UNIVERSITY OF MINNESOTA.

Agricultural Experiment Station.

BULLETIN No. 74.

CHEMICAL DIVISION.

APRIL, 1902.

HUMAN FOOD INVESTIGATIONS.

THE DIGESTIBILITY AND FOOD VALUE OF BEANS, CHEESE, BUTTER, OATMEAL, GRAHAM, ENTIRE WHEAT, AND PATENT GRADE FLOURS, AND BREAD AND TOAST.

INFLUENCE OF THE ENZYEES OR CHEMICAL FERMENTS OF MILK UPON THE DIGESTIBILITY OF FOODS.

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EAGLE PRINTING CO., PRINTERS, DELANO

UNIVERSITY OF MINNESOTA.

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HUMAN FOOD INVESTIGATIONS.

HARRY SNYDER.

Outline of Bulletin. This bulletin gives the results of a number of digestion experiments with men to determine the nutritive value of beans, butter, cheese, milk, potatoes, toast, eggs, oatmeal, and bread made from the different kinds of flour, as graham, entire wheat and patent roller process flour. The foods were combined in different rations and in various ways, and were fed to working men. The general plan of the experiments is somewhat similar to feeding experiments with animals except that men and human foods are used in place of farm animals and fodders.

The value of the foods used in these experiments was determined by feeding to the men a weighed quantity of food, the composition of which had been determined by chemical analysis, and then weighing and analyzing the solid and liquid waste products given off by the body from the foods consumed in order to determine the amount of food which had been digested and utilized. In obtaining the value of the foods it was the aim to determine the kind and amount of nutrients present and the extent to which they are digested and made available to the body. The kinds and amounts of the nutrients were determined by chemical analysis, and their availability was determined by digestion experiments. While all of the methods of chemical analysis have not as yet been perfected, it is believed that results of sufficient practical value have been secured to warrant the undertaking of this study of human foods.

Some of these experiments were begun early in 1899, and many portions of the work have been under investigation since that time. In preparing the manuscript for publication it has been the aim to consider principally the facts which are of most importance and which have a direct bearing upon the economic value of the foods studied; technical terms have been avoided as much as possible. A brief explanation of the terms used in the bulletin, and the application of chemical methods to the study of foods are discussed before the separate foods are considered.

In planning the investigation it was the aim to concentrate the work as much as possible and let the separate experiments have a direct bearing upon some special topic. In the part of the work published in this bulletin are discussed: the dairy products, butter, cheese, and milk, and incidentally the comparative digestibility of butter and oleomargarine; the comparative nutritive value of graham, entire wheat, and standard patent roller process flour milled from the same lot of wheat; the digestibility of toast and bread; and also oatmeal and beans, as types of cereal and leguminous foods.

In studying the values of the various foods, the effects of different methods of cooking and preparation upon digestibility have been considered, as well as the influence of combinations of foods upon digestibility. These subjects have not, owing to their magnitude, been studied as exhaustively as could be desired. A brief summary of results is given at the end of some of the topics.

Tables containing details of the work are given in an appendix, printed as a separate part and not included in the bulletin proper. It is believed that by eliminating all of the numerous tables the bulletin is made more readable to the layman.

EXPLANATION OF TERMS USED IN BULLETIN.

Water Content of Foods. Water is present in all food materials, and in many cases makes up a very large portion of the weight of a substance. In vegetables, in milk, and in juices of meat, water is present to such an extent as to be perceptible to the senses. Substances like flour, meal, and starch, which appear perfectly dry, are not free from water, but contain from 9 to 12 per cent. This hydroscopic water, as it is called, is held mechanically by the particles of which the material is composed, and the amount of water thus held depends upon the extent of the previous drying of the material and the hydroscopic condition of the air. Inasmuch as air always contains some water, it necessarily follows that all substances exposed to the air must likewise contain some water.

In order to remove the last traces of water from a substance, the material is dried in either a water or a hot air oven at a temperature of 212 degrees F., the boiling point of water, so as to convert all of the water in the material into steam, which is then expelled. A water oven, shown in Fig. 80 has double walls, the space between the walls being partially filled with water, which is kept boiling by means of a gas burner which is placed below the oven. The food or substance before drying is weighed in a suitable dish and then dried in the water oven until the weight is reasonably constant, the loss of weight in drying being considered as water.

The determination of water in foods, although apparently simple, is a difficult and troublesome chemical process because many foods, when heated to 212 degrees, suffer changes and give off volatile organic compounds along with the water, or the organic matter may undergo a change in composition, as oxidation. For determining the absolute moisture content of foods, the chemist employs a drying bath of a different pattern from that shown in Fig. 80, and the material is dried in a current of some neutral gas, as hydrogen, to prevent oxidation of the substance. All of the dishes in which the substances are placed, during the analysis, are dried and cooled in dessicators out of contact with air, so as to remove all traces of hydroscopic moisture. The weighings are all made on analytical balances or on scales of extreme accuracy. (See Fig.81). The accurate determination of water is one of the most difficult parts of food analysis.

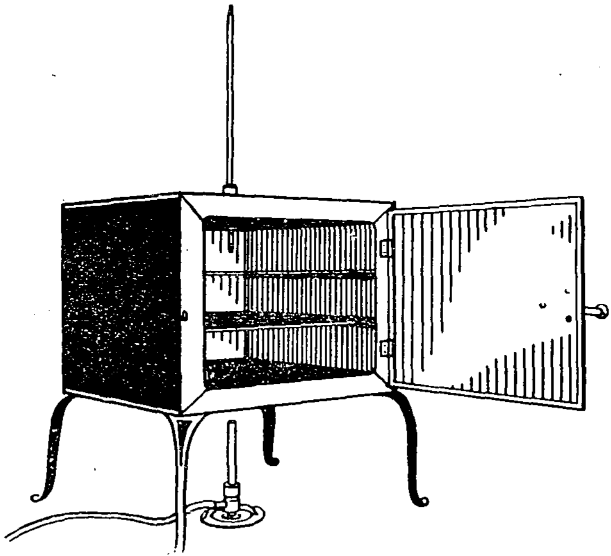


Fig. 80. Water Oven.

