these animals to consume a sufficient amount of the diets. The ration was not palatable. The cooked and dried product was very hard and tough. The poor value of

diet 116 can be explained only by the drying effect upon the starch of the rolled oats. There were no evidences, and it seems improbable, that the antineuritic factor was destroyed in the drying process.

There is an apparent difference, judging from curves of growth, between the nutritive value of the uncooked rolled oat proteins and the cooked rolled oat proteins fed moist on the corresponding 8.35, 10.02, 11.69 and 13.36 per cent protein levels. This apparent difference is due to the fact that the experimental animals consumed more of the diets containing the cooked rolled oats fed moist, and as a consequence grew larger. An analysis of growth, from the standpoint of food consumption on the comparative levels of protein, reveals that one gram of uncooked rolled oat protein is equivalent in nutritive value to one gram of cooked rolled oat proteins fed moist. Therefore, cooking rolled oats in a double boiler has no deleterious effect on rolled oat proteins. Cooking has a beneficial effect from the standpoint of increased food ingestion.

It is well known that milk proteins are of the highest biological value. Therefore, if we use the results of the milk powder proteins as the standard of comparison, we get the following results:

| | | |
|---|---|---|
| Casein | 8.35% | |
| | | 71.9% |
| Yeast | 3.66 | |
| Casein | 10.02 | |
| Yeast | 3.66 | 66.2% |
| Casein | 11.69 | |
| Yeast | 3.66 | 72.4% |
| Casein | 13.36 | |
| Yeast | 3.66 | 64.6% |

| | | |
|---|---|---|
| Rolled oats (cooked and dried) | 13.36 | 76.6 |
| Rolled oats (Cooked & fed moist) | 8.35 | 89.0 |
| " " " | 10.02 | 77.6 |
| " " " | 11.69 | 78.2 |
| " " " | 13.36 | 85.5 |
| Rolled oats (uncooked) | 8.35 | 89.0 |
| " " " | 10.02 | 77.3 |
| " " " | 11.69 | 78.2 |
| " " " | 13.36 | 85.5 |

The results on the diets containing whole milk powder and uncooked rolled oats, on the comparative protein levels of 8.35, 11.69, and 13.36 per cent, are strictly comparable for the reason that the amount of food consumed was approximately the same on all comparable levels. Therefore, in these cases the calarific value and protein consumed during the period of the experiment were approximately the same on the comparative levels of protein.

These results indicate that the rolled oat proteins are of a higher nutritive value than is conceded by many of the numerous investigators who have studied the biological value than casein or casein supplemented with yeast at the protein levels investigated.

### Comparative Reproduction and Lactation on Oat Proteins, Whole milk Powder, and Casein

Evans and Bishop 8, 9, 10, 11, 12, 13, 14, have shown that the dietary factor, Vitamin E, is essential for reproduction. Their results also show that butter fat and yeast are poor sources of this vitamin. Sure

(58) showed that butter fat contains varying but demonstrable amounts of this vitamin. Heller (22,55) demonstrated that yeast contained this vitamin to an appreciable extent. Kennedy (25) showed that oats contained Vitamin E.

The experimental animals, on diets 105 to 124 inclusive, were continued on these rations for a period of five months, in order to secure some data with respect to reproduction and rearing of young on diets containing comparative levels of protein from different sources. Results of the experiment are shown in Table XVIII. Reproduction on all these diets is good, with exception of those containing the cooked and dried rolled oats. The average size of the litters is about the same on all the diets but in each case is probably below the normal. The best results in respect to successful reproduction and rearing of young were obtained on the raw rolled oats and on the cooked rolled oats fed moist. The average weight of the young at 28 days of age for whole milk powder diets was 31 grams; for casein-yeast diets, 32 grams; for the rolled oats cooked and fed moist, 37 grams, and for the diets of uncooked rolled oats 31. grams. The average percentage mortality of the whole milk powder rations was 54.6 per cent, for the casein-yeast rations 83.7 per cent, for the rolled oats cooked and dried 1 0 per cent, for the rolled oats diets, cooked and fed moist, 2.5 per cent, and for the uncooked rolled oat diets, 34.1 per cent. Only on one series of diets, those of the rolled oats cooked and fed moist, was rearing of young normal. The milk powder diets were superior to the comparative casein-yeast diets with respect to lactation. The uncooked rolled oats and the

rolled oats, cooked and fed moist, on the respective levels of protein and calorific content, are markedly superior to whole milk powder. The apparent superiority of the rolled oats, cooked and fed moist, over the uncooked rolled oats is due to the increased consumption of the cooked moist diets. The results on the milk powder diets and those on the raw rolled oats are strictly comparable for the reason that the food consumption was approximately the same for the period of the experiment. The comparative diets also contained the same percentage of protein and calorific value. The food consumption on the casein-yeast diets was appreciably greater than on the whole milk powder and uncooked rolled oat diets, but the efficiency of the casein diets was much lower.

The poor results of lactation on the milk powder diets was probably due to the low content of the vitamin B complex. A control diet of casein and 31.99 percent whole milk powder supplemented with salt mixture ferric citrate, butter fat and dextrin produced normal growth. The fact that normal growth was obtained on this level of milk powder indicates a far greater requirement of vitamin B complex for lactation than for growth. Sure (75,76) has shown that the nursing young of the rat requires rather large amounts of both vitamins B and G and that the mothers use these vitamins very insufficiently. Sure (78) observed that about three times as much of the vitamin B complex was required for lactation as for growth which fact verifies the results of Guest and Nelson.

The inefficiency of the lactating mothers on casein-yeast diets

is no doubt due to the lack of the Vitamin B complex in the 8 per cent yeast employed in the diets. Control experiments showed that at least 5 per cent of this yeast was required for normal growth. Evans and Burr (1928) (16) state that in a simpli-field diet about 5 times the usual intake of vitamin B complex is required in the latter part of lactation.

The failure in the diets of rolled oats, cooked and dried, was due to low food intake. The diet was unpalatable and no doubt difficult to digest.

## Comparative Value of Different Levels of Rolled Oats As the Sole Source of Protein on Reproduction and Lactation

The results of the more detailed study of the effect of rolled oat diets upon growth, reproduction, and rearing of young are shown in Table XIX and the composition of the diets is given in Table XVI . Growth was normal for the first generation when the diet contained as much as 60 per cent rolled oats, the remainder of the diet consisting of 5 per cent filtered butter fat, 3.7 per cent McCollum's salt mixture, 10.185 and 31.3 per cent dextrin. This percentage of rolled oats contains 9.60 per cent of proteins. The growth of the second generation on this diet was below normal, but the third generation grew normally. The same results were observed on all of the diets containing higher levels of rolled oats. The first generations was placed on the diets in September and carried through until May, the second generations from January until May, and the third generation from May until September approximately. It is not known whether or not the time of the year has any effect upon

the growth of the rat. The above results are most likely due to different rates of food consumption. Food consumption records were not kept on these experiments.

The ages of the mothers when they produced their first litters of young was appreciably greater in the second generation than in either the first or the third generation females. This shows a relationship to the growth. This may be due to the period of the year, but most likely is due to the rate of food consumption. The young produced by the third generation had a lower death rate than those from either the first or second generations.

A study of the effect of the period of the year upon food consumption, growth, reproduction, and the rearing of young should be made.

Reproduction and rearing of young was obtained on a diet containing 40 per cent rolled oats as the sole source of proteins and the vitamin B complex. However, only one litter was produced on this level of rolled oats. The young were placed with a lactating female from the growing ration and were maintained on the stock ration. They grew normally and reproduced normally. Young from the 45 and 50 per cent levels of rolled oats diets were placed on the growing rations when weaned (at 28 days of age) and growth, reproduction, and rearing of young were normal. These results show that the low protein and vitamin B of the rolled oat diets did not have a deleterious effect upon the young.

On diets 128 to 135 inclusive a rather large per cent of the first generation females died during of period of pregnancy, at parturition, or shortly after parturition. There were no deaths, however, in either

the second or third generation females at these periods. The reasons for this are unknown.

