Bulletin 340 July, 1932

THE FOOD VALUE OF MILK

A REVISION OF BULLETIN 215, 1919

**Connecticut
Agricultural Experiment Station
New Haven**

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FOREWORD

During the World War the Station issued a series of bulletins under the general title "Economy in Feeding the Family." One of these, Bulletin 215, was called "The Food Value of Milk." The circumstances surrounding its preparation and publication were quite unusual. Miss Edna L. Ferry, who had assisted Dr. Osborne and Dr. Mendel since 1909, read a paper before the annual convention of the Connecticut Dairymen's Association in January, 1919, presenting for the first time in popular form the results of the Station's researches on the nutritive value of proteins and particularly the discoveries relating to milk. This paper made a deep impression on the convention, which later voted "to ask the Experiment Station to prepare a bulletin on the food value of milk, which can be distributed among customers." Bulletin 215 was the result of this request. Miss Ferry's untimely death in that year left to others the task of preparing the manuscript for publication, but the bulletin was largely a transcript of her paper.

One by-product of the war was a great stimulation of interest in the proper feeding of children. Without doubt Miss Ferry's little bulletin had a great influence; it was widely distributed within and without the state and has been used by home economists, dietitians and others interested in improving the diets of children and adults. The early work of the Dairy Councils was based largely on the information it contained, and a marked increase in the consumption of milk has resulted from their activities.

As the years have passed there has been a constant demand for this bulletin and the supply is now exhausted. Much has been added to our knowledge of "the food value of milk" since Miss Ferry's paper was written and an extensive revision of her work therefore seemed necessary before republication. The present bulletin includes much of her account of the earlier investigations at this Station and, with the assistance of Dr. Julia P. Outhouse[1], Coxe Fellow in Professor Mendel's laboratory at Yale University in 1930-31, a review of the more recent additions to the subject has been prepared. Miss Beatrice Hall of the Connecticut Dairy and Food Council, rewrote the section on "The Cost and Economy of Milk."

W. L. S.

[1]Dr. Outhouse is now Assistant Professor of Home Economics in the University of Illinois.

CONTENTS

Foreword 655

Introduction 657

The Composition of Milk 658

Composition of Various Milk Products 659

The Composition of Proteins 660

The Nutritive Value of Proteins 663

The Nutritive Value of the Several Components of Milk 674

The Proteins 674

The Carbohydrates 675

The Fat 675

The Inorganic Salts 676

The Vitamins 677

Vitamin A 677

Vitamin B 679

Vitamin C 680

Vitamin D 680

Vitamin E 681

Vitamin G 681

Energy Value of Milk 681

The Place of Milk in the Diet 681

The Nature of the Dietary Deficiency of Milk 682

Effect of Heat on the Nutritive Value of Milk 683

Biological Effects of Diets that Contain Milk 684

The Daily Milk Requirement 684

The Cost and Economy of Milk 685

The Place of Milk in the Child's Diet 685

Milk an Economical Food 687

Cost of Calcium in Various Foods 689

Milk in the Low-Cost Food Budget 692

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THE FOOD VALUE OF MILK

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Milk has been used as a food for man for many centuries because practical experience taught that it was an extremely valuable adjunct to the human dietary. A sound scientific explanation for this age old custom has been obtained in recent years and we now understand why races accustomed to the use of liberal quantities of milk are unusually sturdy. Designed by nature to meet the requirements of the rapidly growing new-born, milk also finds a place in the dietary of the adult; more than any other single food, it meets the needs of the human body.

At what time man began to use the milk of domesticated animals may never be known, but this certainly occurred at a very early stage of civilization. The place of origin of our domesticated cattle is not known with certainty, but they appear to be closely related to the wild aurochs or urus of Europe, Western Asia, and Northern Egypt. It is probable that the original domestication did not occur in Western Europe but that the ox was brought from Asia by neolithic man in his migrations. Records found in tombs, caves, and camp sites indicate that the Aryans of Asia were among the earliest herdsmen; that the Swiss lake dwellers had domesticated the cow; and that the Egyptians kept cattle as early as 3500 B. C. References to milk or milk products in the Bible are so incidental as to indicate its common use from prehistoric times.

Although the cow is probably the most widely used source of milk for human food, many other species are likewise employed by man. Goats supply milk for the Arabs, South Europeans, Latin Americans, and the Spaniards. The camel supplies the Egyptians and the Arabs; the mare, the Tartars and the Mongols; and the reindeer, the Lapps and Eskimos. The inhabitants of Asia, especially those of India, milk the zebu or Indian cow, and the Chinese and the Filipinos use the water buffalo. Sheep are milked in the Netherlands, in Greece, in Czechoslovakia, in Italy, and in the Balkan states. The yak, belonging to the bison family, supplies the natives of Mongolia and Tibet, and milk from the llama, a relative of the camel, is used extensively in South America. However, in many countries even these substitutes for the cow are lacking. Under such conditions the tendency is to prolong the period of normal nursing, sometimes to an extraordinary extent; thus the mothers in some Indian tribes, among the Eskimos, and the poorer

Chinese and Japanese, nurse their children four to six years or even longer.

In recent years evidence has accumulated rapidly to show that milk contains substances indispensable to life. The earliest reference to this is in the paper by Lunin (1) published in 1888 in Germany. Lunin had been unable to make mice thrive on a dietary of purified protein, fat, carbohydrate and inorganic salts, but when milk was added the animals remained in excellent health. With a similar diet Pekelharing (2), a Dutch scientist, in 1905 had likewise been unable to maintain mice alive unless milk was given; a few years later, Hopkins (3) in England obtained identical results with albino rats. In 1912 this investigator reported that nutritional disaster could be avoided by giving each rat small quantities of milk daily.

The direct connection of this Station with the field of nutrition investigation began in 1909 when the late Dr. T. B. Osborne undertook the evaluation in terms of their biological properties of the many different proteins, both of vegetable and animal origin, he had previously studied. In this work he had the collaboration of Professor L. B. Mendel of Yale University. Their labors, which continued uninterrupted for nearly twenty years, were supported jointly by the Station and by the Carnegie Institution of Washington. These investigations contributed largely to our present understanding of the unique place of milk in the human diet.

THE COMPOSITION OF MILK

Milk is a fluid elaborated and secreted by the mammary glands from nutrients brought by the blood stream to the gland cells. It contains a mixture of several proteins, a carbohydrate, fats, inorganic salts[1], vitamins, and water in such proportions and combinations that it makes an ideal food for the young of the species. The milk sugar, lactose, and the chief milk protein, casein, are found nowhere else in the vegetable or animal kingdom.

Although all milks contain similar, or at least closely analogous, chemical substances, each species of animal produces a milk peculiar to itself. The species characteristic is largely a matter of the relative proportions in which the different components occur, as is shown in Table 1. From these data it will be readily appreciated

[1]The inorganic salts contained in milk comprise what is left when a sample of milk is evaporated and the residue is heated until all combustible components have been burned away. The residue is also frequently referred to as the ash or, sometimes, as the mineral salts of the milk.

that the food value or the composition of milk must be discussed in terms of the species from which the milk is obtained.

TABLE 1. THE AVERAGE PERCENTAGE COMPOSITION OF DIFFERENT MILKS USED BY MAN (4)

Species	Water	Casein	Albumin	Fat	Lactose	Ash
Man	87.41	0.91	1.23	3.76	6.29	0.31
Cow	87.27	2.95	0.52	3.66	4.91	0.69
Goat	84.14	3.04	0.99	6.00	5.02	0.81
Sheep	81.90	4.57	1.26	6.52	4.82	0.93
Buffalo	82.14	4.29	0.49	7.44	4.81	0.83
Camel	87.04	3.49	0.40	2.76	5.57	0.74
Horse	90.68	1.27	0.75	1.17	5.77	0.36
Ass	89.88	0.73	1.31	1.50	6.09	0.49
Reindeer	68.2	8.4	2.00	17.1	2.08	1.5

Table 2, compiled in Germany in 1899, (5), indicates an interesting and plausible relationship between the protein and the inorganic salts content of the milk and the time required for the new-born of different species to double their weight at birth.

TABLE 2. THE COMPOSITION OF MILK IN RELATION TO THE GROWTH OF THE NEW BORN

Species	Period in which weight of new-born is doubled	100 parts milk contain			
		Protein	Salts	CaO	P_2O_5
	days				
Man	180	1.6	0.2	0.033	0.047
Horse	60	2.0	0.4	0.124	0.131
Cow	47	3.5	0.7	0.160	0.197
Goat	22	3.7	0.8	0.197	0.284
Sheep	15	4.9	0.8	0.245	0.293
Pig	14	5.2	0.8	0.249	0.308
Cat	9.5	7.0	1.0		
Dog	9	7.4	1.3	0.455	0.508
Rabbit	6	10.4	2.5	0.891	0.997

Composition of Various Milk Products

Various products obtained from milk are in such general use in many homes today that it is of interest to know how they compare in composition and in food fuel value with the original milk.

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TABLE 3. THE COMPOSITION OF VARIOUS MILK PRODUCTS (6)

Product	Water	Protein	Fat	Carbohydrate	Inorganic salts	Food-fuel value per pound
	%	%	%	%	%	calories
Whole milk	87.0	3.3	4.0	5.0	0.7	315
Skim milk	90.5	3.4	0.1	5.1	0.7	165
Cream	74.0	2.5	18.5	4.5	0.5	880
Buttermilk	91.0	3.5	0.5	4.2	0.8	160
Condensed milk (sweetened)	28.0	7.8	9.0	53.5	1.7	1480
Condensed milk (unsweetened)	73.0	7.0	8.0	10.5	1.5	645
Skim milk powder	4.0	35.0	2.0	51.0	8.0	1640
Whole milk powder	4.0	25.0	29.0	36.0	5.5	2300
Butter	13.0	1.0	83.0		3.0	3410
Cheese (American Cheddar)	33.5	26.0	35.5	1.5	3.5	1950
Cheese (Swiss)	31.4	27.6	34.9	1.3	4.8	1950
Cottage cheese	69.8	23.3	1.0	4.0	1.9	535
Whey	93.4	0.8	0.3	4.8	0.7	115
Kephir	89.6	3.1	2.0	4.5	0.8	220
Kumiss	90.7	2.2	2.1	4.1	0.9	200

THE COMPOSITION OF PROTEINS

The foundation of our knowledge regarding milk was laid by finding out the composition of a large number of different proteins. These substances are the flesh-growing materials of the body and form an indispensable part of all the vital body fluids. This work revealed for the first time their great variety and the fact that a nearly identical percentage composition of their elements (nitrogen, carbon, oxygen, hydrogen, sulfur and sometimes phosphorus) went along with wide differences in composition and in physical and chemical properties; furthermore that in the same food material, whether animal or vegetable, two or more proteins of quite different quality were usually found together.