[Apparatus for determining the water content of foods; made with double walls, the space between being filled with water kept at the boiling point. The weighed food is dried in the water oven at the temperature of boiling water.]

Dry Matter of Foods. The dry matter of a food is the portion which is left after all the water has been removed. The dry matter, as the term implies, is the dry material free from all traces of hydroscopic moisture. The amount of dry matter is determined by subtracting the per cent of water from 100. If flour, for example, contains 12 per cent water, there will be 88 per cent of dry matter. The amounts of dry matter in foods range between wide limits as 7 per cent and less in some fruits to 99 per cent in sugar.

Ash. The ash of a food is that portion which remains after the substance is burned at the lowest temperature necessary for complete combustion. The ash is sometimes

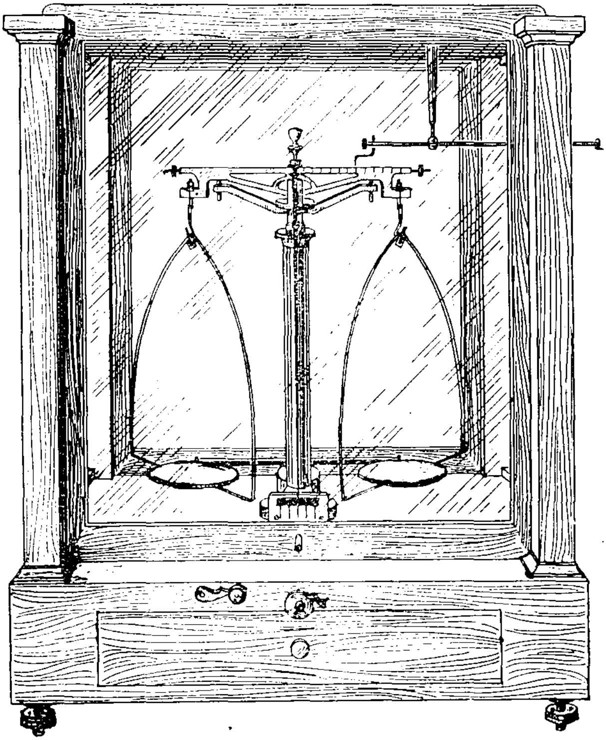


Fig 81. Analytical balance used for making accurate weighings.

spoken of as the mineral or inorganic part, and also as the non-volatile part. The ash of a vegetable food represents all of the materials, with the exception of water and nitrogen, which the plant took from the soil during growth. The term ash as used in the chemistry of foods differs from the term as ordinarily used in that the chemical ash is *pure ash*, free from unburned particles of carbon, and contains all of the ash elements as sodium, chlorine, sulfur, and phosphorus, traces of which are volatile at a high temperature. Crude ash is obtained by burning a substance at a low temperature in a muffle furnace until all of the carbon is oxidized. (Fig. 82)

The amount and composition of the ash varies with the character of the food; in the ash from some of the vegetables, alkaline salts predominate while in that from other foods, calcium and magnesium compounds are found more abundantly.

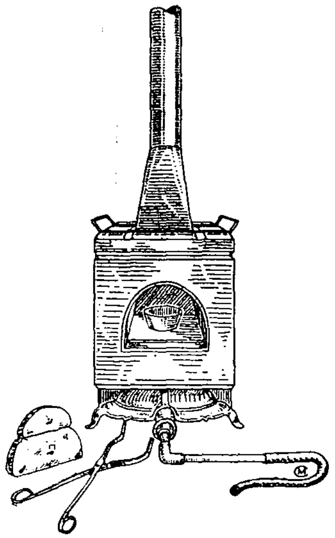
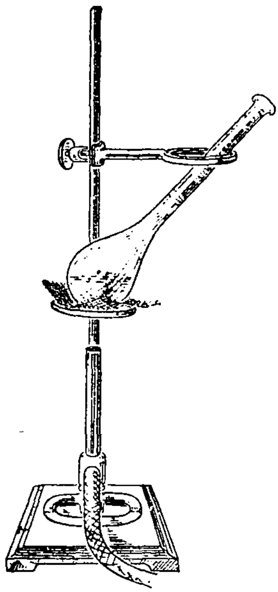


Fig 82. Muffle Furnace used for obtaining the ash of foods The material is burned at a low temperature.

Organic Matter. The organic matter is that portion of a food that is capable of being burned and converted into volatile or gaseous products; it is the combustible part of the food, and is simply a mechanical mixture of the various organic compounds as starch, sugar, fat, etc. of which foods are composed. The term organic compounds was originally applied to those bodies which it was believed could be produced only as the result of life processes, but it is no longer used in that sense because many of the organic compounds are now produced in the laboratory by synthetic methods, independent of life processes. The organic matter of foods is obtained by subtracting the ash from the dry matter. The dry matter of wheat, for example, contains 2.10 per cent ash and 97.90 per cent of organic matter. The organic matter of foods includes a number of classes or types of compounds.

Non-nitrogenous and Nitrogenous Organic Compounds. For purposes of study of foods the organic compounds are divided into two large classes: (1) non-nitrogenous, and (2) nitrogenous organic compounds. This division is made on the presence or absence of the element nitrogen. The nitrogenous or nitrogen containing compounds are those which contain the element nitrogen in combination with carbon, hydrogen, oxygen, and small amounts of other elements; while the non-nitrogenous compounds are those which contain no nitrogen but are composed of carbon, hydrogen and oxygen. Starch, sugar and fats are types of non-nitrogenous compounds, while albumin, casein and fibrin are types of nitrogenous compounds.