The young produced on the rolled oat diets as a rule were slightly under weight at birth and also at the age of 28 days. The mortality was appreciably above normal in most cases.

## SUMMARY

Normal growth was obtained on whole milk powder diets containing 10.02 per cent proteins.

Diets containing 10.02 per cent casein supplemented with 3.66 per cent yeast protein are adequate for normal growth for the albino rat.

When rolled oats, cooked in a double boiler for 5 minutes at 93.3° C. and dried in a partial vacuum of 23 inches at 70° C., supply 13.36 per cent proteins in the diet, growth is not normal.

Normal growth was obtained on diets containing 10.02 per cent protein when supplied by rolled oats cooked in a double boiler and fed moist.

The biological value of oat proteins is 77 to 89 per cent of whole milk powder proteins. The oat proteins are of higher nutritive value than the casein plus yeast proteins.

Diets containing 60 per cent rolled oats, supplying 9.6 per cent protein, are adequate for normal growth through the third generation.

Reproduction and rearing of young was more successful on the comparative levels of rolled oat diets than on the whole milk powder or casein-yeast diets.

The diets of rolled oats, cooked and fed moist, were more palatable than the rations containing uncooked rolled oats.

Normal reproduction and rearing of young were obtained on the diets containing rolled oats cooked and fed moist.

Second generation females on the rolled oat diets failed to grow

as well or rear young as successfully as the females of the first and third generations.

Cooked and dried rolled oats yielded poorer growth, reproduction and lactation than either uncooked rolled oats or rolled oats cooked and fed moist.

## CONCULSIONS

1. Rolled oat proteins are of high biological value.

2. Rolled oat proteins are adequate for successful growth, reproduction, and rearing of young.

3. Food consumption plays an important role in rearing of young.

4. Rolled oats cooked and fed moist are more palatable than either the uncooked or rolled oats cooked and fed dry.

5. Cooking does not impair the nutritive value of rolled oat proteins.

6. Rolled oats contain an appreciable amount of Vitamin E.

7. Diets of comparative levels of protein from rolled oats are more favorable to reproduction and rearing of young than are the corresponding diets of whole milk powder and casein supplemented with yeast.

8. Yeast supplements casein appreciably.

9. The casein-yeast diets contained an appreciable amount of Vitamin E.

10. Cooking and then drying the oatmeal injures its nutritive value.

TABLE XV

COMPOSITION OF DIETS

| Ration No. | Whole Milk Powder | Casein | Rolled Oats Cook & dried | Rolled Oats Cook & fed moist | Rolled Oats (raw) | Butter fat | Dextrin | Salt mixture | Ferric citrate | Yeast | Agar-Agar | Growth curve | Calories per gm. of ration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 105 | 31.99 | | | | | | 61.55 | 2.50 | 0.20 | | 3.76 | - | 4.17 |
| 106 | 38.39 | | | | | | 54.61 | 2.49 | 0.20 | | 4.31 | N | 4.21 |
| 107 | 44.79 | | | | | | 47.66 | 2.33 | 0.20 | | 5.02 | N | 4.26 |
| 108 | 51.19 | | | | | | 40.21 | 2.06 | 0.20 | | 6.34 | N | 4.30 |
| 109 | | 8.78 | | | | 9.17 | 66.17 | 3.73 | | 8.00 | 4.15 | - | 4.17 |
| 110 | | 10.53 | | | | 10.90 | 61.68 | 4.09 | | 8.00 | 4.80 | N | 4.21 |
| 111 | | 12.29 | | | | 11.68 | 59.36 | 4.29 | | 8.00 | 4.38 | N | 4.26 |
| 112 | | 14.04 | | | | 15.18 | 50.84 | 4.49 | | 8.00 | 7.45 | N | 4.30 |
| 113 | | | 49.76 | | | 5.04 | 39.48 | 3.7 | | | 2.02 | - | 4.17 |
| 114 | | | 59.71 | | | 6.04 | 28.39 | 3.7 | | | 2.16 | - | 4.21 |
| 115 | | | 69.67 | | | 7.05 | 17.20 | 3.7 | | | 2.38 | - | 4.26 |
| 116 | | | 79.62 | | | 8.06 | 5.40 | 3.7 | | | 3.22 | - | 4.30 |
| 117 | | | | 52.20 | | 5.30 | | 3.7 | | | | - | 4.17 |
| 118 | | | | 62.63 | | 6.39 | | 3.7 | | | | N | 4.21 |
| 119 | | | | 73.06 | | 7.44 | | 3.7 | | | | N | 4.26 |
| 120 | | | | 83.50 | | 8.50 | | 3.7 | | | | N | 4.30 |
| 121 | | | | | 52.20 | 5.50 | | 3.7 | | | | - | 4.17 |
| 122 | | | | | 62.63 | 6.39 | | 3.7 | | | | - | 4.21 |
| 123 | | | | | 73.06 | 7.44 | | 3.7 | | | | N | 4.26 |
| 124 | | | | | 83.50 | 8.50 | | 3.7 | | | | N | 4.30 |

TABLE XVI

COMPOSITION OF DIETS

| Ration No. | Rolled Oats | Salt Mixture | Butter fat | Dextrin |
|---|---|---|---|---|
| 125 | 35.0 | 3.7 | 5.0 | 56.3 |
| 126 | 40.0 | 3.7 | 5.0 | 51.3 |
| 127 | 45.0 | 3.7 | 5.0 | 46.3 |
| 128 | 50.0 | 3.7 | 5.0 | 41.3 |
| 129 | 56.0 | 3.7 | 5.0 | 35.3 |
| 130 | 60.0 | 3.7 | 5.0 | 31.3 |
| 131 | 65.0 | 3.7 | 5.0 | 26.3 |
| 132 | 70.0 | 3.7 | 5.0 | 21.3 |
| 133 | 75.0 | 3.7 | 5.0 | 16.3 |
| 134 | 80.0 | 3.7 | 5.0 | 11.3 |
| 135 | 85.0 | 3.7 | 5.0 | 6.3 |
| 136 | 91.3 | 3.7 | 5.0 | 0.0 |

## TABLE XVII

GROWTH ON DIETS CONTAINING PROTEINS FROM WHOLE MILK POWDER, CASEIN & YEAST, AND ROLLED OATS

| Ration No. | Source of Protein | Protein in food | Initial Body Wt. Tot. for 6 rats | Gain in 11 weeks Tot. for 6 rats | Total Intake | | Intake per gram of gain | | Gain per gram of food | Gain per gram of Protein |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | Food | Protein | Food | Protein | | |
| | | Percent | gm. | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 105 | Whole Milk Powd. | 8.35 | 313 | 432 | 3150 | 263 | 7.29 | 0.61 | 0.14 | 1.64 |
| 106 | " " " | 10.02 | 328 | 699 | 4060 | 407 | 5.81 | 0.58 | 0.17 | 1.72 |
| 107 | " " " | 11.69 | 328 | 761 | 3833 | 448 | 5.04 | 0.59 | 0.20 | 1.70 |
| 108 | " " " | 13.36 | 331 | 766 | 3645 | 487 | 4.76 | 0.64 | 0.21 | 1.58 |
| 109 | Casein | 8.35 | | | | 324 | | | | 1.71 |
| | Yeast | 3.66 | 337 | 552 | 3882 | 142 | 7.03 | | | |
| | Total | 12.01 | | | | 466 | | 0.83 | 0.14 | 1.18 |
| 110 | Casein | 10.02 | | | | 376 | | | | 1.56 |
| | Yeast | 3.66 | 338 | 387 | 3750 | 137 | 6.39 | | | |
| | Total | 13.68 | | | | 513 | | 0.87 | 0.16 | 1.14 |
| 111 | Casein | 11.69 | | | | 455 | | | | 1.61 |
| | Yeast | 3.66 | 328 | 734 | 3895 | 143 | 5.31 | | | |
| | Total | 15.35 | | | | 598 | | 0.81 | 0.18 | 1.23 |
| 112 | Casein | 13.36 | | | | 567 | | | | 1.31 |
| | Yeast | 3.66 | 349 | 743 | 4250 | 156 | 5.74 | | | |
| | Total | 17.02 | | | | 723 | | 0.97 | 0.17 | 1.02 |
| 113* | Rolled Oats (Cooked & Dried) | | | | | | | | | |
| 114* | " " | | | | | | | | | |
| 115* | " " | | | | | | | | | |
| 116 | " " | 13.36 | 321 | 508 | 3136 | 419 | 6.17 | 0.82 | 0.13 | 1.21 |

* Impossible to obtain accurate food records due to wasting of the ration by the animals.