Dr. Osborne's work, with that of others, showed that a protein is no such simple thing as salt or sugar; but is usually made up of about eighteen different complexes or nitrogen-containing groups called amino-acids, each of them a complicated structure in itself. The following table gives the names of these amino-acids, the approximate percentage of each in several of the common proteins and shows the striking differences in the relative composition of these proteins with respect to the amino-acids.

TABLE 4. COMPARATIVE COMPOSITION OF PROTEINS

Amino-acids	Zein (maize)	Gliadin (wheat)	Casein (milk)	Lactalbumin (milk)
	%	%	%	%
Glycocoll	0.0	0.0	0.45	0.37
Alanine	9.8	2.0	1.85	2.41
Valine	1.9	3.34	7.93	3.3
Leucines	25.0	6.62	9.7	14.03
Proline	9.0	13.22	8.7	3.76
Oxyproline	0.0	....	0.23	....
Phenylalanine	7.6	2.35	3.88	1.25
Glutaminic acid	31.3	43.66	21.77	12.89
Oxyglutaminic acid	2.5	7.7	10.5	10.0
Aspartic acid	1.8	0.8	4.1	9.3
Serine	1.0	0.13	0.5	1.76
Tyrosine	5.9	3.04	6.55	1.95
Cystine	0.75	2.40	0.25	4.25
Methionine	?	?	0.4	?
Histidine	0.8	1.49	2.5	1.52
Arginine	1.8	2.91	3.81	3.00
Lysine	0.0	0.63	5.95	8.8
Tryptophane	0.17	1.09	1.70	2.69
Ammonia	3.64	5.22	1.61	1.31
	102.96	96.60	92.38	82.59

In view of the great differences, the question arose: Have the proteins nevertheless about the same food value, as has been assumed, or have they not? If they have not, the principles on which the whole art of animal feeding have been founded in the past are clearly unsound.

The only way to settle this question was to study the effect of each protein, when fed by itself, on growth, maintenance and production.

Before the work at this Station was begun all experimenters who had endeavored to feed animals on diets composed of pure nutrients had failed; both mature and young animals promptly declined in weight on such artificial diets. At the present time there is so much clearer an understanding of the influence of food on growth that, merely by changing a single constituent of the diet, one can stop the growth of a young animal at any stage of its development, maintain it for many months without growth, and later cause it to grow again at a normal rate to full maturity; furthermore the rate of growth of animals is, to a large extent, subject to direct experimental control.

It was the use of milk, or of milk products, in the earlier attempts to feed animals under experimental conditions that led to the first successes and to the development of the methods of feeding, and these early experiments have given rise to what is today the well founded science of nutrition.

The first attempts at this Station to make an animal grow on a mixture of pure protein, fat, carbohydrate, and inorganic salts were no more successful than were those of other investigators, but it was soon found that animals which failed to thrive on artificial diets could be restored promptly to excellent condition by giving them a mixture of dried milk, starch, and lard, and that control animals, fed on a similar diet from weaning, grew normally to full maturity and reproduced. Although the artificial diets were almost exactly like the milk diets in respect to the kind and proportion of the then known nutrients, the milk diet was apparently entirely adequate as a food, whereas the artificial diet was wholly inadequate. Wherein this profound difference lay was a mystery. By a process of elimination the conclusion was finally reached that the water-soluble portion of the milk contained something that was essential for life, and later that the fat component contained something that was indispensable for long-continued growth. The discovery that milk contained at least two hitherto unsuspected substances, now designated as vitamins B and A respectively, made it possible for the workers at this Station to become pioneers in the study of various problems relating to growth and maintenance. The field of study thus opened has been cultivated by numerous investigators in this country and abroad with results of far-reaching importance.

The experiments here to be described were made with albino rats because these small animals are omnivorous, their life span is relatively brief, and their small size permits the preparation of the required quantities of purified dietary constituents in the laboratory without undue expense. To insure perfect accuracy it is necessary that the rations shall consist of ingredients that are chemically pure; and to prepare such rations in quantity is very laborious and costly.

The question may be asked: Are the results of experiments in feeding rats, or other of the lower animals, applicable to human beings? Although the foods suited to different species of animals may differ widely in their appearance and physical properties, the digestible nutrients contained in them are very much alike in their chemical characters, so that by the processes of digestion quite similar products result from apparently different kinds of food. Such differences as exist are in proportion rather than in kind. Furthermore, the tissues of the different types of animals are chemically even more alike than their foods and, consequently, the nutritive requirements are in principle much more nearly the same than those unfamiliar with the chemistry of nutrition might suppose.

The conditions in feeding farm animals are necessarily so complex that it is generally impossible to recognize the influence of any individual constituent of the ration. In the experiments with rats, on the contrary, the conditions were so simplified that definite conclusions could be drawn regarding the role of each factor involved. Thus, if two series of animals are fed on mixtures of protein, fat, carbohydrate and inorganic salts, which are identical except for the kind of protein used, and the animals in one series grow normally whereas the others fail to grow at all, it is obvious that the protein alone is the growth determining element in the food. By means of large numbers of such experiments, extending over a period of several years, the nutritive values of many proteins, several fats, and some of the inorganic salts have been fixed. Also a number of combinations of natural food products, both of animal and vegetable origin, which are extensively used in the daily rations of man or domestic animals, have been studied.

THE NUTRITIVE VALUE OF PROTEINS

Previous to 1912 a discussion of the nutritive value of any foodstuff would have been confined to a consideration of the total quantities of protein, fat. carbohydrate, and salts it contained and of its value as a source of energy, that is, its calorific or fuel value.

As a result of work that has been done at this Station, and later in other laboratories, the field for discussion has become much broader, for it was demonstrated that the *quality* of the protein present in any food is of even more importance than the *quantity,* and a realization of the essential rôle that the vitamins play in normal nutrition has raised many more problems.

Milk contains several different proteins, but there are only two that occur in notable quantity: *casein,* the protein found in cheese, and *lactalbumin,* the principal protein of whey. These two proteins differ not only in their chemical structure, but also in their nutritive value. Both suffice to promote the normal growth of young rats, but lactalbumin is somewhat more efficient for growth than is casein, for in comparable periods of time a given quantity

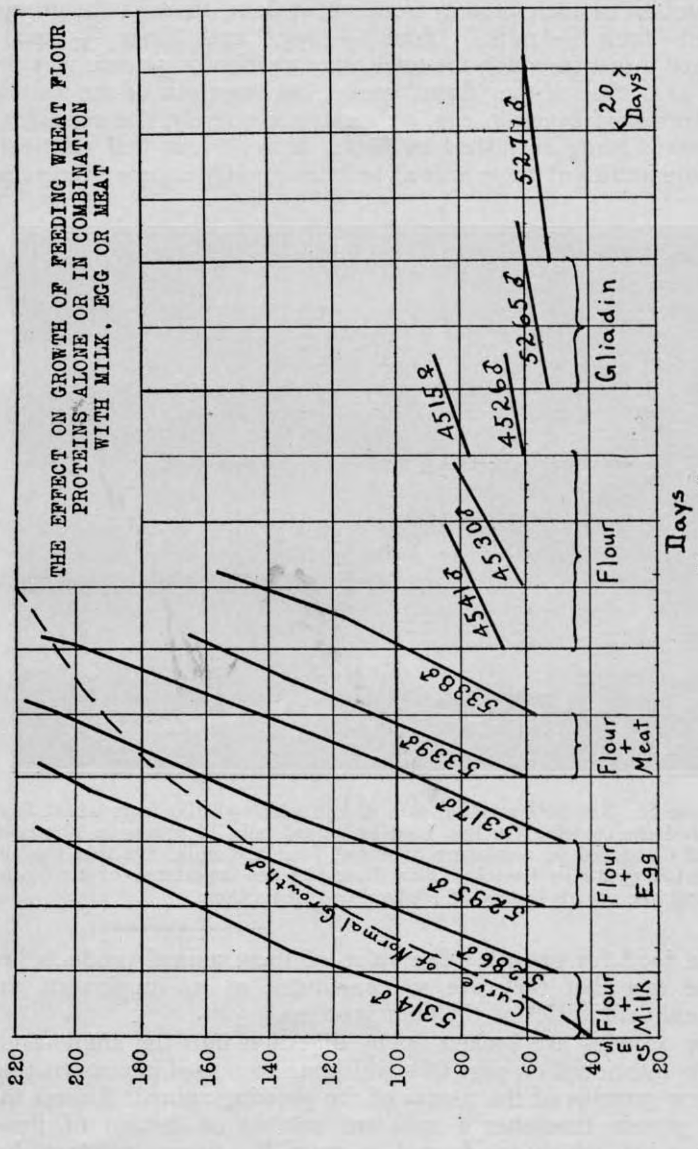
THE EFFECT ON GROWTH OF FEEDING WHEAT FLOUR PROTEINS ALONE OR IN COMBINATION WITH MILK, EGG OR MEAT
220
200
180
160
140
120
100
80
60
40
20
Gms
5314 ♀
Curve of Normal Growth ♂
5286 ♂
5295 ♀
5317 ♂
5339 ♀
5338 ♀
4541 ♂
4530 ♂
4515 ♀
4526 ♂
5265 ♂
5271 ♂
20 Days
Flour + Milk
Flour + Egg
Flour + Meat
Flour
Gliadin
Days

FIGURE 57.

the mixtures were practically identical, the foods differing only in the kind of protein. The animals in the group labeled "flour" received all of their protein from wheat flour, those in the groups labeled "flour + milk," "flour + egg," and "flour + meat" received a diet in which the total concentration of protein was the same as in that of the "flour" group, but one-third of the protein was furnished by milk, egg, or meat, respectively, the remaining two-thirds being furnished by flour. It is obvious that relatively small quantities of these animal proteins greatly improve the value