Crude Protein. This term is applied to the nitrogenous compounds of foods, taken collectively, as a group. The word crude is used to distinguish this group because, closely associated with the true proteids, it contains various nitrogenous bodies not proteids. Pure protein is a simple chemical compound while crude protein consists of a group of compounds of which pure protein is one. The albumin of eggs and milk and the gluten of grains are types of pure protein. In many foods, as potatoes, roots, and fruits less than half of the crude protein is pure protein. Crude protein, from different sources, is unlike in character, composition, and to a certain extent even in food value. Less is known of the composition and food value of crude protein than of any other class of nutrients in foods. A great deal of confusion has been caused by the indiscriminate use of several terms as albuminoids, total nitrogenous compounds, flesh formers, proteids, etc., to designate this class of bodies.



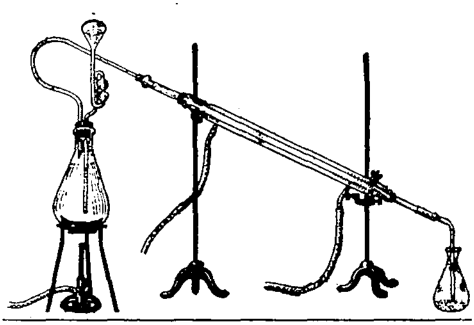


Fig 84. Distillation Appartus.

(Figs. 83 and 84, apparatus used for determining total nitrogen and crude protein content of foods. The nitrogen is obtained by digestion with sulphuric acid, as ammonium sulphate, fig. 83, and the ammonia is then liberated, distilled and obtained, Fig. 84.)

Fig. 83. Digestion Apparatus.

The *crude* proteids contain nitrogen in combination with carbon, hydrogen, oxygen, sulfur, and occasionally with small amounts of other elements as phosphorus. The *true* proteids all have about the same general percentage composition; the carbon ranges from 51.2 to 54.7 per cent, hydrogen from 6.7 to 76, oxygen from 20.2 to 25.5, sulfur from .5 to 2.0 and nitrogen from 15.2 to 18. The proteids contain, on the average, about 16 per cent nitrogen or there is about 1 part of nitrogen to every 6.25 parts of protein (100÷16=6.25).

In the analysis of foods, the chemist first determines the per cent of total organic nitrogen and then multiplies this amount by 6.25 to represent the equivalent amount of *crude* protein. The nitrogen can be determined with accuracy, in fact the method for the determination of the nitrogen in foods is one of the most accurate processes in chemistry. In brief, the method consists in first digesting a small weighed quantity of the food in a flask with sulfuric acid, to oxidize the organic matter and convert the nitrogen into ammonium sulfate. See Fig. 83. The nitrogen in the form of ammonium sulfate is then liberated as free ammonia, distilled and its amount determined. See Fig. 84.

Ether Extract. The term ether extract is applied to that class of compounds which is soluble in ether. In the case of human foods, the ether extract consists largely of fats and oils with variable amounts of waxes, resins, chlorophyll, vegetable coloring matters and nitrogenous and phosphorized bodies as lecithin. The value of the ether extract depends entirely upon its source; in milk, meats, and cereals and their products in general the ether extract is nearly pure fat, while in many vegetables it is less than half fat. The methods of chemical analyses have not, as yet, been sufficiently perfected to allow the separation and determination of the pure fat of all foods. The ether extract is obtained by placing a small weighed quantity of the dry material in tube 3 (Fig.85). The tube containing the dry food is then placed inside of a glass extractor, which is connected with a small weighed flask, containing ether. The flask is immersed in a water bath heated by a gas burner, the ether is voltatilized, and the vapor passes through openings 2 and 4 and into the condenser where it is cooled and falls back in drops from point 4 onto the food at 5. The ether percolates through the food and returns to the flask. The fats and ether soluble matters are not volatilized but remain in the flask while the ether is vaporized and condensed again and again. After the extraction is completed the ether is distilled from the flask and the ether extract is dried and weighed and the percentage amount calculated. While the process for the determination of ether extract appears to be simple, it is a difficult operation to control, because even after many days' extraction some foods will continue to give up ether extract, and unless unusual care is taken some of the fats are oxidized, and then too the ether extract is liable to be contaminated with impurities if ether of a high degree of purity is not used. When the ether extract determinations are made under uniform conditions the results are comparable and are of value when properly interpreted.

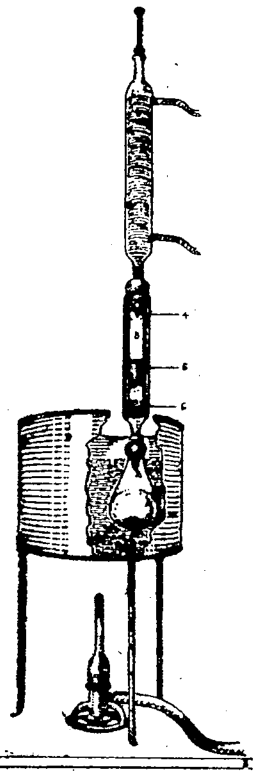


Fig. 85. Apparatus for determining the ether extract or crude fat content of foods.

Crude Fiber. The crude fiber of foods includes the cellulose and lignin bodies which make up the frame work of vegetable substances. In human foods, as flour and cereal products in general, the amount of crude fiber is small compared with that in animal foods. Crude fiber and cellulose are not identical terms. Crude fiber includes cellulose which is a term applied to a group of chemical compounds of which pure cotton is an example. There are a number of different kinds of cellulose; hydro-cellulose, found in young and growing plants, and ligno-cellulose, found in mature plants, which are distinct types of these bodies. In the analysis of foods, the crude fiber is determined by first digesting the material in dilute sulfuric acid to dissolve all soluble bodies as sugar, hydrolized starch, some of the proteids and related bodies. After treatment with the acid the substance is digested with dilute sodium hydroxid to remove all compounds which have failed to dissolve in the acid. Crude fiber and the insoluble mineral matter are about the only substances which are insoluble in the dilute acid and alkali, and hence the fiber is obtained by dissolving all other compounds and then deducting the insoluble mineral matter present. For the determination of cellulose more exact methods have been devised. The crude fiber determination, however, is valuable because it shows the amount of acid and alkali insoluble materials contained in foods.