TABLE XVII (cont.)

| Ration No. | Source of Protein | Protein in food | Initial Body Wt. Tot. for 6 rats | Gain in 11 weeks Tot. for 6 rats | Total Intake | | Intake per gram of gain | | Gain per gram of food | Gain per gram of Protein |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Food | Protein | Food | Protein | | |
| | | Percent | gm. | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 117 | Rolled Oats Cooked & Fed Wet | 8.35 | 325 | 431 | 3523 | 295 | 8.19 | 0.68 | 0.12 | 1.46 |
| 118 | " " " | 10.02 | 307 | 575 | 4281 | 429 | 7.44 | 0.74 | 0.13 | 1.34 |
| 119 | " " " | 11.69 | 310 | 693 | 4457 | 521 | 6.43 | 0.75 | 0.15 | 1.33 |
| 120 | " " " | 13.36 | 298 | 730 | 4139 | 553 | 5.67 | 0.76 | 0.18 | 1.32 |
| 121 | Rolled Oats(Raw) | 8.35 | 341 | 383 | 3136 | 262 | 8.61 | 0.68 | 0.12 | 1.46 |
| 122 | " " " | 10.02 | 346 | 416 | 3087 | 314 | 7.38 | 0.75 | 0.13 | 1.33 |
| 123 | " " " | 11.69 | 355 | 554 | 3550 | 415 | 6.41 | 0.75 | 0.16 | 1.33 |
| 124 | " " " | 13.36 | 352 | 612 | 3476 | 464 | 5.68 | 0.76 | 0.18 | 1.32 |

TABLE XVIII

REPRODUCTION AND LACTATION ON DIETS
CONTAINING COMPARATIVE LEVELS OF PROTEINS FROM WHOLE MILK POWDER AND ROLLED OATS

| Ration Number | Per cent of Protein | Number of Males | Number of Females | Number of Males that Died | Number of Females that Died | Number of Litters | Total Number of Young Born | Number of Young Born Dead | Number of Young that Died | Number of Young Reared | Percent of Mortality | Ave. Weight of Young at Birth (gm) | Ave. Weight at 28 days (gm) | Ave. age of Mother at First Litter (days) | Time on Ration (Months) | Growth Curve | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 105: | 8.35: | 3 | 3 | 0 | 1 | 3 | 14 | 0 | 7 | 7 | 50 | :4.3: | 27: | 126: | 5 | : | whole milk |
| 106: | 10.02: | 3 | 5 | 0 | 0 | 3 | 24 | 0 | 18 | 6 | 75 | :4.2: | 32: | 112: | 5 | : M | |
| 107: | 11.69: | 3 | 4 | 0 | 1 | 6 | 40 | 0 | 25 | 15 | :62.5 | :4.5: | 29: | 105: | 5 | : M | |
| 108: | 13.36: | 3 | 3 | 0 | 0 | 4 | 20 | 0 | 3 | 17 | 15 | :4.5: | 36: | 133: | 5 | : M | |
| 109: | 12.01: | 3 | 3 | 0 | 0 | 2 | 5 | 0 | 5 | 0 | 100 | :4.0: | 0: | 133: | 5 | : - | casein |
| 110: | 13.68: | 3 | 3 | 0 | 0 | 4 | 26 | 0 | 19 | 7 | :73.1 | :4.3: | 28: | 133: | 5 | : - | |
| 111: | 13.35: | 3 | 3 | 0 | 0 | 4 | 30 | 1 | 22 | 7 | :76.7 | :4.3: | 26: | 98: | 5 | : M | |
| 112: | 17.02: | 3 | 4 | 0 | 1 | 7 | 40 | 1 | 55 | 6 | 85 | :4.5: | 42: | 105: | 5 | : M | |
| 113: | 8.35: | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0: | 0: | 0: | 4 | : - | cooked drink oats |
| 114: | 10.02: | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0: | 0: | 0: | 4 | : - | |
| 115: | 11.69: | 3 | 3 | 0 | 0 | 1 | 3 | 0 | 3 | 0 | 100 | :4.0: | 0: | 140: | 4 | : - | |
| 116: | 13.36: | 3 | 3 | 0 | 0 | 3 | 16 | 0 | 16 | 0 | 100 | :4.4: | 0: | 119: | 4 | : - | |
| 117: | 8.35: | 3 | 3 | 0 | 0 | 2 | 11 | 0 | 0 | 11 | 0.0 | :4.3: | 36: | 140: | 5 | : - | cooked moist oats |
| 118: | 10.02: | 3 | 3 | 0 | 0 | 4 | 34 | 0 | 0 | 34 | 0.0 | :4.4: | 30: | 145: | 5 | : M | |
| 119: | 11.69: | 3 | 3 | 0 | 0 | 3 | 17 | 0 | 0 | 17 | 0.0 | :4.5: | 36: | 140: | 5 | : M | |
| 120: | 11.36: | 3 | 3 | 0 | 1 | 4 | 33 | 0 | 0 | 31 | 6.1 | :4.6: | 44: | 140: | 5 | : M | |
| 121: | 8.35: | 3 | 3 | 0 | 0 | 2 | 11 | 0 | 6 | 5 | :54.5 | :4.4: | 22: | 123: | 5 | : - | Raw oats |
| 122: | 10.02: | 3 | 3 | 0 | 0 | 3 | 18 | 0 | 6 | 12 | :33.3 | :4.5: | 30: | 140: | 5 | : - | |
| 123: | 11.69: | 3 | 3 | 0 | 1 | 4 | 24 | 1 | 11 | 13 | :45.8 | :4.5: | 28: | 126: | 5 | : M | |
| 124: | 11.36: | 3 | 3 | 0 | 0 | 5 | 35 | 0 | 1 | 34 | 2.9 | :4.5: | 42: | 126: | 5 | : M | |