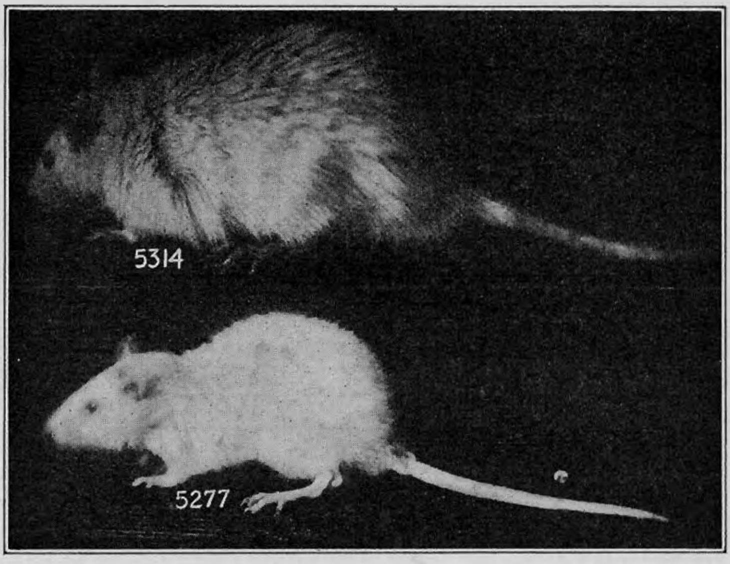

FIGURE 58. Rat 5277 was fed on a diet in which gliadin from wheat flour furnished the protein. On this food he gained only 10 grams in 10 weeks. Rat 5314 was fed on a mixture of wheat flour and milk. On this food he gained 160 grams in 9 weeks. This illustrates the importance of combining milk with the cereals instead of feeding the cereals alone.

of the food for growth. The value of these animal products lies in the fact that they are so constituted as to supplement the chemical deficiencies of the flour proteins.

The proteins are broken up by digestion into the amino-acids already mentioned on page 661, which are then used in constructing the new proteins of the tissues of the growing animal. Unless the food protein furnishes a sufficient amount of certain of these amino-acids, which are needed to make the tissues required for normal growth, the animal grows correspondingly more slowly than it would if more of the needed amino-acid were available.

Wheat flour contains two proteins one of which, gliadin, yields only a very small amount of the amino-acid called lysine. The effect of a limited supply of lysine on growth is illustrated by rats 5277 and 5265, whose curves of body weight are shown in Figure 57. These were fed on a diet in which all of the protein was furnished by gliadin. They were maintained in good health, but gained only about 10 grams.

FIGURE 59. The contrast between feeding a good or a bad protein to a young rat. The upper two rats are 5 months old and have been fed on diets exactly alike except that the one at the top had casein from milk on which it grew normally, and the one in the middle had gliadin from wheat flour on which it could not grow at all, so that when it was 5 months old it weighed exactly the same as the rat at the bottom, which was only 1 month old.

The rats on the "flour" diets grew somewhat more than those on the gliadin food because flour contains another protein which yields more lysine than does gliadin and hence supplements to some extent this deficiency of the gliadin. However, the amount of lysine thus supplied was too little to promote normal growth. In this connec-

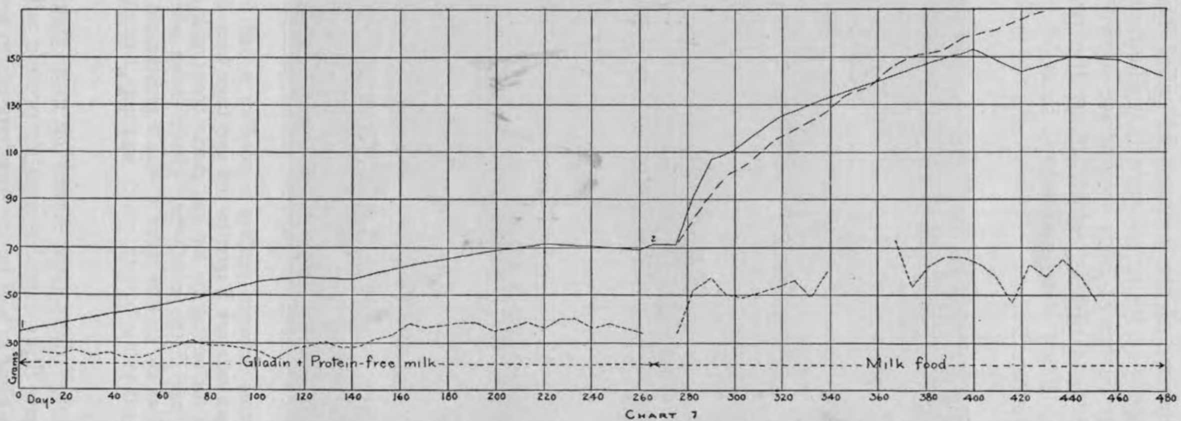

FIGURE 60. The solid line shows the body weight of a rat which was fed for about 9 months from the time of weaning on a diet containing gliadin from wheat flour as the sole source of protein. After 268 days, as indicated by the figure 2, the proteins of milk replaced the gliadin. Growth soon began at a normal rate for the size of the rat, which is shown by the broken line. The dotted line below shows the amount of food eaten during the experiment.

tion it is interesting to note how perfectly a young animal can be maintained in health, but without growing, even for a very long time when its diet is adequate in respect to everything except the chemical constitution of its food protein.

Figure 60 shows how little growth was made during nine months on a diet in which gliadin from wheat flour furnished all the protein. At the end of these nine months the rat was given a similar diet containing enough dried milk to replace the gliadin, and in two weeks on that food it gained as much in body weight as it had during the preceding nine months. It continued to grow normally on the milk diet to full adult size, a striking illustration of the value of milk proteins for growth. If, instead of replacing the gliadin with milk, a small amount of lysine had been added to the gliadin food the effect would have been the same.

Figure 61 shows the weight curves of several rats whose growth was alternately stimulated or checked by the addition to a gliadin diet of very small quantities of lysine or by its removal. In every day practice, however, it is impossible to feed lysine, as such, and the problem therefore resolves itself into finding available proteins which are sufficiently rich in lysine to be capable of supplementing this deficiency of the flour proteins. Two foods which thus far have proved to be efficient supplements to flour are milk and eggs; either of these is somewhat better than meat. Thus, under similar conditions of feeding when the food contains two parts of flour proteins to one part of meat protein, rats gain about three times as much per unit of protein eaten as when flour furnishes all the protein, and nearly four times as much when milk or eggs are used as supplements.

The same is true for corn. Zein, the principal protein of corn, lacks two essential amino-acids, tryptophane and lysine. Hence when zein furnishes all of the protein of the diet, the animal loses weight rapidly, and dies almost as soon as if no food were eaten. When a small quantity of one of these missing amino-acids, tryptophane, is added to the zein diet, the animal maintains its weight and lives for a long time but does not grow. If in addition to tryptophane, lysine also is added, the animal grows.

Figure 62 shows in a striking manner how essential it is to supply the young animal with protein that furnishes sufficient lysine. The lower picture is that of a young rat that lived for seven months in perfect health on a food containing zein + tryptophane as its sole protein. During all of this time it failed to grow and weighed only 70 grams. It did not even show signs of maturing but looked exactly like a recently weaned rat; it remained

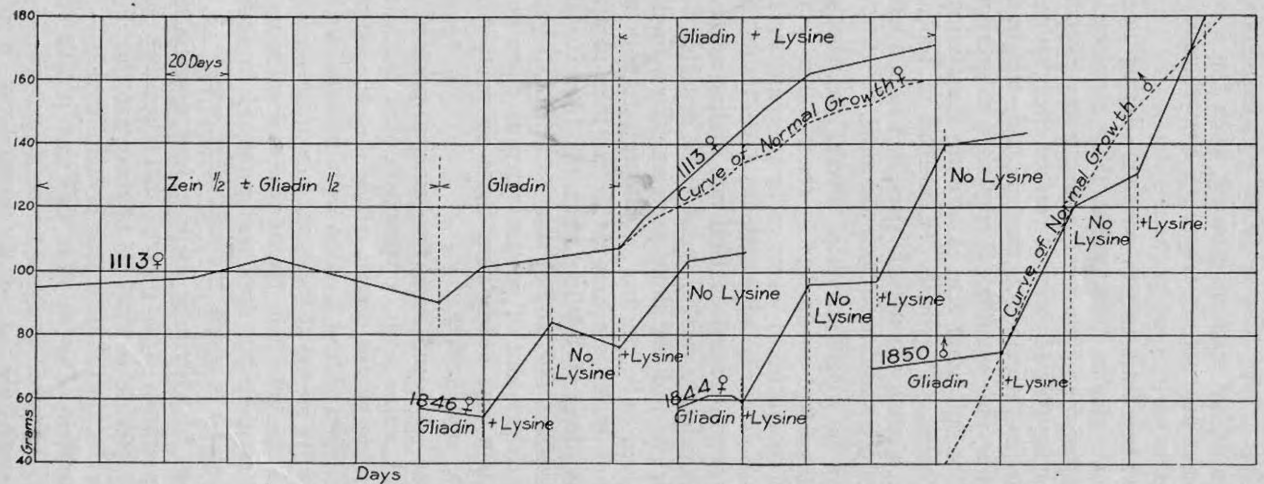

FIGURE 61. Shows the failure of young rats to grow when gliadin from wheat flour is the sole source of the protein in the diet. When a little of the amino-acid lysine was added the rate of growth became normal. Cereal proteins yield little lysine, milk proteins yield much. This explains why combinations of cereals with milk are superior to cereals alone as food for the young.

a baby. At the end of seven months casein was used to replace the zein + tryptophane. No other change was made in the diet. During the next three months it grew at the normal rate to 240 grams, and as the upper picture shows, became a fine, vigorous animal.