Nitrogen-free-extract Compounds. In the processes of analysis the chemist determines the water, ash, crude protein, ether extract, and crude fiber. In wheat, for example, there is 9.25 per cent water, 4.95 ash, 13.25 crude protein, 2.20 ether extract and 2.25 crude fiber or 28.90 per cent of all of these compounds taken collectively. The remaining 71.10 per cent is called *nitrogen-free-extract.* The term nitrogen-free-extract means that the bodies contain *no* nitrogen, that is, they are nitrogen-free or non-nitrogenous, and soluble in dilute acids and alkalies. In wheat, the nitrogen-free-extract is composed mainly of starch, in some foods, as in carrots, it is composed largely of sugar. In human foods, the nitrogen-free-extract compounds are mainly carbohydrates as starch and sugar, while in animal foods they consist of a large number of compounds dissimilar in character and food value. In all vegetable foods, the nitrogen-free-extract constitutes the largest of any of the groups of compounds. Meats and animal food products, except milk, contain only very small amounts of nitrogen-free-extract.

Nutrients. Not all of the crude protein, ether extract, crude fiber, and nitrogen-free-extract of foods undergo digestion. The parts which are digested and utilized by the body are called the digestible nutrients. A digestible nutrient is any compound or group of compounds capable of being digested and utilized by the body for the production of heat and energy, or for the purposes of growth.

Uses of Nutrients by the Body. The different classes of nutrients in foods are used by human and animal bodies for, (1) the production of heat and energy, (2) the repair of the tissues of the body, and (3) growth and the production of new tissue and animal products. Only the protein nutrient is capable of performing all of these functions. The ether extract, and nitrogen-free-extract compounds, as fats starches and sugars can produce only heat and energy, they cannot produce new muscular tissue or supply the materials to repair worn out tissue. The protein compounds are the building materials out of which the greater portion of the muscles of the body are formed; they enter into the composition of the bones, tendons, ligaments, hair, skin, nails, nerve tissues, and all the vital fluids of the body. Important as protein is, it cannot be considered as the only nutrient that is of value in human or animal foods, neither is it possible to correctly estimate the value of a food on the basis of its protein content without regard to the other nutrients. In discussing the food value of protein, there is a tendency on the part of some writers to ascribe to it certain absurd life giving qualities nearly akin to the old alchemists' ideas of the "essence of life." An excessive amount of protein in either a human or an animal ration is equally objectionable as a scant amount. The best uses of the nutrients in foods are made when the protein, fats, and carbohydrates are present in proportion to the needs of the body.

Application of Chemical Methods to the Study of Human Foods. While the division of the nutrients of foods into ether extract, crude protein, nitrogen-free-extract and crude fiber is by no means perfect, it is the best classification which has, as yet, been made. The methods employed in the chemical analysis of foods have not reached as high a degree of perfection as could be desired. They are, however, more applicable to the study of human than to animal foods because in human foods, the nutrients all fall in the three groups: ether extract, crude protein and carbohydrates, to a much greater extent than in the case of animal foods which contain such large amounts of crude fiber, pentose compounds and other bodies. In most human foods, the ether extract is mainly fat, the carbohydrates starch or sugar, and the crude protein, protein. When the results of a food analysis are properly interpreted, they are of value, and in the application of the results, the greatest reliance can be placed upon the total nitrogen and the caloric value because the methods employed for their determination are quite accurate. The determinations of dry matter and ash, as far as accuracy is concerned, stand next to the nitrogen and caloric value. The methods for the determination of nitrogen-free-extract, crude fiber and ether extract are not satisfactory, and, in the application of the results, no great stress should be laid upon these determinations, not because these nutrients are of no value in foods, but because the methods for their determination are not as accurate as could be desired.

When, however, the determinations which have reached the highest degree of accuracy as nitrogen, caloric value, ash and dry matter, are considered, a great deal of information in regard to the composition of foods is available. These determinations give, with a high degree of accuracy, the amount of the total nutrients and the general character of the nutrients in foods, whether or not they are nitrogenous, and whether they have the power of producing a large or a small amount of heat when digested. Since the value of any food depends largely upon the two factors, (1) the amount of heat or energy which it is capable of producing, and (2) the amount of nutrients which are available for the building of muscular tissue in the body and repair of the waste tissue, it is possible, by the use of simply the caloric value and total nitrogen content of foods, to determine the general character and value of foods without depending upon the less accurate analytical methods, viz: those for the determination of crude fiber, ether extract and nitrogen-free-extract.

When properly used, the results of chemical analyses of foods are of value, but it is not possible to determine the absolute value of foods from their proximate composition only, because there are many other factors beside chemical composition which give value to foods. Two foods, for example, may have the same percentage amounts of nutrients, but the nutrients in each may have a different degree of digestibility, or one food may have a smaller percentage of nutrients with a higher degree of digestibility than another food. For example, when entire wheat flour and straight grade flour are milled from the same lot of wheat, the entire wheat flour has the larger per cent of protein, but the straight grade flour is more digestible than the entire wheat flour. Hence there is a larger amount of nutrients available to the body from the straight grade than from the entire wheat flour. Furthermore the way in which food is combined and used with other foods in a ration, as in the case of milk reported in this bulletin, influences the digestibility of the nutrients. The amount of food consumed, and its method of preparation are also factors which affect digestibility. Then, too, there is a difference in the digestive capacity of different individuals; some persons are capable of digesting their food more completely than others. For example, in the digestion experiments with beans, one subject digested 14 per cent more of the protein nutrient than another. In fact, no two individuals have been found in the experimental work who were capable of digesting any one or all of the nutrients of foods alike.