TABLE XIX

GROWTH, REPRODUCTION, AND LACTATION ON ROLLED OATS DIETS

| Ration Number | Percent Protein | No. of Males | No. of Females | No. Males that died | No. Females that died | No. of Litters | Total No. Young born | No. Young born dead | No. Young died | No. Young reared | Percent Mortality | Ave. Wt. at birth | Ave. Wt. at 28 days | Ave. Age Mothers at 1st litter | Time on Ration | Growth Curve |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FIRST GENERATION | | | | | | gm. | gm. | days | Mo. | |
| 125 | 5.60 | 3 | 5 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 7 | - |
| 126 | 6.40 | 3 | 3 | 0 | 0 | 1 | 6 | 0 | 1 | 5 | 16.7 | 3.5 | 10 | 148 | 7 | - |
| 127 | 7.20 | 3 | 4 | 0 | 2 | 2 | 12 | 0 | 8 | 4 | 66.6 | 3.5 | 10 | 137 | 7 | - |
| 128 | 8.00 | 3 | 5 | 1 | 3 | 4 | 21 | 0 | 15 | 8 | 62 | 4.0 | 20 | 98 | 7.5 | - |
| 129 | 8.96 | 4 | 2 | 0 | 0 | 4 | 25 | 0 | 23 | 0 | 100 | 3.5 | 0 | 153 | 7.5 | - |
| 130 | 9.60 | 3 | 3 | 0 | 0 | 7 | 44 | 1 | 31 | 12 | 72.8 | 4.5 | 25 | 94 | 7.5 | N |
| 131 | 10.40 | 3 | 3 | 0 | 1 | 8 | 43 | 6 | 28 | 9 | 75.7 | 4.5 | 37 | 81 | 7.5 | N |
| 132 | 11.20 | 3 | 3 | 0 | 1 | 10 | 44 | 0 | 31 | 13 | 70.0 | 4.5 | 31 | 70 | 7.5 | N |
| 133 | 12.00 | 3 | 3 | 0 | 3 | 8 | 55 | 0 | 21 | 34 | 38.2 | 4.5 | 30 | 75 | 8.5 | N |
| 134 | 12.80 | 3 | 3 | 0 | 1 | 10 | 58 | 4 | 6 | 48 | 17.4 | 4.5 | 30 | 66 | 9 | N |
| 135 | 13.60 | 3 | 3 | 0 | 1 | 10 | 61 | 0 | 11 | 50 | 18.2 | 4.5 | 30 | 63 | 9 | N |
| 136 | 14.61 | 3 | 4 | 1 | 1 | 9 | 56 | 0 | 17 | 39 | 30.4 | 4.5 | 30 | 71 | 9 | N |
| | | | | | | SECOND GENERATION | | | | | | | | | | |
| 128 | 8.00 | 3 | 3 | 0 | 0 | 3 | 19 | 2 | 11 | 6 | 68.5 | 4.5 | 20 | 124 | 5 | - |
| 130 | 9.60 | 3 | 3 | 0 | 0 | 4 | 22 | 1 | 3 | 18 | 13.7 | 4.5 | 30 | 156 | 4 | - |
| 131 | 10.40 | 3 | 3 | 0 | 0 | 3 | 23 | 0 | 4 | 19 | 17.4 | 5. | 27 | 145 | 5 | - |
| 132 | 11.20 | 3 | 3 | 0 | 0 | 3 | 15 | 0 | 1 | 14 | 6.7 | 4.5 | 27 | 138 | 5 | - |
| 133 | 12.00 | 3 | 3 | 0 | 0 | 3 | 17 | 0 | 3 | 14 | 17.6 | 5. | 34 | 154 | 4 | - |
| 134 | 12.80 | 3 | 3 | 0 | 0 | 3 | 20 | 1 | 9 | 10 | 50 | 4.5 | 23 | 133 | 4 | - |
| 135 | 13.60 | 3 | 3 | 0 | 0 | 3 | 15 | 0 | 1 | 14 | 6.7 | 4.5 | 35 | 115 | 4 | - |
| 136 | 14.61 | 3 | 3 | 0 | 0 | 3 | 16 | 0 | 7 | 9 | 43.7 | 4.5 | 37 | 141 | 4 | - |
| | | | | | | THIRD GENERATION | | | | | | | | | | |
| 130 | 9.60 | 3 | 3 | 0 | 0 | 5 | 24 | 0 | 11 | 13 | 45.9 | 5. | 27 | 100 | 3 | N |
| 131 | 10.40 | 3 | 3 | 0 | 0 | 2 | 8 | 0 | 0 | 8 | 0.0 | 4. | 27 | 96 | 3 | N |
| 133 | 12.00 | 3 | 3 | 0 | 0 | 3 | 20 | 0 | 0 | 20 | 0.0 | 4.5 | 34 | 108 | 3 | N |
| 134 | 12.80 | 1 | 5 | 0 | 0 | 5 | 36 | 0 | 11 | 25 | 29.9 | 5. | 32 | 112 | 4 | N |
| 135 | 13.60 | 3 | 3 | 0 | 0 | 3 | 17 | 0 | 0 | 17 | 0.0 | 5. | 49 | 122 | 4 | N |
| 136 | 14.61 | 4 | 2 | 0 | 0 | 1 | 8 | 0 | 2 | 6 | 25 | 5. | 40 | 106 | 4 | N |

# PART III

## THE SUPPLEMENTARY VALUES OF ROLLED OATS WITH WHOLE MILK AND WITH CREAM

# INTRODUCTION

It is a well known fact that no single article of food is adequate to meet the nutritive requirements of an individual. Even milk, which is recognized as the most satisfactory single article of food known, is not a complete food in itself when taken over a long period of time. Therefore, for the normal well-being and functioning of an organism it is essential that the food be selected so as to compensate for the deficiencies of one article of food by the supplementary values of another, and thus make a properly balanced dietary. The oat kernel is known to be deficient in the fat soluble vitamins certain inorganic constituents, and the per cent of protein present. And since the greater part of the oat products consumed by human beings is in the form of oatmeal, the investigations in this paper are concerned with a study of the supplementary values of rolled oats and whole milk and rolled oats and cream.

## REVIEW OF LITERATURE

Studies have consistently shown that no single article of food is adequate for normal well being, when taken over a long period of time. McCollum, Simmonds and Pitz[34] observed that the oat kernel was deficient in the fat soluble vitamin A, the inorganic constituents, calcium, chlorine and sodium, and that the oat proteins were of low biological value. McCollum and Simmonds[27] later modified their opinion in regard to the nutritive value of the oat protein.

Mitchell[47] using a modified Thomas method[89] found that rolled oat proteins when fed at a five per cent level had a biological value of 82. Mattill[36], using the same method, confirmed the results of Mitchell. The work in this thesis (Part II) shows that the oat protein when fed at higher levels contains sufficient amounts of the essential Amino acids for normal growth, reproduction and lactation.

In studying the supplementary protein values in foods, McCollum, Simmonds and Parsons[29,30,31,32] found that the proteins of kidney, liver and muscle were remarkably effective as supplements for the proteins of rolled oats; that the nitrogenous compounds of the potato enhanced the biological value of rolled oats to a certain extent; that cereal grains had little effect in supplementing each other, while peas had considerable supplementing value with oat proteins. These investigators fed a diet containing nine per cent of protein, two thirds of which was derived from rolled oats and one third from milk powder. This combination of proteins appeared to have a higher value than any other cereal and milk mixture investigated.

McCollum, Simmonds and Pitz[34] state that casein does not appear to supplement the proteins of the oat kernel in a satisfactory manner. On comparative protein levels wheat and corn were supplemented to a much greater extent than oats by the addition of casein to the diet. These investigators also state that gelatin supplements oat proteins to a much greater extent than does casein. Osborne and Mendel[57] observed that when one fourth of the oat protein was replaced by either casein or gelatin, the total percentage of protein remaining constant, the rate of growth was markedly increased. Hartwell[21] states that the addition of food casein, gluten, gelatin or egg albumin to the oatmeal diet produced better growth in the suckling young. Mitchell[52] in the study of the supplementary relations among proteins was unable to establish any certain supplementary relation between gelatin and oat proteins.

## SOURCE AND PREPARATION OF MATERIALS USED

The source and treatment of materials used in the experiments discussed in this part are as follows:

Rolled oats. Rolled oats obtained from the Quaker Oats Company were used in all of the experiments. The rolled oats were fed in two different ways, namely, as cooked and uncooked rolled oats. The uncooked rolled oats were finely ground and incorporated in the diets. The cooked rolled oats were prepared in the following manner: rolled oats, sugar, and sodium chloride were added to boiling water and cooked for three minutes; then the whole milk or cream was added and thoroughly mixed in.

Whole milk. A good quality of whole milk was obtained daily from the college dairy.

Cream. A good quality of cream was obtained from the college creamery.

Sugar. Cane sugar was obtained from a local grocery.

Socium Chloride. The sodium chloride was ordinary table salt and was obtained from a local grocery.

Calcium Carbonate. The calcium carbonate was a C. P. product.

Experimental animals. Rats were used in all the experiments and were obtained from the breeding colony in our own laboratory.

Cages. The cages, 10 x 12 x 24 inches in dimensions, were constructed of galvanized iron screen on a wooden frame with a removable screen for the bottom. No shavings were used.