What this means might be illustrated in this way. For about one-fifth of its life period the rat did not grow. Calling a man's span of life seventy years the case would be somewhat like that

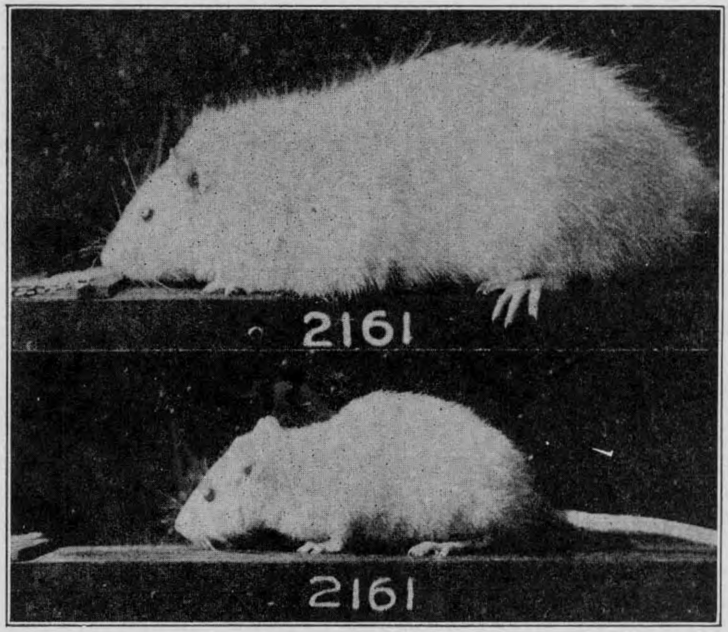

FIGURE 62. The lower photograph is that of a rat which has been fed for 7 months on a diet containing zein (one of the proteins from corn) together with a small amount of the amino-acid tryptophane. On this diet the rat could live but could not grow. The upper photograph is one of the same animal taken a few months later, after casein from milk had replaced the zein and tryptophane.

of a boy, kept as a healthy infant in arms until fourteen years old—weighing perhaps 16 to 20 pounds—and who, by a change of diet when 14 years old, attained a man's size and weight at the age of 21.

Two of the rats, 5293 and 5316, whose graphs of body weight are shown in Figure 63, received a ration in which the protein was furnished by gluten feed. Rats 5302, 5318, 5287, and 5315, on the other hand, had two-thirds of their protein in the form of gluten feed and the other third as milk or meat. The nutritive ratios of all of these three foods were alike, but the results were strikingly different.

This juggling with proteins and amino-acids is very interesting to the chemist and physiologist, for it represents a triumph of science that excites the wonder of those who appreciate the almost insurmountable difficulties encountered in these investigations. It would be of little use to discuss it here if these facts could not be

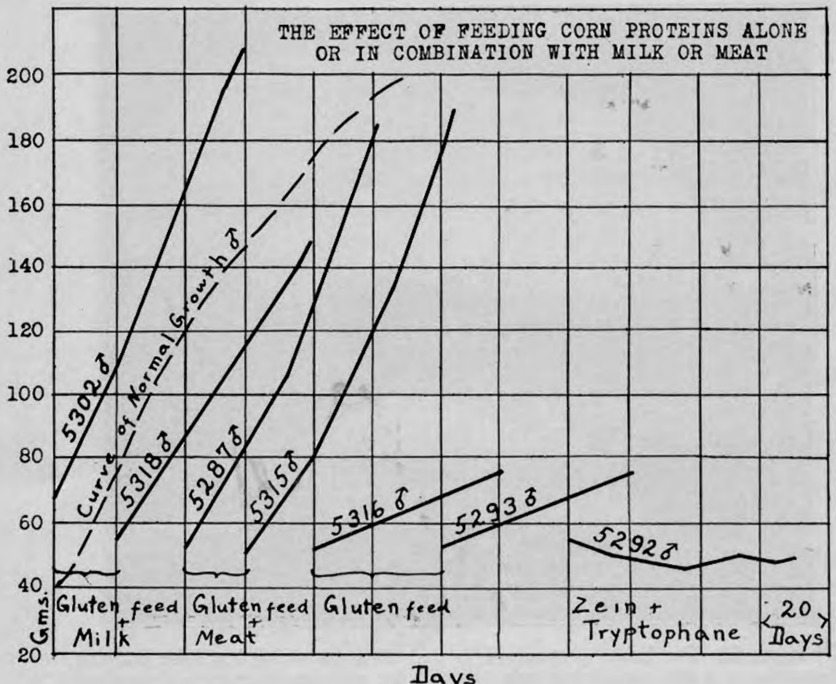

FIGURE 63.

applied to the feeding problems of the household and farm. Amino-acids are not commercially obtainable but products are at hand which contain proteins that furnish these amino-acids in readily obtainable form.

When whole corn is fed, the other proteins in this seed supplement the zein to such an extent that the animal can grow slowly, but if the corn is combined with milk, the proteins of which are rich in both tryptophane and lysine, growth is very rapid. Thus it appears that the chemical constitution of the protein of the food influences growth and that it is absolutely necessary to provide animals with proteins of the right kind, if they are to grow well. This applies not only to growth, but also to milk or egg production. Both milk and eggs are rich in protein. The animals producing them need large amounts of protein in their food, but until the

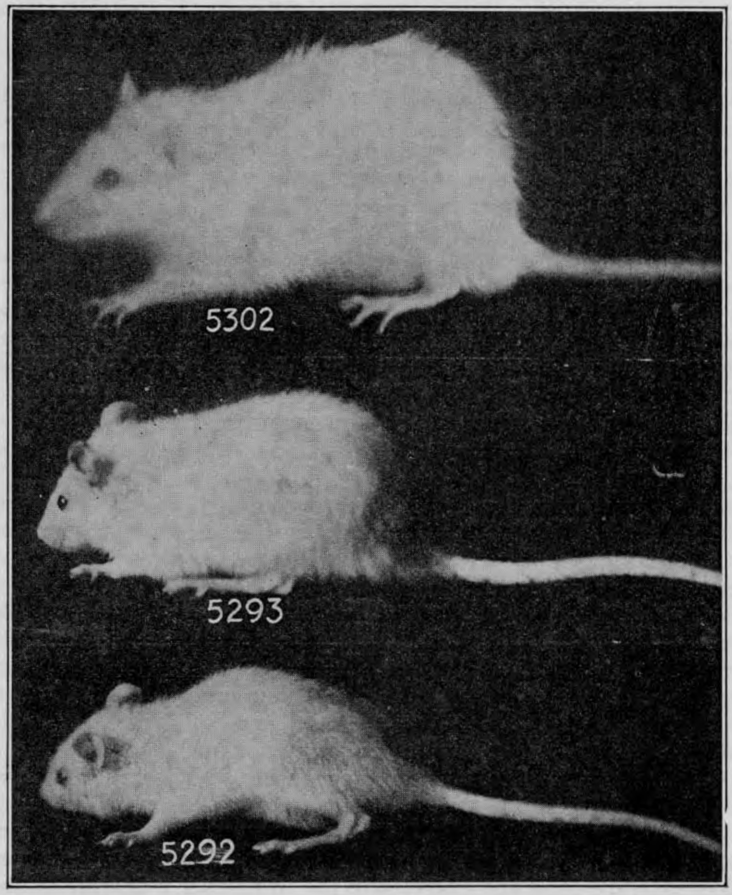

FIGURE 64. Photographs of some of the animals whose curves of body weight are shown in Figure 63. Although all three were of the same age, Rat 5302 which had received a mixture of gluten feed and milk is nearly three times as large as 5293 which received the gluten feed alone, and is more than four times as large as 5292 which was fed on zein plus tryptophane.

differences in chemical constitution of the proteins of different feeds were discovered, it was not appreciated how important it is to provide proteins of the right kind.

NUTRITIVE VALUE OF THE SEVERAL COMPONENTS OF MILK

The Proteins

Milk contains the proteins casein, lactalbumin, lactoglobulin, and an alcohol soluble protein discovered by Osborne and Wakeman at this Station in 1918. These supply about 19 per cent of the total calories of milk. The principal protein, casein, best known perhaps in the form of cottage cheese, is characterized by containing 0.8 to 0.9 per cent phosphorus. It is present in cow's milk to the extent of 3 to 4 per cent and in human milk in a decidedly smaller amount—0.05 to 1.5 per cent.

Lactalbumin, the principal protein of whey, or milk serum, is present as 0.5 per cent of whole cow's milk and represents about one-sixth of the total protein. Human milk contains a greater proportion of lactalbumin than does cow's milk. The lactalbumin content of cow's milk is equivalent to one-tenth of the casein, whereas in human milk it is equivalent to one-fifth of the casein.

These two proteins, comprising about 93 per cent of the total milk proteins, are both biologically complete, that is, either one given in sufficient quantity has been found by Osborne and Mendel to support satisfactory growth and reproduction in suitable test animals, provided the protein is fed in conjunction with an otherwise adequate diet. The amino acid cystine, a protein digestion product necessary for growth, occurs in casein in less satisfactory amounts than do the other essential amino-acids; for this reason a larger percentage of casein must be fed than would otherwise be necessary to supply adequate amounts of the other amino-acids. Lactalbumin contains a larger proportion of cystine than does casein. The indispensable amino-acid lysine occurs in considerable quantities in both lactalbumin and casein, and both proteins contain sufficient quantities of histidine and tryptophane.[1]

Of particular interest are the experiments of Rose and McLeod (7) which demonstrate that the nitrogen of milk is more efficiently utilized by the human body than is the nitrogen of various other foods. This is determined by measuring the quantities of nitrogen taken in in the food and excreted in the urine over a definite period of time. Rose and McLeod fed young adult women a nitrogen-free basal diet to which the protein was added in equivalent amounts in the form of natural foods. Over a twelve day period there was stored on a diet (a) of soy beans, 2.12 grams of nitro-

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[1]The different amino-acids are not all equally essential in animal nutrition. Four of them, tryptophane, lysine, cystine, and histidine are absolutely indispensable; several others may be required, and there is at least one amino-acid, the composition of which is not yet known, that is required by animals for growth; this substance has only recently been detected in casein. The animal body is indifferent, however, to the relative proportions in which the greater number of the amino-acids are fed.

animals with proteins of the right kind, if they are to grow well. This applies not only to growth, but also to milk or egg production. Both milk and eggs are rich in protein. The animals producing them need large amounts of protein in their food, but until the