The factors which influence the digestibility and nutritive value of foods are: (1) mechanical condition of the food, (2) its combination with other foods, (3) amounts consumed, and (4) the way in which the food is cooked and prepared for use. Since all of these factors may affect the digestibility and nutritive value of foods, and since different individuals do not all have the same power to digest and utilize the nutrients of foods to the same extent, it is evident that chemical investigations relating to the digestibility and nutritive value of foods must necessarily consider all of these conditions in order to be of the highest value. This involves a large amount of chemical work, and is probably the reason why only comparatively little is known of the nutritive value of human foods. The subject, however, is of sufficient importance to warrant scientific investigation, and it is believed that results of practical value can be secured from the study of human foods.

BEANS.

Nature of the Work. This investigation was undertaken to determine the nutritive value of beans as human food. Their digestibility when fed to working men, the influence upon digestibility when beans were combined with different foods in a ration and the influence of fat upon their digestibility form parts of this work. Experiments were also made to determine the effect of the removal of bean skins upon their digestibility, the amount of nutrients in bean skins and in the drain water from par-boiled beans, and the effect of the use of soda in the cooking of beans. Notes are also given upon the cost of nutrients in beans and their use in the dietary.

Digestibility of Beans. Three digestion experiments were made to determine the digestibility and nutritive value of beans. The common white or navy beans were used. Before baking, the beans were placed in boiling wàter and boiled vigorously for twenty minutes to loosen the skins which were then readily removed by rubbing the beans against each other in cold water. A small amount of soda dissolved in the boiling water aided in loosening the skins. Salt and butter were used in the baking. From each pot of baked beans, a sample was taken for analysis. The beans were fed with a bread and milk ration, the digestibility of the bread and milk having been determined in former experiments. In addition to the three digestion experiments with beans and bread and milk, beans were used in other digestion experiments with a larger number of foods so that their digestibility was determined also in mixed rations. In the experiments with bread and milk and beans, a large proportion of the total nutrients was supplied by the beans. The results obtained in these experiments are summarized in the following table:

TABLE No. 13. Digestibility of Beans.

	Dry Matter per cent Digested	Crude Protein per cent Digested	Fat per cent Digested	Carbohydrates per cent Digested
Man 1.	91.36	86.81	81.35	95.95
Man 3.	91.19	72.26	85.72	95.88
Man 2.	90.19	81.58	72.41	96.75
Average	90.91	80.22	79.82	96.19

From the table it will be observed that, as the average of the three experiments, 90.92 per cent of the total dry matter of the bean was digested. The carbohydrates were found to be more completely digested than the other nutrients; in fact, the results show that 96.19 per cent of the carbohydrate compounds of the beans were digested. The digestibility of the protein nutrient ranged between wider limits (72.26 to 86.81 per cent) than of any other nutrient. The results of these experiments on the digestibility of beans correspond, in general, with those obtained by Rubner and others, namely: that the carbohydrates of beans are more completely digested than the protein and that the digestibility of the protein may vary with different individuals between quite wide limits.

In the digestion experiments in which other foods were combined with beans, particularly butter and oleomargarine, also potatoes, eggs and milk, the digestibility of the protein and other nutrients was found to be greater than when the diet was restricted to only three food articles. In the digestion experiments where butter and oleomargarine were used (pages 137—141) the food consisted, in one series of experiments, of bread, skim milk, beans and butter, and in the other, of bread, skim milk, beans and oleomargarine. In all of these experiments the protein was from the same food materials: bread, milk and beans, but, when butter or other fat was present, a different per cent of the protein nutrient was digested than in the ration with bread, milk and beans alone. The average digestibility of the protein, when butter or oleomargarine formed a part of the ration, is given in the following table:

TABLE No. 14. Digestibility of Protein of Rations Consisting of Bread, Milk, Beans, Butter and Oleomargarine.

	Protein Digested per cent
Man 1, Beans, bread, milk and oleomargarine ration	88.40
Man 2, Beans, bread, milk and oleomargarine ration	91.69
Man 3, Beans, bread, milk and oleomargarine ration	84.12
Average	88.07
Man 1, Beans, bread, milk and butter ration	....
Man 2, Beans, bread, milk and butter ration	92.71
Man 3, Beans, bread, milk and butter ration	86.61
Average	89.66
Man 1, Beans, bread and milk ration	89.58
Man 2, Beans, bread and milk ration	87.59
Man 3, Beans, bread and milk ration	87.74

When butter or other fat, as oleomargarine was present in the ration the co-efficient of digestibility of the protein nutrient was increased in the case of man No. 2, 4.60 per cent over the ration which contained no butter, but in the case of man No. 3, the butter caused a decrease of 1.10pr. ct. in the digestibility of the protein. Likewise in the ration consisting of bread, milk, beans, eggs and potatoes, reported in another part of the bulletin, the beans were more digestible than in the experiments with three or four food articles. The results of the digestion experiments show that when used as a part of a ration and combined with other foods, particularly butter and milk, beans have a higher co-efficient of digestibility than when the ration is restricted to three food articles only.

There appears to be a great difference in the ability of different individuals to digest beans. In the experiments performed, there was a difference of 14 per cent in the completeness of digestibility of the protein nutrient. One of the men, on the bread and milk and beans ration, digested 86 per cent, while another man, fed on the same foods digested only 72 per cent of the protein nutrient.

Beans are generally considered indigestible. The results of these experiments show that they are not indigestible when we consider the completeness of the digestion process. There is, however, a difference in the digestive capacity of individuals to digest beans, but when properly combined with other foods they cannot be considered indigestible. Beans are, however, slow of digestion and require more intestinal work than many other foods, but, when properly combined so that they form a portion of a ration, the work of digestion is more evenly distributed than when they are used alone and in large amounts. In using beans in the dietary, they are frequently eaten in excessive quantities at irregular intervals, rather than in reasonable amounts combined with other foods as a regular part of the ration.