# EXPERIMENTAL

## General

Vigorous rats weighing from 50 to 60 grams were employed in the investigations of the supplementary values of rolled oats and whole milk and of rolled oats and cream. Prior to being placed on the experimental diets, the animals had received a growing ration supplemented with whole milk, which was adequate for normal growth, reproduction, and rearing of young. Usually six rats, three males and three females, were placed on each of the experimental diets. The animals were observed every day to note their condition and to supply adequate amounts of food and distilled water. The animals were weighed every seven days.

The investigation is concerned with the supplementary values of rolled oats with whole milk and of rolled oats with cream, with respect to growth, reproduction, and lactation. In each case the female was removed to an individual cage at the first signs of pregnancy. The number of young born and their weight were recorded. In the study upon lactation the adequacy of the diet was judged by the percentage of young reared and their weight at the time of weaning. All of the young born were retained by the mother.

The growing ration of the stock colony, which is adequate for normal growth, reproduction, and lactation, was used as the control diet.

## EXPERIMENTS ON THE SUPPLEMENTARY VALUE OF ROLLED OATS AND WHOLE MILK

In the experiments on the supplementary value of rolled oats and whole milk, diets consisting of 35, 40, 50, 60, and 75 per cent rolled oats, the remainder of the diets being whole milk, were employed. In addition, a study was made on diets consisting of rolled oats and whole milk fed ad libitum, diets representing normal servings of rolled oats and whole milk as served in hotels and restaurants, and rolled oats supplemented with whole milk, sugar, sodium chloride, and calcium carbonate. All of the diets were fed ad libitum and food consumption records were kept on all of the diets consisting entirely of rolled oats and whole milk. The results of the experiments were given in Tables XXII, XXIII, and XXIV; and the composition of the diets is shown in Table XXI.

Growth was below normal on diets 137, 138, and 139, containing 75, 60, and 50 per cent of rolled oats respectively plus whole milk to 100 per cent. The duration of the experiment was three and one half months.

The composition of diet 140 was rolled oats 40 per cent and whole milk 60 per cent. This diet was adequate for normal growth and reproduction through the third generation. The three females of the first generation produced 10 litters, consisting of 77 young. Sixty young were reared, giving a percentage mortality of 22.1. Two young were born dead. Most of the young that died lived approximately two days. The average age of the mothers when they produced their first litter was 84 days. The animals were kept on the diet seven months. The three females of the second generation continued on the diet for four months--produced one litter each. Of the 21 young born 20 were reared, giving a percentage

mortality of 4.8. The average age of the mothers when they produced their first litters was 119 days. Some of these animals had a rough coat and lost some hair. They were also somewhat pot bellied. Six litters, consisting of 33 young, were produced by the three females of the third generation, during a period of four months. Twenty-six young were reared, giving a percentage of mortality of 21.2. Two litters consisting of seven young died within 48 hours after birth. The average age of the mothers when they produced their first litters was 84 days. The average weight of the young produced, for all generations on this diet, was 4.5 grams at birth and 35 grams at 28 days of age.

Growth was normal on diet 141, containing 35 per cent of rolled oats and 65 per cent of whole milk. The five females on the diet produced 11 litters, consisting of 88 young. Forty-two young were reared. Twenty-four young were born dead; and eight young died because of the fact that the mothers died just after parturition. The percentage of mortality was 52.2. The average age of the mothers when they produced their first litters was 84 days. Two females on this diet died shortly after parturition. The time on the diet was seven and one half months. Two of the three second generation females continued on the diet - produced one litter each, all together 15 young. The other female died at parturition. All of the young were reared. The average ages of the mothers when they produced their first litters was 84 days. The hair of the second generation was rough, and some of it came out. The animals were also pot bellied. Each of the three females of the third generation - continued on the experiment - produced one litter, all together 27 young. Twenty-five young were reared,

giving a percentage of mortality of 7.4. The average age of the mothers when they produced their first litters was 94 days. The condition of the third generation was decidedly better than that of the second generation. The average weight of the young shortly after birth was 4.5 grams, and at 28 days of age was 40 grams for all generations.

Diet 142 consisted of rolled oats, whole milk, and distilled water fed ad libitum. Growth was above normal on this diet for the three generations studied. The three females of the first generation produced 11 litters, consisting of 76 young. Nine young, constituting the first litter produced on the diet, died within 48 hours after birth. The remainder of the 76 young were reared, giving a percentage of mortality of 11.8. The average age of the mothers when they produced their first young was 77 days. The time on the ration was eight months. The three females of the second generation which were continued on the diet produced one litter each. Of the 26 young born twenty-five were reared, giving 3.8 as the per cent of mortality. The average age of the mothers when they produced their first litters was 97 days. The second generation was continued on the diet 4 months. Two females and four males of the third generation were kept on diet 142 three months. The two females produced one litter each, a total of 19 young. All of the young were reared. The average age of the mothers of the third generation when their first litters were produced was 75 days.

The young produced on diet 142 were above normal, weighing over five grams at birth and averaging 50 grams at 28 days of age. The first generation males averaged 32 per cent above normal at the end of the second month on the diet and 25 per cent above normal at the end of the third

month. The second and third generations averaged 40 per cent above normal at the end of the second month on the diet and 37 per cent at the end of the third month. Records of food consumption on this diet show that during the rapid growing period of the young and during the period of pregnancy the proportion of whole milk consumed to rolled oats is much greater than at any other period. Charts I and II show the proportion of whole milk to rolled oats consumed during the different periods the animals were on the diet.

Over the period of the experiment the ratio of foods consumed was 28 per cent of rolled oats and 72 per cent of whole milk.

Diet 143 contained rolled oats 47.1 per cent, whole milk 42.8 per cent, sodium chloride one per cent, and cane sugar 9.1 per cent. Growth on this diet was above normal. The three females on the diet produced six litters of 40 young. All of the young were reared. The young averaged 4.5 grams just after birth and 35 grams at 28 days of age. The average age of the mothers when they produced their first litters was 98 days. The animals were kept on the diet five months.

Ration 144 contained one per cent of calcium carbonate and 8.1 per cent of cane sugar. In other respects it was the same as diet 143. Growth on this diet was appreciably above normal. The three males averaged 24 per cent above normal at the end of the third month on the ration. The second generation made similar growth. The three females of the first generation produced six litters of 44 young. All of the young were reared. The young averaged 5.5 grams the day after birth and 45 grams at 28 days of age. The average age of the mothers when they produced their first litters was 84 days. The first generation was kept on the diet five months.

The three females of the second generation - continued on the diet for three months - produced one litter of young each. All of the young, 28 in number were reared. The young averaged 5 grams shortly after birth and 45 grams at 28 days of age. The average age of the mothers when they produced their first young was 76 days.

An analysis of the proportion of rolled oats, whole milk or cream, and sugar present in a normal serving of rolled oats was made by Dr. C. S. Miner of the Miner Laboratories of Chicago. Table XX shows the composition of what we chose to call a normal serving.

Diet 149 contained rolled oats 46.03 per cent, whole milk 41.84 per cent, cane sugar 9.76 per cent, and sodium chloride 2.37 per cent. This percentage of substances represents the normal serving of rolled oats at hotels and restaurants. The growth of the first and second generations on this diet was appreciably above normal. At the end of the third month on the ration the first and second generations males were 18 per cent above the normal. The third generation was slightly below normal, but the fourth generation grew at slightly more than the normal rate. The three females of the first generation produced two litters of young each, consisting of a total of 34 young. All of the young were reared. The average weight of the young shortly after birth was five grams and at 28 days of age was 50 grams. The average age of the mothers when they produced their first litters was 100 days. The duration of the experiment was five and one half months. The three females of the second generation - retained on the diet for three months - produced four litters of young. Of the 18 young born 17 were reared, giving a percentage of

mortality of 5.5. The young averaged five grams shortly after birth and 38 grams at 28 days of age. The average age of the mothers when they first produced young was 105 days.

Four litters of 18 young were produced by the three females of the third generation after being maintained on diet 149 four months. Sixteen young were reared, giving a percentage of mortality of 11.1. During a period of four months three litters of young were produced by the fourth generation females. Thirteen of the 15 young born were reared. The percentage of mortality was 13.3. The average weight at birth of the young produced by the third and fourth generation females was 4.5 grams and 39 grams at 28 days of age. The average age of the mothers of the third and fourth generations when they produced their first young was 140 and 91 days respectively.