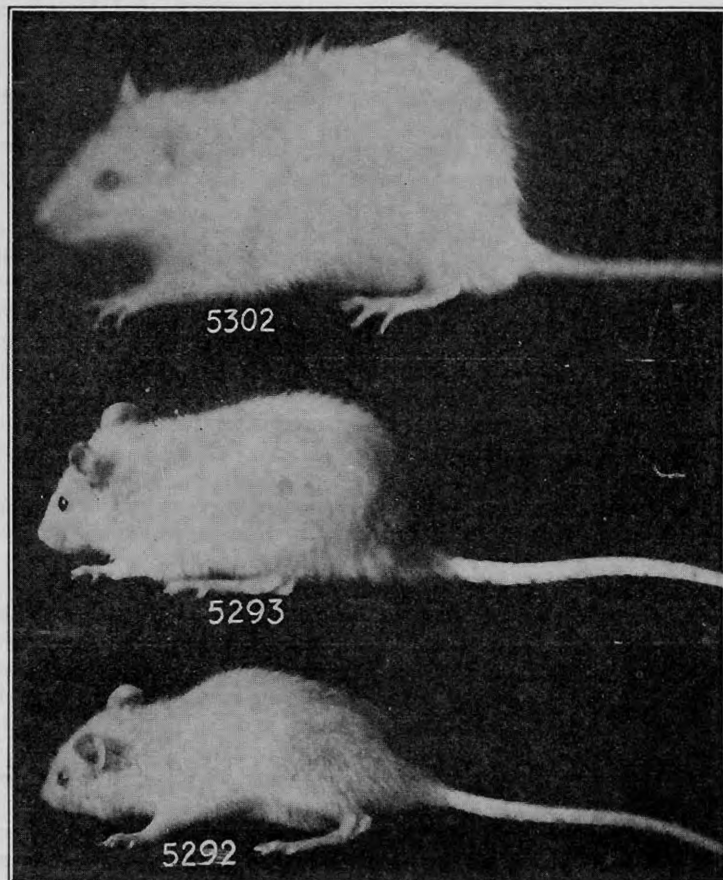

FIGURE 64. Photographs of some of the animals whose curves of body weight are shown in Figure 63. Although all three were of the same age, Rat 5302 which had received a mixture of gluten feed and milk is nearly three times as large as 5293 which received the gluten feed alone, and is more than four times as large as 5292 which was fed on zein plus tryptophane.

differences in chemical constitution of the proteins of different feeds were discovered, it was not appreciated how important it is to provide proteins of the right kind.

gen; (b) of meat, 4.33 grams; (c) of milk and bread, 30.37 grams; and (d) of milk alone, 41.43 grams nitrogen. It would appear that, per unit of weight, the proteins of milk are more readily and completely assimilated by the animal body than are proteins from other sources.

The proteins of milk are equally readily assimilated whether presented in the form of whole milk, evaporated milk, dried milk, cheese, or purified casein. Infants appear to utilize the protein from heat treated milk rather more readily than that from untreated milk, since in the former case undigested protein curds do not appear in the stools.

The Carbohydrates

Lactose, on digestion, is split into glucose and galactose. It is non-fermentable by ordinary baker's yeast. In the preparation of kephir and kumiss the lactose undergoes alcoholic fermentation with the production of lactic acid through the action of ferments other than yeast. Lactose possesses slight laxative properties.

Liberal quantities of this carbohydrate in the diet produce a favorable medium in the intestine for the growth of the non-putrefactive organisms, such as *Bacillus acidophilus*. This type of bacterial flora has received considerable attention in recent years.

Lactose plays a peculiar rôle in the diet inasmuch as it increases, in some unexplained manner, the absorption of the salts of calcium, or phosphorus, or both, from the gut, and their retention in the animal body. Under certain conditions the influence of this sugar in inducing proper deposition of inorganic salts into the bones may be as great as that of the bone-calcifying vitamin D. In this connection it should be pointed out that the incidence and severity of rickets is much less in babies reared on human milk than on cow's milk in spite of the richer supply of inorganic salts in the latter milk. This may be associated with the higher lactose content of human milk.

The Fat

The fat of milk consists of the triglycerides of caproic, caprylic, capric, lauric, myristic, butyric, palmitic, stearic, and oleic acids, together with small amounts of cholesterol and phospholipids. Milk fat is easily digestible. Owing to its fine emulsification in milk a considerable portion may undergo digestion in the stomach. The size of the fat globules is a species characteristic. The fat globules of human milk and goat's milk are relatively smaller in diameter than are those in the milk of the cow, and are consequently more easily digested by the enzymes of the gastro-intestinal tract.

From a nutritional point of view butter fat is notably valuable as a source of the fat-soluble vitamins, which will be discussed later. There is also a growing belief that fat, or rather certain fatty acids, are necessary adjuncts to a normal diet.

The Inorganic Salts

The inorganic salts or ash constituents comprise the residue that remains when all the organic matter in the food is burned away by heating in the presence of air; they supply an essential part of the diet. Numerous substances of this type are necessary for the growth of the skeleton, for the development of the soft tissues of the body and for the maintenance of the osmotic pressure and of the neutrality of the body fluids. These substances are more satisfactorily supplied by milk than by any other feasible combination of natural foods. During the early period of infancy, when the rate of growth is so phenomenally rapid, milk is the major source of the inorganic substances in the diet of most mammals and at this time the demand for these substances is great, owing to the enormous growth in size of the skeleton.

Iron and copper are the only known essential elements that occur in milk in less than optimal quantities; although only small quantities are required, red blood cells cannot be formed by the body unless these metals are supplied. Young animals at birth, however, possess a goodly supply of both these elements and this tides them over until a mixed diet can be given. When the supply of iron and copper in the body is exhausted normal growth ceases and anaemia may result. Restoration to normal growth and health by the addition of other foods will occur only in so far as these contain iron and copper.

The calcium content of cow's milk is three times that of wheat and six times that of corn. Milk is the best source of dietary calcium; all other foods, with the exception of the green leafy vegetables, are relatively poor sources of this substance. Calcium retention by the animal body, furthermore, is greater when milk is fed than if the same amount of calcium were given in the form of vegetables. Babies reared on cow's milk absorb and retain more calcium and phosphorus than do those reared on human milk. The much quoted experiments of Sherman and Hawley (8) on children between the ages of 3 and 13 years have demonstrated that optimum storage of calcium is made when the daily diet of the child contains at least one quart of milk.

The inorganic constituents of milk vary according to the stage of lactation, the season, and the locality in which the milk is produced. Data reported for the iodine content in two sections of the United States are of particular interest (9). Cows in a dairy section of New York produced in the summer a milk which, in a dry powdered form, contained 145 parts of iodine per billion;

during the winter months the iodine fell to 67 parts per billion. Milk powder from Wisconsin, however, contained 704 parts of iodine per billion in the summer and 961 parts in the winter.

Dried and evaporated milks may contain more iron and copper than the original fluid milk (10). Milks desiccated by the revolving cylinder process have been reported to contain two to five times more iron than the original milk owing to the dissolution of iron from the metallic cylinders. The copper vacuum pans and tubes used in the commercial evaporation of milk may also increase the copper content of the milk. Milks dried by the spray process do not contain additional iron.

Pasteurization, boiling, or evaporation may cause a slight precipitation of calcium phosphate. The amount lost in this manner is small, and, since cow's milk is at least four times richer in calcium than human milk, the possible loss to the infant is inappreciable. Evaporated milk is as good a source of the inorganic salts essential for human nutrition as pasteurized milk (11). Vigorous boiling is said to reduce the iodine content by as much as 20 per cent.

The efficiency of the salt mixture found in milk has been demonstrated in experimental laboratories for years. In the early nutrition studies milk itself was used as a source of the inorganic salts. Later, in an attempt to ascertain the nature of the factors in milk which stimulated growth in rats, Osborne and Mendel prepared an artificial salt mixture the composition of which was designed to simulate that of milk ash as closely as possible. Additional iron, of course, had to be incorporated. This salt mixture was found to be very satisfactory and is now used in many laboratories to supply the mineral requirements in experimental studies with animals.

The Vitamins

Milk contains all the vitamins which have been shown to be necessary for man but, with the possible exception of vitamin A, can not be considered a rich source of any of them. Consequently milk should never be fed as the sole supply of these dietary essentials. During growth the demand for vitamins is so great that it is not always possible for the baby to consume as much milk as is required to furnish some of them in sufficient amount. For this reason many pediatricians prescribe cod-liver oil and tomato juice or orange juice as early as the third week of life. Likewise, the adult who may be forced to subsist largely on a milk diet, must have access to foods more concentrated in the vitamins.

Vitamin A. The earliest observations of the presence of vitamin A in milk fat were made simultaneously by McCollum and Davis

(12) and by Osborne and Mendel (13). It had been noticed that animals grew well for a certain period on various mixtures of purified food materials but that they ultimately declined rapidly in weight and died unless butter fat were included in the diet. This led at first to the view that butter contains an unknown substance the chief function of which is to promote growth. Later, when the diets were more carefully refined and purified and contained little, if any, natural food, Osborne and Mendel (14) found that the absence of butter fat from the food not only brought about a rapid decline in weight but also gave rise to a definite

FIGURE 65. Photograph of a Danish child that had been fed on skim milk until pronounced symptoms of vitamin A deficiency had developed; note the ulcer on the right eye. Lesions of this type occurred in Denmark during the early years of the war, but were no longer observed after the exportation of butter was forbidden. (Photograph from Bloch (15)).

pathological condition of the eye characterized by a dryness of the tissues and their subsequent invasion by bacteria. This lesion has been named xerophthalmia; the unidentified substance in butter fat which prevented it was designated vitamin A. More recent investigations have shown that the epithelial tissues of the body in general are involved and that the eye lesion is a late manifestation of a condition often far more serious and advanced within the body.

Xerophthalmia has been observed in children who did not have access to liberal amounts of a good milk, butter, eggs, yellow or green vegetables, or cod-liver oil. Numerous cases occurred in

Denmark during the early years of the World War when margarines were substituted in the diet for butter, which was being exported. From 1917 to 1919 the exportation of butter was forbidden and this eye lesion disappeared (See Figure 65).