Composition of Beans. Beans are a food characteristically rich in protein. The beans used in these experiments, contained 23.75 per cent protein. Beans do not contain a large amount of fat; there is less fatty or ether extract material than in any of the grains or cereal products. The beans used in these experiments contained only 1.71 per cent of fat. After baking, the dry matter contained 6.46 per cent fat due to the butter that was used in preparing them for the table. Because of the small amount of fat in beans, a larger amount is required in their cooking than in the case of any similiar food product.

The proteid material in beans is different in character from that of cereals and meats. In most of the grains and cereal products, the larger portion of the proteid is in the form of glutens, commonly called insoluble proteids. In the bean the protein is mainly in the form of legumin, a globulin proteid with different characteristics and properties from the glutens. A part of the legumin of beans is in chemical combination with some of the organic acids and mineral compounds. The fact that the proteid material in beans is different from that in cereals and their products is undoubtedly one of the reasons why the protein of beans has a different degree of digestibility from the protein of many other foods. The best conditions for digesting the protein of beans are secured in a mixed diet rather than when the food is restricted to only two or three articles.

Use of Soda in the Preparation of Beans. In the preparation of beans for the table, soda is frequently employed for softening the skins so that they can be readily removed. In these experiments about three grams (one half teaspoonful) of cooking soda dissolved in two quarts of water were used for a pound of beans. The larger portion of the water was absorbed during the boiling process. Of the water used on the pound of beans only about one third was drained off. Since only a portion of the water employed was removed by draining, and the larger portion was absorbed by the beans, tests were made to determine the amount of soda which was retained by the beans. Of the original soda employed, only sixteen per cent was recovered in the drain water, 84 per cent remaining in chemical combination with the beans. The legumin, or proteid material of beans is capable of combining with either acids or alkaline compounds, forming acid or alkali proteids. The use of carbonate of soda in the boiling process resulted in changing the chemical character of of the protein of the beans. This was found to have a favorable effect upon the digestibility and food value of the beans as it enabled the protein to be more readily acted upon by the digestive fluids. It is a matter of common observation that when beans are properly prepared with a small amount of soda and salt, there is less difficulty from the formation of gas in the intestines during digestion. Flatulence or the formation of gas during digestion is discussed in Farmers'

Bulletin No. 121 of the U. S. Department of Agriculture, from which the following extract is taken: "This effect (flatulence) is not confined to people of delicate digestion, although it is to them more distressing, nor does it seem to have any thing to do with the extent to which the nutrients of the food are used in the system. Experiments with animals indicate that the formation of methan gas is entirely due to bacterial action in the intestines." The removal of the skins from beans by the aid of a small amount of soda will, to a great extent, prevent flatulence and the formation of gas in the intestines during digestion.

Nitrogen in Drain Water from Beans. When the skins of beans are removed by treatment with hot water and soda, a small amount of proteid material is dissolved and lost in the drain water. From a pound of beans (453 grams) 0.246 grams of nitrogen were dissolved by the soda and removed in the drain water. The beans used contained 16.45 grams of nitrogen, hence a loss of .246 grams in the drain water is equivalent to abont two thirds of one per cent only of the total nitrogen. On the basis of the nitrogen as the measure of the proteid content of beans, it would appear that 99.33 per cent of the total proteid matter remained in the beans and about 0.67 per cent was lost in the drain water. The amount of protein lost in drain water from beans parboiled with soda to remove the skins, is too small to be of any economic importance.

Nutrients in Bean Skins. The amount of nutrients removed in the bean skins was determined. One pound of beans yielded about 1.1 ounces of dry skins which showed the following composition upon analysis:

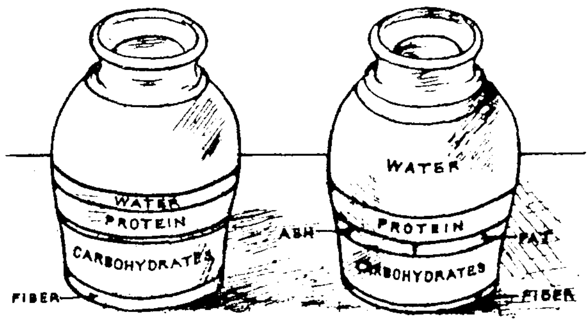
	Per cent.
Ash	6.73
Crude Protein	10,67
Ether Extract	2.10
Crude Fiber	39.55
Nitrogen Free Extract	40.95
	100.00

While the skins contain an appreciable amount or nutrients, this is only a small part of the total nutrients of the beans. In the case of the protein, for example, the original beans contained 106.4 grams of protein while the skins contained 3.19 grams which is about three per cent of the total. The total loss of protein in both drain water and skins was 3.66 per cent.

The skins contain a large amount of crude fiber, 39.55 per cent, which is over one third of the total amount in the beans. This fiber lessens the digestibility of the beans, by preventing the solvent action of the digestive fluids. The treatment with soda and the removal of the skins changed the chemical and physical composition of the beans so that they were more completely and readily digested.

With the removal of the skins, a part of the germ or embryo is also removed. In the analysis of the bean skins reported, no attempt was made to separate the germ from the skins. They were taken as they would ordinarily be removed by the process described. The nutrients that are present in the bean germ are quite different from those in the main part of the bean. The nitrogenous material in the bean germ readily ferments and produces gaseous products, in fact, the most fermentable parts of the bean are the skin and germ. Experiments with the skins showed that sulfuretted products are among the gases formed from fermentation of the bean skin and germ. The presence of the skin and germ undoubtedly is one reason why beans frequently cause so much trouble during digestion by the formation of gas in the intestines, and hence their removal in cooking will, to a great extent, prevent flatulence. There is a difference as to the readiness with which different kinds of beans yield to the treatment of soda and hot water for the removal of the skins. The skins of some beans, particularly old ones, can be removed only with difficulty, while others even of the same variety readily yield to the parboiling treatment. In the case of old beans, longer boiling (a half hour) and more soda (one teaspoonful) were found necessary. A large amount of water is not necessary for the removal of the skins, but it is quite essential that the water should be boiling when the beans are added and that the boiling should be continued vigorously for about twenty minutes.