# Chart I

Graph showing the consumption of whole milk and rolled oats on diet 142

-----Whole milk } ad libitum
——Rolled oats }

3 males and 3 females on diet

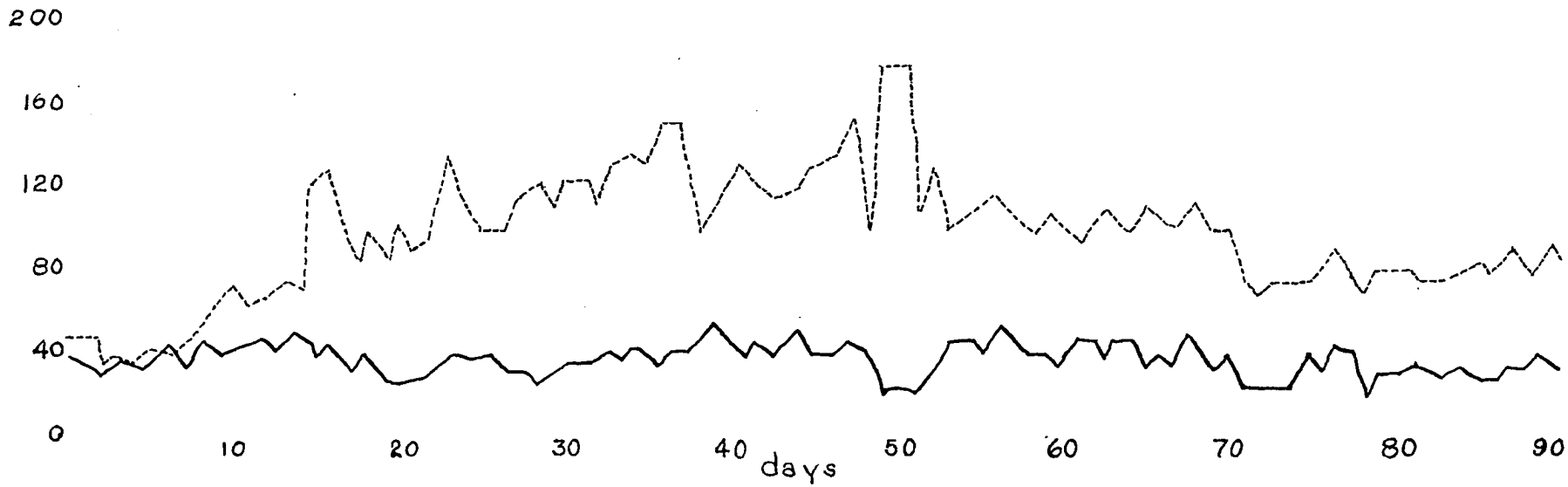
Female # 97 removed on 50th day pregnant. Returned on 55th day.
The litter of 2 young died.

Female # 96 removed on 52nd day pregnant. Returned on 58th day.
5 young born on 54th day- young killed by accident.

Female # 95 removed on 58th day pregnant. 9 young born on 64th day.

Female # 97 removed on 74th day pregnant. 9 young born on 77th day.



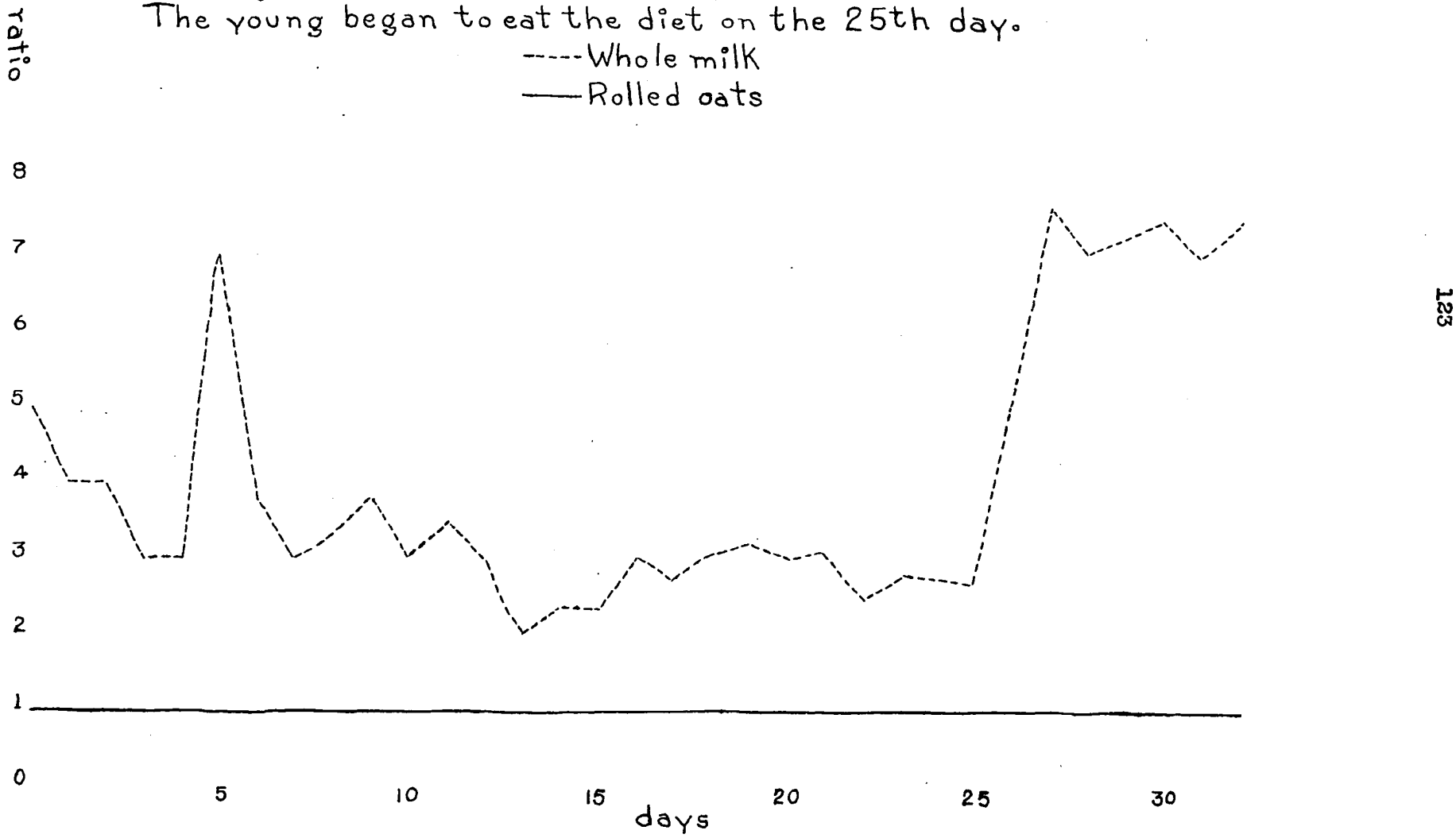


# Chart II

Graph showing the ratio of whole milk to rolled oats consumed by a female on diet 142.

9 young were born on the 4th day

The young began to eat the diet on the 25th day.



EXPERIMENTS ON THE SUPPLEMENTARY VALUE OF ROLLED OATS AND CREAM

In the experiments on the supplementary value of rolled oats and cream a study was made on diets consisting of 60 per cent of rolled oats supplemented with cream, salt mixture, and dextrin; rolled oats 46.03 per cent supplemented with cream, cane sugar, and sodium chloride, representing a normal serving of rolled oats with cream at restaurants and hotels; rolled oats 47.1 per cent supplemented with cream, sugar, sodium chloride, and calcium carbonate. The results of the experiments are shown in Tables XXIII, and XXIV, and Table XXI gives the composition of the diets.