The vitamin A content of human milk may be equivalent to that of cow's milk, but its presence in any milk is dependent entirely on the amount taken in in the mother's diet. It is believed that the vitamin A of mother's milk, although no more concentrated than in cow's milk, is more completely utilized by the infant, even if identical amounts of the vitamin are given in the form of cow's milk. Since vitamin A is confined to the cream portion, about 90 per cent is removed by the process of skimming. Therefore skimmed milk formulas would fail to furnish the baby with sufficient vitamin A and this essential material must be supplied in some other way.

Although vitamin A is destroyed by prolonged exposure to air, and by heat and storage, the temperatures ordinarily reached in cooking and in the preparation of infant formulas only slightly diminish its original concentration in milk. In the most careful commercial evaporation or powdering of milks, no appreciable destruction of this vitamin results.

Vitamin B.[1] This vitamin is not plentiful in milk. Cow's milk is about one and one-half times richer than human milk but, weight for weight, is less than one-fiftieth as potent as a good sample of dried brewery yeast. Vitamin B is soluble in water and therefore is contained in the skimmed milk portion. It is fairly resistant to heat and oxidation and thus is unaffected by ordinary cooking, by desiccation, or evaporation.

Like vitamin A, this vitamin is present in the milk only to the extent that it occurs in the maternal diet and, since it is not stored in the body during periods of plenty, its absence from the food is quickly reflected in the quality of the milk. Macy and her coworkers (16) have found that the vitamin B content of human milk varies inversely with the quantity secreted. Thus women who produce large quantities of milk may be supplying their babies with a food far below the optimum in vitamin B. Since the rate of growth of experimental animals can be retarded or accelerated at will by the amount of vitamin B administered in their diet, it is evident that some other source of it than the mother's milk must frequently be supplied in order to insure the normal growth of the young.

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[1]The term vitamin B was originally applied to an essential food factor without which animals failed to grow and developed symptoms that resembled those observed in the human disease beri-beri. Latterly the factor has been found to be complex and at least two different substances have been shown to occur in it. Of these one retains the old designation vitamin B, the other is named vitamin G. In Europe these two factors are designated B_1 and B_2 respectively.

Vitamin C. Milks, even in a fresh condition, are rather poor sources of the scurvy-preventing substance, vitamin C. Summer milk may be richer than winter milk, but this is dependent on the type of fodder fed. Herds that receive the same ration winter and summer, without access to fresh green pasturage, will probably produce a milk constant in its vitamin C value although carrying a minimal amount.

Vitamin C is quickly destroyed by oxidation and by exposure to air and heat, hence the milk delivered to the average consumer is relatively deficient in this substance. Milk quickly boiled without stirring may retain most of its vitamin C, but pasteurization at 63°C for 30 minutes will destroy it almost completely. Evaporated milk and sweetened condensed milk are consequently nearly devoid of it. Milk powders vary in their vitamin C content with the process of manufacture. The roller process leads to somewhat less destruction of this vitamin than does the spray process.

Since milks contain so little vitamin C, even when freshly secreted, and since destruction occurs so readily on exposure to air and to high temperatures, it is imperative that adults, as well as children, should be assured of other sources of vitamin C. Liberal portions of fresh fruit juices, fruits, and vegetables are necessary to forestall the bleeding and tenderness of the gums, the loosening of the teeth and the swollen and tender joints that are symptomatic of scurvy.

Vitamin D. Milks, in general, very seldom contain sufficient vitamin D to prevent or cure rickets in babies. Assays of human milk have revealed an almost total absence of this factor, although cow's milk probably contains a small amount. As is the case with the other vitamins the concentration in the milk depends somewhat on the access of the cow to foods rich in vitamin D. It is not possible, however, to increase the potency of human milk by dietary means. Exposure of the lactating mother to sunshine or to artificially produced ultraviolet light will stimulate the secretion of vitamin D into her milk. This is true, also, for the goat. Similar exposure of the cow does not thus enrich the milk.

Vitamin D is not readily destroyed by heat, therefore ordinary boiling or pasteurization may be carried out with impunity. Commercially evaporated milks have been shown to be as potent as are pasteurized milks in inducing maximal calcification of bones.

It is a curious fact that, although average human milks contain little demonstrable vitamin D, rickets develops less often and in far less severity in exclusively breast fed children. We have yet to learn whether the explanation of this lies in the high lactose content of human milk, in the concentration of its inorganic salts, or in both.

It should be stressed here that no milk, either human or cow's, can furnish enough vitamin D to the rapidly growing infant to allow for the perfect development of its bones. Intake of cod-liver oil, or egg yolk, and exposure to the unobstructed rays of the sun should be begun in the early weeks of life.

Vitamin E. This is the dietary factor that has been found in experimental studies to be essential for successful reproduction in the albino rat. Its value for the human species has not as yet been proved. The concentration in cow's milk is extremely small, even when the ration of the cow contains ample portions of fresh alfalfa. Since the vitamin is found in the fat fraction skimmed milk is devoid of it. Human milk has not been tested for its vitamin E content. Destruction due to heating and oxidation does not readily occur.

Vitamin G. Pellagra, a serious disease that is prevalent in the southern part of the United States, has been found within recent years to be of dietary origin. It may be prevented or cured by a substance of unknown composition in milk, glandular meats, yeast, and also in certain vegetables. Liberal quantities of cow's milk must be ingested if this food supplies the only source of the pellagra-preventing vitamin G. Human milk contains less of it than is found in cow's milk. Evaporated, condensed, and dried milks have not been studied for their vitamin G content, but since it is known to be extremely resistant to heat, it is probably present to the same extent as in raw or pasteurized milk.

Energy Value of Milk

Because of its large water content whole milk has a relatively low energy value per unit of weight. Table 3 on page 660 shows the calorific value of milk and of different milk products. The figure there given, 315 calories per pound, indicates that an average person would require about three and one-half quarts daily to supply the needed 2500 calories of energy. A person employed at vigorous manual labor would need nearly twice as much. Milk is manifestly unsuited to serve as the sole food of adult man not only because of the deficiencies mentioned in the previous sections, but also because of its low energy value. However, its value as one of the fundamental constituents of a well chosen dietary can hardly be overemphasized.

THE PLACE OF MILK IN THE DIET

Milk contains an abundance of protein, fat, carbohydrate, and inorganic salts; its unique proteins are not only of superior value when used alone, but are also especially adapted to supplement the deficiencies of the proteins of the cereals that form so large a part of the daily ration of mankind. The scientific investigations of milk that have been made in the past three decades have all demonstrated that it plays an essential rôle in the human dietary and is of particular benefit to the very young. Furthermore, they have also furnished an explanation of the esteem in which milk and its products have been held by the human race since the dawn of civilization.

Nevertheless it is necessary to point out that milk is not a perfect food inasmuch as it does not, when used as the sole source of nutriment, supply adequate quantities of all of the factors required for the normal growth and wellbeing of animals. Although the consumption of liberal quantities of milk along with a dietary of other natural foods enhances physical development and health, its exclusive use over long periods of time has always led to nutritional disaster. This conclusion is the result of many futile attempts to rear and propagate calves, dogs, pigs, rabbits, and rats on milk diets under experimental conditions. Calves, fed milk alone, may grow fairly well for two to four months, but their weights then remain stationary, the animals become indifferent to food, and their joints become enlarged and stiff with resultant interference with locomotion: nervous disorders are also common symptoms. When rats are fed exclusively on whole milk, either fresh, boiled, autoclaved, or dried, their initial growth may be satisfactory, but later on they become retarded in growth and reproduction does not occur. If the diet is continued sufficiently long, nutritional anaemia may result, depending on the availability of copper and iron in the cage and bedding.

The unfortunate "experiments" that have been unwittingly conducted on babies reared with the mistaken idea that milk is their perfect food should be mentioned in this connection. Malnutrition, loss of appetite, inability to sit erect and walk at the normal age, fretfulness, anaemia, and rickets are some of the untoward effects of a diet of milk alone over very long periods of time. The evidence is overwhelmingly convincing that milk is not a complete food for either man or animal and should never be used as the *sole* food for any prolonged period of time, either for babies or for adults.

The Nature of the Dietary Deficiency of Milk

The addition of various food products, natural or purified, to milk dietaries may improve the diet in varying degrees, depending on the nature of the added food and the proportions in which it is administered. Bunge long ago showed that milk contained very little iron but that young animals are able to grow for a time by virtue of a storage of this substance in their bodies at birth. Daniels

(17) found that soy beans, either as the meal or *meal ash*, were a satisfactory addition in promoting growth and reproduction in rats. Hart and co-workers (18) were able to prevent or cure the characteristic milk anaemia in rats and other animals by introducing small amounts of copper, in addition to iron, into the ration.

McCollum and his associates (19) conducted some interesting experiments with rats in an effort to find what foods could supply the substances in which milk is deficient. They fed diets that in most cases contained 60 per cent of whole milk powder, the rest consisting of dextrinized starch, together with one of the following foods: Wheat and its various products, casein, gelatin, alfalfa, butter fat, cod-liver oil, lard, egg yolk and albumin, hemoglobin, agar agar, beef liver, orange juice, and inorganic iron and copper salts. Of 38 diets used, only 24 allowed for production of young and only four of these produced fifth generation young. Of the natural foods, liver appeared to be the most potent in supplementing the milk, but gave no better growth and reproduction than was secured by inorganic iron and copper together. The conclusions reached by numerous investigators are that the outstanding deficiencies of milk are iron and copper, and that when these are supplied, although only very small amounts are needed, a milk diet will allow the animal body to function normally.

Effect of Heat on the Nutritive Value of Milk

When milk is subjected to heat certain changes take place which affect its physical character more than its nutritive value. A film forms on the surface of the milk boiled in an open utensil; constant removal of this film will result in a diminution of both protein and inorganic salt content.

Alteration of the protein occurs to such an extent that, when the heated milk is coagulated by rennin or by the acid of the gastric juice, a softer and finer textured curd is obtained than with raw milk. Digestion and absorption of the protein are thereby facilitated. The lactalbumin of the whey undergoes partial denaturation, but is not damaged from a nutritive standpoint, by long continued heating such as accompanies the commercial evaporation of milk. Hence persons who are unable to drink raw milk can often take evaporated milk without disagreeable results.