Comparative Composition of Raw and Baked Beans. Since, in the process of baking, a large amount of water is used, the skins are removed and salt and fat are added, raw and baked beans have a different percentage composition. While the raw beans contain about 12 per cent water, the baked beans may contain from 68 to 73 per cent water. The salt and small amount of soda used in the cooking of the beans increases the percentage amount of ash or mineral matter, while the fat that is added increases the percentage of that nutrient. The removal of the skins reduces the percentage of crude fiber and carbohydrates and, to a slight extent, of other nutrients. The relative composition of raw



A. Raw Beans. B. Cooked Beans.

Fig. No. 86. Comparative composition of raw and cooked beans, showing the influence of the removal of the skins upon the reduction of the fiber content and the effect of the addition of water, salt, and fat in cooking.

and baked beans can be observed in the illustration, Fig. No. 86. It will be seen that the raw beans do not quite fill half of crock A; but because of the additional amount of water that has been added the same amount of beans, when baked nearly fills crock B. The removal of the skins results in the loss of about 6.5 per cent of the total dry material of the original beans. This loss is largely crude fiber which is present to the extent of about 40 per cent in the skins. In raw beans the amount of fat is about 1.5 per cent while in the baked beans the amount may range from 2 to 7 per cent of the dry matter according to the amount that has been added. The dry matter removed in the skins is about equal in amount but inferior in value to the fat added in baking. The relative amounts of crude protein in the raw and baked beans are about the same, when the two are compared on the basis of the dry matter.

Digestible Nutrients in Beans. In the following table (No.15) the total and digestible nutrients in beans are given. The digestible nutrients are obtained by multiplying the per cent of each nutrient by its digestion coefficient as obtained in these digestion experiments. For example, the beans used contained 59.50 per cent of carbohydrates; the digestion experiments show that 96.19 per cent of the carbohydrates were digested, hence the beans contained 57.23 per cent digestible carbohydrates. (59.50 x .9619 - 57.23).

TABLE No. 15—Total and Digestible Nutrients in Beans.

	Total Nutrients.	Digestible Nutrients.
	Per Cent.	Per Cent.
Dry Matter	86.68	80.62
Crude Protein	23 75	19.05
Ether Extract	1.71	1.37
Carbohydrates	59.50	57.23

If a measure were filled with dry beans and all of the water, ash, protein, ether extract and carbohydrates were separated they would fill the parts of the measure as indicated in Fig. No. 87. The dark or shaded part represents the indigestible portions of the various nutrients.

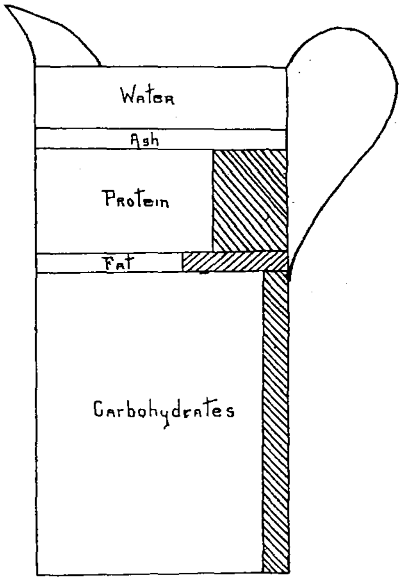


Fig. No. 87. The Composition of Beans.
[If a measure were filled with beans and all of the water, ash, protein, ether extract, and carbohydrates were separated they would fill the parts of the measure as indicated in the figure. The dark or shaded part represents the indigestible portion of the various nutrients.]

Influence of the removal of the Skins of Beans Upon Their Digestibility. In order to determine the influence which the skins of beans exert upon their digestibility, three lots of beans were prepared in the following way: one lot of 300 grams was parboiled with water and soda, then treated with cold water and rubbed to remove the skins and finally baked. Lot No. 2 was parboiled and the same amount of soda was added but the skins were not removed. Lot No. 3 was placed directly into the oven without parboiling or removing the skins and no soda was used. The beans were all baked in the same way for about 18 hours, and the same amounts of salt and butter were used in all alike. A sample of each lot of beans together with a sample ot dried bean skins were subjected to artificial digestion with pepsin, diastase and pancreatin solutions. A weighed quantity of the beans was placed in a flask and digested in an acid pepsin solution at a temperature of 98.5 degrees F. for four hours; this was followed by a second digestion with a diastase solution, prepared from malted barley, to remove the starch so that the alkaline pancreatin solution would have a better opportunity to act upon the protein. The amount of protein which tailed to dissolve by joint action ot the acid pepsin and alkaline pancreatin solutions was determined in each of of the four samples. The results are given in the following table:

TABLE No. 16—Digestibility of Beans in Pepsin-Pancreatin Solutions.

	Beans Used.	Dry matter	Nitro gen	insol'le Nitro-gen	soluble Nitro-gen
	grams	grams	grams	grams	per c't.
Lot 1. Beans skins removed by parboiling and use of soda	12.2	4.50	.87	.108	42.25
Lot 2. Beans with skins, parboiled and soda used	10.0	3.87	.161	.117	27.33
Lot 3. Beans baked without parboiling and no soda used.	10.0	4.33	.104	.100	3.85

While the results obtained by digestion with pepsin, pancreatin and diastase solutions are not comparable with those obtained by the natural digestion process, they represent with a fair degree of accuracy the ease with which beans prepared in the different ways undergo digestion. Ordinarily it takes twenty-four hours for food to pass through the digestive tract. In the artificial digestion experiments the ferment solutions acted upon the beans for about twelve hours. In the natural digestion process 80.22 per cent of the total protein was digested, while in the artificial digestion trials 42.25 per cent was rendered soluble.