Diet 145, containing 60 per cent of rolled oats, 25 per cent of cream, 3.7 per cent of McCollum's salt mixture number 185, and 11.3 per cent of dextrin, is adequate for normal growth. The animals fed on this diet grew appreciably above normal. The three females produced four litters, consisting of 32 young. Twenty-four young were reared, the percentage of mortality being 24. Eight young died within three days after birth. The average weight of the young at birth was 4.5 grams and at 28 days of age was 34 grams. The average age of the mothers when their first litters were produced was 91 days. The first generation was maintained on the diet four months. Three females from the second generation, during a three months period, produced three litters of 16 young. All of the young were reared. The young at birth averaged five grams and at 28 days of age 40 grams. The average age of the mothers when they produced their first young was 110 days.

On diet 146, containing 42.1 per cent of rolled oats, 42.8 per cent of cream, and 10.1 per cent of cane sugar - growth was normal. Six

litters of young were produced by the three females on the diet. Of the 38 young born, 20 were reared; this gave a percentage of mortality of 47.4. The animals became chilled on account of a draft and practically all developed marked colds. The young which died were produced during this period. Eighteen young died within one week after birth. The average weight of the young shortly after birth was 4.5 grams and 30 grams at 28 days of age. The average age of the mothers when they produced their first young was 150 days. The time on the diet was six and one half months.

Growth was normal or slightly above normal on diet 147, containing 47.1 per cent of rolled oats, 42.8 per cent of cream, one per cent of sodium chloride, and 9.1 per cent of cane sugar. Two of the three females on the diet produced one litter each, a total of 30 young. All of the young were reared. The average weight of the young at birth and at 28 days of age was five grams and 33 grams respectively. The average ago of the mothers when they produced their first litters was 91 days. One male and one female on this diet died from lung trouble.

On ration 148, in which the rolled oats and cream were supplemented with one per cent of calcium carbonate and one per cent of sodium chloride, the growth of the first and second generation males was 12 per cent above the normal at the end of the third month. During the six months period of the experiment, the first generation females produced six litters, consisting of 55 young. One young died, giving 1.9 as the percentage of mortality. The average weight of the young at birth was 5 grams and at 28 days of age 30 grams. The average age of the mothers when their first young were produced was 84 days. The three females of the second generation produced one litter each, consisting of 21 young. Eight young died

within five days after birth. The percentage of mortality was 38.1.

Diet 150 contained cooked rolled oats, cream, sugar, and sodium chloride in the proportion that is obtained in normal servings of rolled oats with cream at hotels and restaurants. The growth of the first, second, and fourth generations on this diet was appreciably above the normal. The third generation did not grow so well; however, their growth curves were normal. During the five and one half months on the diet the three females of the first generation produced seven litters, consisting of 52 young. Forty-eight young were reared, making the percent of mortality 7.7. Four young died within three days after birth. The average weight of the young at birth was five grams, and at 28 days of age 45 grams. The average age of the mothers when they produced their first litters was 98 days.

During the three-month period in which the second generation was kept on the diet, six litters of 47 young were produced. Thirteen young died because their mothers produced no milk. In these cases there was no development of the mammary glands. These two females later produced and reared young. The percentage of mortality was 46.8. The average weight of the young at birth and at 28 days of age was 4.5 grams and 26 grams respectively. The three females of the third generation produced three litters of 19 young. Eighteen young were reared; the percentage of mortality was 5.3. The young averaged 4.5 grams shortly after birth and 39 grams at 28 days of age. Three litters of 16 young were produced by the fourth generation females continued on the diet. Of the 16 young born, 14 were reared. The percentage of mortality was 12.5. The average weight of the young at birth was 4.5 grams and at 28 days of age 40 grams.

## DISCUSSION OF RESULTS

The poor growth on the diet of 25 per cent of whole milk and 75 per cent of rolled oats (Diet 137) is due to a deficiency of the sodium or chlorine ion - or both - and to a deficiency of vitamin A. McCollum, Simmonds, and Pitz (35) state that vitamin A is present in the oat kernel in very small amounts. Outhouse, Macy, Brekke, and Graham (64) observed that at least three cubic centimeters of fresh raw cow's milk daily is required to supply sufficient vitamin A for satisfactory growth in the rat. On the above diet containing 25 per cent of whole milk and 75 per cent of rolled oats the rats consumed less than 1.7 cubic centimeters of whole milk.

Diet 138, containing rolled oats 60 per cent and whole milk 40 per cent, was inadequate for growth because of the deficiency of sodium chloride. The same is true for the diet containing 50 per cent rolled oats and 50 per cent of whole milk. This is indicated by the fact that growth was normal on diet 143, containing 47.1 percent of rolled oats, 42.8 per cent of whole milk, and one per cent of sodium chloride, and 9.1 per cent of cane sugar.

Diet 140 containing 40 per cent of rolled oats and 60 percent of whole milk, was adequate for normal growth and reproduction but inadequate from the viewpoint of lactation. The same results were obtained with diet fro 141, containing 35 per cent of rolled oats and 65 per cent of whole milk. The inadequacy of diets 140 and 141 for lactation was probably due to a deficiency of sodium chloride.

The rats fed diet 142, containing rolled oats, whole milk, and distilled water <u>ad libitum</u> , grew considerably above normal. The young pro-

duced through the fourth generation were above normal and extremely vigorous. Reproduction and lactation were normal on this diet. During the rapid growing period and during the period of pregnancy a much higher ratio of whole milk to rolled oats was consumed. This would indicate that the appetite and instincts of the rat aid in the selection of food.

Diet 145, containing 60 per cent of rolled oats, 25 per cent of cream, 3.7 per cent of salt mixture, and 11.3 per cent of dextrin, produced growth greater than the normal rate. The growth in the second generation was better than that of the first generation. Results of reproduction and lactation were normal. This diet contained 9.6 per cent of rolled oat proteins. These results are further proof that the oat protein is of a high biological value.

The resluts on diets 146, 147, and 148, containing 47.1 per cent of rolled oats and 42.8 per cent of cream indicate that there is a slight deficiency of calcium at this level of rolled oats. This is indicated by the increase in growth observed on the addition of calcium carbonate. However, normal growth was obtained without the addition of calcium carbonate.

Growth, reproduction, and lactation were very good on diets 149 and 150, representing the normal servings of rolled oats with milk and with cream. Growth for the first and second generations was 18 per cent above normal on the milk diet and 16 per cent above the normal rate on the cream diet. The growth of the third and fourth generations was appreciably better on the rolled oat-cream diets than on the rolled oat and whole milk diet. Reproduction on the rolled oat and cream diet was better than that on the whole milk and rolled oat diet. The average size of the litters on the cream diet was seven as compared to five on the whole milk

diet. There was practically no difference from the standpoint of lactation, which was approximately normal in each case. The protein content of the rolled oat and cream diet was 7.36 per cent. In the rolled oat and whole milk diet, the rolled oats supplied proteins to the extent of 7.36 per cent of the diet, and the milk supplied proteins to the extent of 1.54 per cent of the diet. Records of food consumption were not kept on diets 149 and 150.

## SUMMARY AND CONCLUSIONS

1. Diets composed of 75 per cent of rolled oats and 25 per cent of whole milk are deficient in sodium chloride and vitamin A.

2. Diets containing 50 per cent of rolled oats and 50 per cent of whole milk are deficient in sodium chloride.

3. Rolled oats 40 per cent and whole milk 60 per cent constitute a diet which is adequate for normal growth and reproduction but not adequate for normal lactation.

4. Rolled oats and whole milk fed ad libitum give better than normal results for growth, reproduction, and rearing of young. The ratio of the foods consumed was 28 per cent of rolled oats and 72 per cent of whole milk.

5. Appetite and instincts of the rat aid in the selection of food.

6. Rolled oats present in a diet to the extent of 47.1 per cent and supplemented with 42.8 per cent of cream supply sufficient calcium, vitamins, and protein for normal growth, reproduction, and lactation.

7. Rolled oats with whole milk and rolled oats with cream together with sugar and sodium chloride in the proportion consumed by humanbeings constitute a complete food for growth, reproduction, and lactation.