When milk is heated a small amount of both calcium and phosphorus may be precipitated, but the nutritive value and ease of assimilation of the inorganic salts are probably not changed. The lactose and fat undergo no change except that the latter, in evaporated milks, is broken up into much finer globules which are more evenly distributed, more thoroughly emulsified and hence are more readily acted upon by the digestive enzymes. A slight caramelization of the sugar may occur, thereby changing the taste slightly to resemble that of boiled milk.

The scurvy-preventing substance, vitamin C, is the only vitamin that undergoes rapid destruction upon being heated under ordinary conditions. Although boiling without stirring, for a short period of time, may not destroy it, commercial methods of concentration, evaporation, or drying leave little vitamin C in the final product.

During pasteurization the only constituent of milk that suffers deterioration is vitamin C. This is of no great consequence, however, since its original content in milk is so far below the optimal for the child that additional vitamin C must be supplied from earliest infancy.

Biological Effects of Diets that Contain Milk

Other experiments have been reported which show remarkable growth and reproduction in rats, and give a scientific explanation for the wholesome effects observed in man when milk forms a liberal part of his diet. Perhaps the most widely discussed study is that conducted over a period of years by Sherman and Campbell (20). Two groups of rats, consisting of one male and three females each, were fed similar diets, the only difference being that one contained one-sixth whole milk powder and five-sixths whole wheat, whereas the other consisted of one-third milk powder and two-thirds of whole wheat. On the latter diet the rats grew faster, reproduced earlier, gave birth to more young, and reared a larger number of young rats. At the end of a year there were 361 descendants from this group, in contrast to 77 from the group that received the lesser proportion of milk powder. Furthermore the animals that received more milk were of a somewhat larger size at all ages and, when maintained on the diet until natural death ensued, on the average lived distinctly longer than the others (21).

The Daily Milk Requirement

A discussion of the nutritive value of milk would not be complete without consideration of the quantity required to make a dietary optimal. During infancy and childhood, because of the rapid increase in size of the skeleton, the need for inorganic salts is relatively enormous. Their assimilation and retention by the growing body is proportional to the amount eaten. In other words, large salt intakes induce the utilization of especially large amounts of calcium and phosphorus. Sherman and Hawley (8) have found in children that maximum retention of these constituents occurs when a minimum of one quart of cow's milk is consumed daily.

This amount, then, has been taken as the standard required by a child to supply sufficient material for the normal growth of its skeleton.

Many pediatricians, however, believe that, on account of the bulkiness of a quart of milk and its low calorie value, it may be difficult for a child to eat enough other foods to obtain a well balanced dietary. Loss of appetite, poor gastric motility, and anaemia are among the symptoms attributed to excessive milk drinking. Eliot, in the bulletin published by the Childrens' Bureau, "The Care of the Pre-school Child," advises that at least one and one-half pints of milk be consumed daily.

If one quart of milk be given, careful selection of other foods must be made in order to supplement the deficiencies of milk. As brought out in this bulletin, these deficiencies are calories, iron and copper, and the vitamins other than A. Additional roughage is also advisable. Generous amounts of fruits and vegetables, both raw and cooked, egg yolk, glandular meats, cod-liver oil, and small amounts of whole cereal grains to supply calories make ideal additions to a diet built around one quart of milk per day.

THE COST AND ECONOMY OF MILK

Most students of the science of nutrition are united in the belief that, under the economic and social conditions existing in this country, milk furnishes more of the substances essential in human food for the same amount of money than does any other single item of the dietary. Many technical reasons for this belief in the superior food value of milk have been given in the preceding sections; the present section deals with the extent to which milk can be considered as an economical food.

The economy of milk involves much more than a mere consideration of cost, for the question of the unique food value of milk must also enter into the discussion; the cost is significant only in terms of food value received for money expended.

The Place of Milk in the Child's Diet

In order to reduce the problem to practical terms it is necessary to consider the economy of milk from the relationship of the monetary value of a given quantity of milk to its content of the dietary essentials, and also to show the contribution of this given quantity to the total daily food requirements of an individual. The daily food needs of a school-age child have therefore been chosen as the dietary standard to be met, and one quart the unit quantity of milk. These selections were made on the basis of the Sherman-Hawley experiments, which showed that optimum storage of calcium in children is attained when one quart of milk is consumed daily.

Figure 66 shows the contributions that certain of the constituents of milk make toward the satisfaction of the requirements of a child of 10 to 12 years of age, who normally ingests food of a total energy value of 2500 calories daily. Each bar represents a single essential and its height shows, on a percentage scale, the part that is contributed by the milk on the basis of a daily consumption of one quart. It is at once evident that, when fed at this level, milk supplies the whole of the calcium and 90 per cent of the

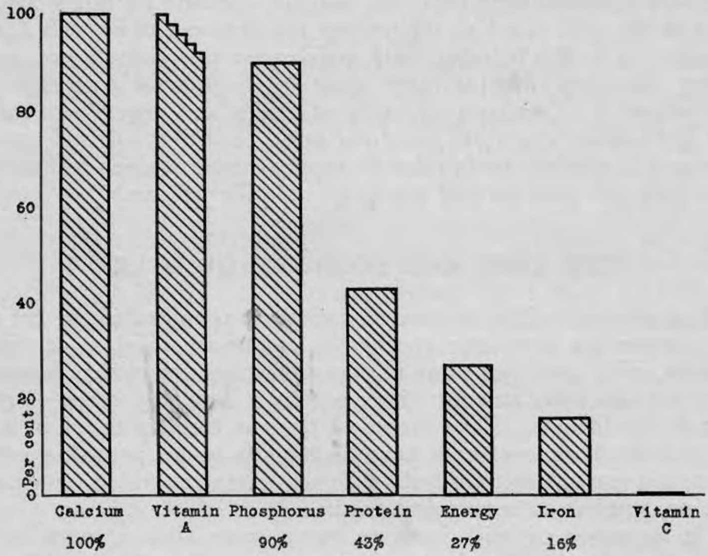

FIGURE 66. The contribution made by one quart of milk to certain dietary needs of the child.

phosphorus needed. The generally accepted standards of one gram of each per day for the growing child were used. The bar representing vitamin A is shown with an irregular line at the top to indicate some uncertainty as to the proportion of the requirement met by one quart of milk daily. Although the number of units of vitamin A in many food stuffs is known, the quantity required by the human body has not been definitely established. The experience of many investigators has indicated, however, that one quart of milk supplies the requirements of the child for vitamin A and, consequently, the bar extends almost to the top of the diagram.

The quantities of protein and iron in milk are measurable and the food fuel or energy value of one quart of milk is known; bars representing these three essentials may therefore be added to the figure with little comment. The child's need for protein was calculated on the basis of 12 per cent of the 2500 calorie standard and the daily iron requirement was taken as 0.015 gram. Bars to represent vitamins B, G, and D have not been given because the number of units of these vitamins required by the human body is not known with any certainty, and also because there is only meager evidence available with regard to the amounts of them present in commonly used foodstuffs.

It is clear that a liberal proportion of the essential constituents of a child's diet is supplied by the consumption of one quart of milk daily, and that milk is a satisfactory basic food around which to build an adequate diet. The next point for consideration is, therefore, the correct selection of foods with which to supplement the quart of milk in making up the dietary. The cost of these foods, when compared with the price paid for milk, will reveal to what extent milk can be considered an economical food.

Milk an Economical Food

Obviously, with less than half of the dietary essentials to be supplied and, at the same time, with more than two-thirds of the calories still lacking, there is a wide range of foods from which to choose the remainder of the diet. Many combinations that insure an adequate diet have been devised and, for the purpose of the present discussion, one of the simplest is here presented. According to this the daily diet of a child should contain the following foods, if the diet is to be complete: *in addition to the quart of milk,* two or more kinds of fruit, of which one should be a citrus fruit or tomato; two or more vegetables, one preferably raw; one or more servings of whole grain cereal or bread; one or more servings of a high protein food such as meat, fish, eggs, or cheese; and enough additional food to fulfill the energy requirement. The problem in this case, then, is to select foods that yield about 1800 calories which, when added to the 675 calories supplied by the quart of milk, furnish the 2500 calories required by the child. An illustrative list of foods that might be selected is shown in Table 5.

Figure 66 shows that, by supplementing milk with these foods, not only the necessary energy is supplied, but the diet is rendered adequate in other respects as well. Ample quantities of vitamin C, for instance, are contained in the raw fruits and vegetables, and iron is provided by the meat, fruits, green vegetables, egg, and whole grain cereal. The protein and phosphorus requirements are met by the meat, cereal, and egg, and a liberal excess of vitamin A is supplied by the butter, egg yolk, and green vegetables, thus providing for the much desired "health reserve" of this vitamin. The calcium requirement has already been met by the milk, and properly so in view of the probability that the calcium of milk is more completely utilized by children than is that from other sources.

TABLE 5. AN ILLUSTRATIVE LIST OF FOOD STUFFS THAT MIGHT BE SERVED DAILY TO SUPPLEMENT ONE QUART OF MILK FOR A CHILD 10 TO 12 YEARS OLD

Foods	Calories
1 orange	75
1 apple	100
1 serving prunes	100
1 serving coleslaw	50
1 serving peas	50
1 serving whole grain cereal	100
1 egg	70
1 serving meat	100
4 servings bread stuffs	400
1 ½ oz. butter	300
1 medium-sized potato	100
1 serving Brown Betty	200
2 small cookies	100
Sugar or other sweets	100
Total	1845

Let us now examine the cost of these foods. When one quart of milk, which forms the foundation of the diet, costs 12 cents, this sum has satisfied the child's requirement for calcium; has provided all, or practically all, of the vitamin A needed; has supplied nearly all of the phosphorus, two-fifths of the protein, more than one-fourth of the energy, and one-sixth of the iron. On the other hand, what must be paid for the foods that supplement the milk in completing the diet? Purchased at moderately priced markets and at a time when staple food products are extremely low in price this supplementary list of food costs approximately 30 cents. This brings the cost of the meals for one day to about 42 cents. There is of course a considerable variation in the price that has to be paid for these supplementary foods, and the selection of a wider variety of foods of choice quality adds materially to the total cost. But, bearing in mind the large nutritive contribution made by the quart of milk and the small fraction of the cost of the day's meals for which it may be procured, it is clear that milk may be regarded as a fundamental item of the child's diet and, in the true sense of the word, as an economical food.

Cost of Calcium in Various Foods

A still closer analysis of certain of the dietary factors of milk taken singly shows that many of these can be supplied at lower cost in milk than in any other way. One of the most striking examples of this arises from a consideration of the requirement of the human body for calcium. The question is frequently raised whether adults ordinarily obtain sufficient calcium from other foods than milk. Fruits and vegetables are generally regarded as good sources of calcium and are often depended upon to take the place of milk in this respect. The question really involves two quite different considerations: First, is it possible to supply the calcium needed by substituting fruits and vegetables for milk, and, second, if this is so, is the substitution economical from the point of view of cost?

For the present discussion the calcium requirement of the adult is taken at the generally accepted standard of 0.67 gram daily. This amount of calcium would be supplied by the ingestion of slightly more than one pint of milk which is the quantity usually recommended for the adult. In what quantities must fruits and vegetables be eaten if milk is to be supplanted by them as a source of calcium? For convenience let us take the fresh fruits and vegetables from the supplementary food list in Table 5,—oranges, apples, peas, and cabbage. The calcium content of these foods is as follows:

Foods	Measure	Calcium gm.
Apple	1	0.011
Orange	1	0.066
Peas	½ cup	0.014
Cabbage (shredded)	1 cup	0.036
Total		0.127

It is evident that, when served in the quantities designated, these fruits and vegetables do not meet the daily calcium requirement of the adult. Figure 67 shows this point graphically. The first bar represents the adult's requirement of calcium per day—an amount nearly fulfilled by one pint of milk; the second bar represents the contribution made by the calcium present in the quantities of fruits and vegetables proposed. The second bar is one-fifth the length of the first. This means that only one-fifth of the day's calcium requirement is met by the fruits and vegetables if these are eaten in the amounts stipulated. It is clear that, if they are to be depended upon as the sole source of calcium, it would be necessary to consume five times the suggested quantity in order to meet the calcium requirement. In other words, it would require five oranges, five apples, five servings of peas, and five cups of cabbage to furnish the amount of calcium needed each day. Aside from the practical difficulty of consuming such quantities of these foods, there is the more pertinent question of cost.

To obtain the calcium needed for the day, in milk, may cost 6 cents; to obtain the same amount of calcium in the form of oranges, apples, peas, and cabbage, the cost would be, at the lowest, 45 cents. But the reader may point out that it is not the primary function of fruits and vegetables to furnish calcium. It is true that these foods

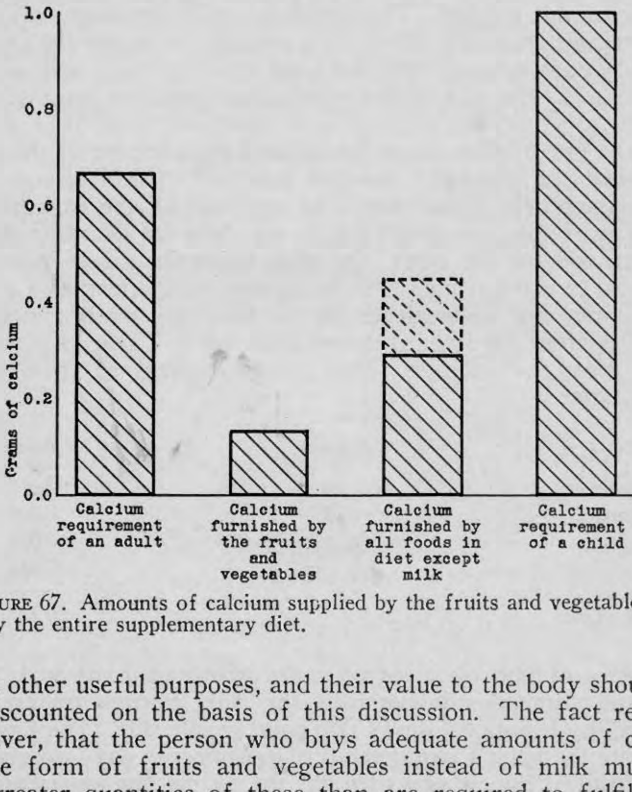

FIGURE 67. Amounts of calcium supplied by the fruits and vegetables listed and by the entire supplementary diet.

serve other useful purposes, and their value to the body should not be discounted on the basis of this discussion. The fact remains, however, that the person who buys adequate amounts of calcium in the form of fruits and vegetables instead of milk must eat far greater quantities of these than are required to fulfill their other functions in the body. Obviously such a procedure would not be defensible if economy were the main consideration.

Although it is evidently impractical to maintain the calcium intake at a proper level by depending alone on fruit and vegetables, one may still feel that the other foods in the diet, exclusive of milk, fruits and vegetables, may meet this requirement. That this is not the case may be shown by referring once more to the supplementary food list. The calcium content of the foods in this list is fairly representative, but the quantities recommended are those to be used in supplementing the daily quart of milk in the diet of a child. The energy value is approximately 1800 calories whereas an adult at a sedentary occupation requires approximately 2800 calories. It is necessary therefore to increase the suggested quantities by approximately 50 per cent. Table 6 gives the calcium content of the items of food in the supplementary food list. The total calcium that can be derived from this diet is about 0.3 grams. If this is increased by 50 per cent in order to make up the amount of energy necessary for the adult the intake of calcium would be 0.45 grams. It is clear, therefore, that this diet is markedly deficient in calcium. The substitution of cheese for a part of the protein would, however, do much toward correcting this deficiency since cheese contains relatively more calcium than any of the other foods mentioned.

TABLE 6. THE CALCIUM SUPPLIED BY THE ITEMS OF THE SUPPLEMENTARY DIET SHOWN IN TABLE 5

Foods	Calcium gm.
Prunes	0.018
Rolled oats	0.017
Egg	0.032
Meat	0.008
Bread stuffs (4 servings)	0.076
Potato (1 serving)	0.017
	0.168
Orange, apple, peas, cabbage	0.127
Total	0.295

The necessary quantities of these foods may be bought for from 18 to 25 cents. Again the economy of milk is evident. One pint supplies practically the whole of the adult's daily need of calcium for about 6 cents; the other foods in the diet supply from one-half to two-thirds of the quantity needed at more than three times the cost.

The fourth bar on Figure 67 represents the daily need of calcium for a child. It is placed here to emphasize the larger quantities of calcium required for growth and to show the necessity of adequate amounts of milk in the child's diet. Although a child's need for calcium is satisfied by one quart of milk, the equivalent in calcium is not only difficult to obtain in other foods, but is much more costly in comparison with the milk.

Milk in the Low-Cost Food Budget

In the making of food budgets, milk and its products have always been accorded a place. One widely used guide for the division of the food fund is the "one-fifth" plan first suggested by Gillett (22). This plan recommends spending one-fifth of the food budget for milk and cheese, and approximately one-fifth for each of the other four main groups of food stuffs. It should be noted particularly that this division is suggested for a family living at a fairly comfortable level of expenditure for foods. The extent to which Gillett regards milk as an economical food is revealed by her recommendations when the food fund is reduced below the comfort level. She has found from experience that, when there is less money to spend, it is necessary to use nearer one-third of the food money for milk and cheese in order to provide adequately for the

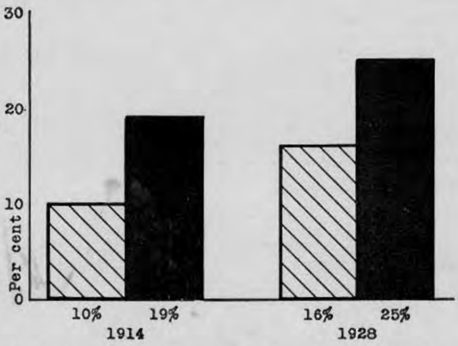

FIGURE 68. The proportion of certain family food budgets expended for milk and cheese. The black bars represent "influenced" diets. Gillett and Rice (22).

needs of the family. As the total amount of money spent for food is decreased care must be exercised to see that the quantity of milk used is not lessened.

In direct line with the above suggestions regarding the distribution of the food fund are the specific recommendations made by Sherman (23) as to the purchase of foods when the diet must be reduced to its cheapest level. He says, in brief: "The diet should be built around bread and milk. The lower the level of expenditure, the more one must forego other foods and concentrate effort upon providing these two, supplemented by a little of some inexpensive fruit or vegetable." He follows this with the statement, "Milk builds bone and muscle better than any other food and, more than this, milk is both the cheapest and surest protection from nutritional deficiencies . . . ."

Gillett and Rice (22) have recently shown, by a study of the budgets of city families, that those families which spent a larger proportion of their food fund for milk and cheese actually bought their total food supply more economically. The study involved a detailed investigation of the diets of city families on low incomes. One hundred of the families were "uninfluenced" in the buying of their food; an additional twenty families were "influenced" by investigators who gave specific instructions in food values. The findings of the study made in 1928 were compared with the findings of a similar study made on approximately the same number of families and under similar conditions, in 1914.

It is interesting to see the extent to which the investigators were successful in influencing families in the distribution of their food money with respect to the purchase of milk. Figure 68 shows the percentage of the food fund actually spent for milk and cheese by the four groups of families studied. It is evident that there was a definite although small increase in the proportion spent for milk and cheese from 1914 to 1928. This was probably the result of the general dissemination of knowledge of food values over a period of years among the "uninfluenced" group. The pronounced and significant difference between the "uninfluenced" group and those under the tutelage of trained advisors of both years, 1914 and 1928, is striking. The 1928 study was prompted by the desire to obtain information to guide in making revision, if such were necessary, of the suggestions on food expenditure for low-income families. Whether or not such change in the distribution of the food budget (as is indicated in the case of milk in Figure 68) is significant, rests entirely upon the effect on the cost and quality of the family diets. Is there, for instance, an advantage in so shifting the distribution of the food fund that more money is spent for milk? And, if so, is this advantage so pronounced that low-income groups ought to be urged to adopt this plan for their own food expenditure? The findings of the study appear sufficiently conclusive to answer the questions in the affirmative. The survey of family dietaries showed that, as the distribution of the food fund approached that recommended, it was possible to purchase diets of higher food value at less cost.

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