TABLE XX

COMPOSITION OF NORMAL SERVING OF ROLLED OATS AND SUGAR WITH CREAM OR MILK

| | | Protein gm. | Calcium gm. | Iron gm. | Phosphorus gm. | Calories | Fat gm. |
|---|---|---|---|---|---|---|---|
| Oats | 33 gm. | 5.51 | 0.0228 | 0.001254 | 0.1293 | 132 | 2.38 |
| Sugar | 7 gm. | | | | | 28 | |
| Milk | 30 gm. | 0.99 | 0.036 | 0.000072 | 0.0296 | 20 | 1.20 |
| Cream | 30 gm. | 0.75 | 0.0256 | 0.000066 | 0.0201 | 60 | 5.55 |
| Cream Total | | 6.06 | 0.0484 | 0.001320 | 0.1494 | 220 | 8.93 |
| Milk Total | | 6.30 | 0.0588 | 0.001326 | 0.1569 | 180 | 3.58 |
| Daily requirement for man | | 75.00 | 0.67 | 0.015 | 1.44 | 3000 | 50.00 |
| Cream Mixture—% daily req. for man | | 8.0 | 7.2 | 8.8 | 10.4 | 7.0 | 17.9 |
| Milk Mixture—% daily req. for man | | 8.4 | 8.7 | 8.8 | 10.8 | 6.0 | 7.2 |

Average cream mixture — percent of daily requirement 9.7.

Average milk mixture — percent of daily requirement 8.3.

TABLE XXI

COMPOSITION OF DIETS

| Ration | Rolled Oats | Whole Milk | Cream | NaCl | $CaCO_3$ | Cane sugar | Salt mixture | Dextrin | Growth |
|---|---|---|---|---|---|---|---|---|---|
| 137 | 75. | 25 | | | | | | | - |
| 138 | 60 | 40 | | | | | | | - |
| 139 | 50 | 50 | | | | | | | - |
| 140 | 40 | 60 | | | | | | | N |
| 141 | 35 | 65 | | | | | | | N |
| 142 | Ad lib | Adlib | | | | | | | N+ |
| 143 | 47.1 | 42.8 | | 1.0 | | 9.1 | | | N+ |
| 144 | 47.1 | 42.8 | | 1.0 | 1.0 | 8.1 | | | N+ |
| 145 | 60 | | 25 | | | | 3.7 | 11.3 | N+ |
| 146 | 47.1 | | 42.8 | | | 10.1 | | | N |
| 147 | 47.1 | | 42.8 | 1.0 | | 9.1 | | | N |
| 148 | 47.1 | | 42.8 | 1.0 | 1.0 | 8.1 | | | N |
| 149 | 46.03 | 41.84 | | 2.37 | | 9.76 | | | N+ |
| 150 | 46.03 | | 41.84 | 2.37 | | 9.76 | | | N+ |

TABLE XXII

REPRODUCTION AND LACTATION ON ROLLED OATS AND WHOLE MILK DIETS

| Ration No. | No. of males on ration | No. of females on ration | No. of males died | No. of females died | No. of litters | Total young born | No. of young died | No. of young reared | % mortality | Ave. Wt young at 4 wks. | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FIRST GENERATION** | | | | | | | | | | | |
| 137 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | | 0 | 3 |
| 138 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | | 0 | 3½ |
| 139 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 3½ |
| 140 | 3 | 3 | 0 | 0 | 10 | 77 | 17 | 60 | 22.1 | 30 | 7 |
| 141 | 3 | 5 | 0 | 2 | 11 | 88 | 46 | 42 | 52.2 | 40 | 7½ |
| 142 | 3 | 3 | 0 | 0 | 11 | 76 | 9 | 67 | 11.8 | 50 | 8 |
| **SECOND GENERATION** | | | | | | | | | | | |
| 140 | 3 | 3 | 0 | 0 | 3 | 21 | 1 | 20 | 4.8 | 35 | 4 |
| 141 | 3 | 3 | 0 | 1 | 2 | 15 | 0 | 15 | 0.0 | 37 | 4 |
| 142 | 3 | 3 | 0 | 0 | 3 | 26 | 1 | 25 | 3.8 | 50 | 4 |
| **THIRD GENERATION** | | | | | | | | | | | |
| 140 | 3 | 3 | 0 | 0 | 6 | 33 | 7 | 26 | 21.2 | 35 | 4 |
| 141 | 3 | 3 | 0 | 0 | 3 | 27 | 2 | 25 | 7.4 | 39 | 4 |
| 142 | 4 | 2 | 0 | 0 | 2 | 19 | 0 | 19 | 0.0 | 49 | 3 |

## TABLE XXIII

REPRODUCTION AND LACTATION ON DIETS OF ROLLED OATS SUPPLEMENTED WITH WHOLE MILK AND WITH CREAM

| Ration No | No. of males on ration | No. of females on ration | No. of males died | No. of females died | No. of litters | Total young born | No. of young died | No. of young reared | % mortality | Ave. Wt. young at 4 weeks | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FIRST GENERATION** | | | | | | | | | | | |
| 143 | 3 | 3 | 0 | 0 | 6 | 40 | 0 | 40 | 0.0 | 35 | 5 |
| 144 | 3 | 3 | 0 | 0 | 6 | 44 | 0 | 44 | 0.0 | 45 | 5 |
| 145 | 3 | 3 | 0 | 0 | 4 | 32 | 8 | 24 | 25 | 34 | 4 |
| 146 | 3 | 3 | 0 | 0 | 6 | 38 | 18 | 20 | 47.4 | 30 | 6½ |
| 147 | 3 | 3 | 1 | 1 | 4 | 30 | 0 | 30 | 0.0 | 33 | 5 |
| 148 | 3 | 3 | 0 | 0 | 6 | 53 | 1 | 52 | 1.9 | 30 | 6 |
| **SECOND GENERATION** | | | | | | | | | | | |
| 144 | 3 | 3 | 0 | 0 | 3 | 28 | 0 | 28 | 0.0 | 45 | 3 |
| 145 | 3 | 3 | 0 | 0 | 2 | 16 | 0 | 16 | 0.0 | 40 | 3 |
| 148 | 3 | 3 | 0 | 0 | 3 | 21 | 8 | 13 | 38.1 | 30 | 4 |

## TABLE XXIV

REPRODUCTION AND LACTATION ON DIETS REPRESENTING NORMAL SERVINGS OF ROLLED OATS WITH WHOLE MILK AND ROLLED OATS WITH CREAM

| Ration No. | No. of males on ration | No. of females on ration | No. of males died | No. of females died | No. of litters | Total young born | No. of young died | No. of young reared | % mortality | Ave. Wt. young at 4 wks. | Months on ration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FIRST GENERATION** | | | | | | | | | | | |
| 149 | 3 | 3 | 0 | 0 | 6 | 34 | 0 | 34 | 0.0 | 50 | 5½ |
| 150 | 3 | 3 | 0 | 0 | 7 | 52 | 4 | 48 | 7.7 | 45 | 5½ |
| **SECOND GENERATION** | | | | | | | | | | | |
| 149 | 3 | 3 | 0 | 0 | 4 | 18 | 1 | 17 | 5.5 | 38 | 3 |
| 150 | 3 | 3 | 0 | 0 | 6 | 47 | 22 | 25 | 46.8 | 26 | 3 |
| **THIRD GENERATION** | | | | | | | | | | | |
| 149 | 3 | 3 | 0 | 0 | 4 | 18 | 2 | 16 | 11.1 | 40 | 4 |
| 150 | 3 | 3 | 0 | 0 | 3 | 19 | 1 | 18 | 5.3 | 39 | 5 |
| **FOURTH GENERATION** | | | | | | | | | | | |
| 149 | 2 | 4 | 0 | 0 | 3 | 15 | 2 | 13 | 13.3 | 38 | 4 |
| 150 | 3 | 3 | 0 | 0 | 3 | 16 | 2 | 14 | 12.5 | 40 | 4 |

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