The artificial digestion experiments showed that when the skins of the beans were removed nearly 25 per cent more protein was digested than when the skins were present. When the beans were not parboiled only a very small amount of protein was dissolved (3.85 per cent). The results show that the removal of the bean skins renders the protein more soluble in acid pepsin and alkaline pancreatin solutions. These are the same solvents present in the digestive tract.

Cost of Nutrients in Beans. The value of any food depends not only upon its composition and digestibility but also upon its market value or cost. The price of beans has usually ranged from three to six cents per pound. A pound of beans contains about four fifths of a pound of digestible dry matter which is approximately one fourth digestible protein and three fifths digestible carbohydrates. At five cents per pound about a fifth of a pound of protein and somewhat less than three fifths of a pound of digestible carbohydrates can be procured. In the case of wheat flour, cornmeal and oatmeal, a larger amount of digestible carbohydrates can be secured, but, in all of these foods, there is less digestible protein. There is no other vegetable food which will supply digestible protein in such large amounts at such a low cost as beans. There is nearly a fourth of a pound more protein in beans than in beef. Beans, peas and other legumes are the only vegetable foods which contain as much or more protein than beef, fish or meats in general. In many European countries, beans are used quite extensively to take the place, in a ration, of beef and other meats.

Character of Nutrients in Beans. In the common navy beans, about 50 per cent of the nutrients are carbohydrates, the main portion of the carbohydrates being in the form of starch. Bean starch granules, compared with those of cereals, are quite large, and when examined under the microscope resemble, to a slight extent, coffee berries, while some resemble lumps of dough moulded for rolls. Fig. No. 88 is a micro-photograph of the bean starch granules taken by Mr. Hummel, assistant chemist. The bean starch granules are from three to five times larger than the starch granules of the cereals as wheat, barley and corn. Bean starch has distinct form and markings which enable it to be readily detected from other starch. The amount of crude fiber in beans ranges between quite wide limits, the average bean containing about 7 per cent, the larger portion of which is present in the skins.

The ether extract of beans consists only in part of pure fat; according to Stellwagg, it is less than 60 per cent pure fat. A portion of the ether extract is in the form of lecithin, a compound containing both nitrogen and phosphorus. The amount of lecithin in the beans used in these experiments was determined by extracting the material with ether and then with alcohol, and determining the posphoric acid content of the ether soluble portion; as the result of this determination .32 per cent lecithin was obtained. The nitrogen content of the ether extract was also determined and found

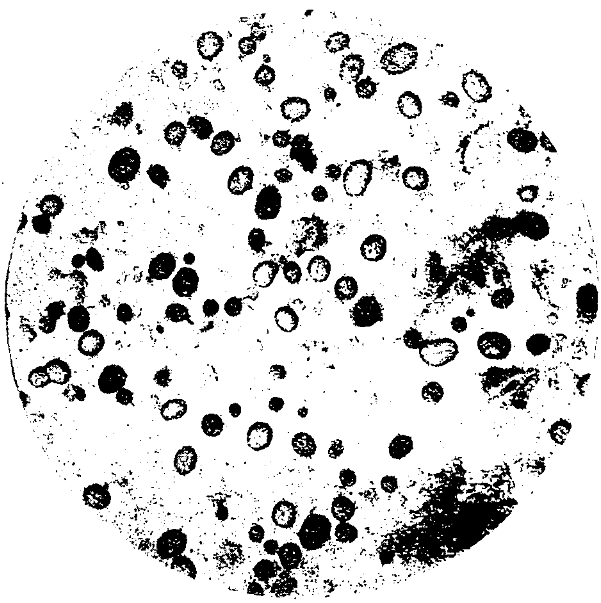


Fig. No. 88. Micro-photograph of Bean Starch. x125.

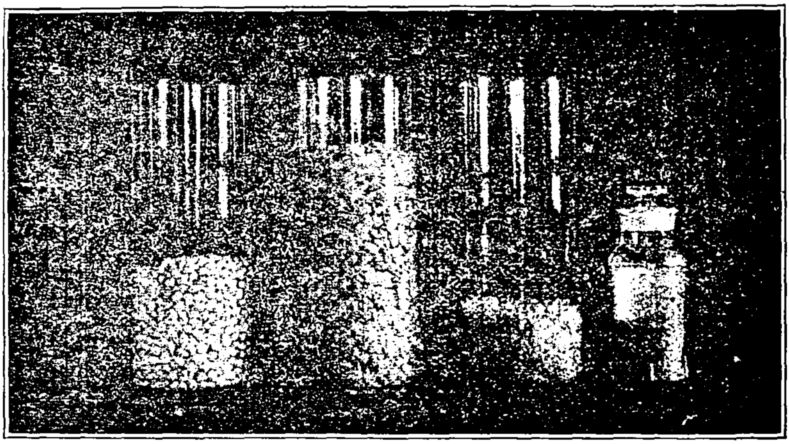
to be .05 per cent. If all oi this nitrogen were present as lecithin, there would be .69 per cent but there are other compounds besides lecithin containing nitrogen in the ether extract of beans. Since beans contain but little ether extract, compared with cereals and other foods, and about one third is in the form of lecithin, and an additional amount of the ether extract is present in the form of free fatty acids, it is evident that the actual amount of pure fat in beans is very small. The caloric value of the bean ether extract was determined by combustion in the bomb calorimeter, described in the article on butter. The results obtained were 9.42 and 9.39 calories per gram of ether extract. Since fats yield from 9.2 to 9.5 calories per gram, it would appear that while the ether extract of beans may contain an appreciable amount of lecithin and free fatty acids, the caloric value or heat producing power is practically the same as for pure fatty materials.

The small amount of fat in beans and the relatively large amount of proteid material necessitate the use of fat in the preparation of beans as food. As previously stated, the fat which is added in the baking has a tendency to render the protein and other nutrients more digestible and available.

The ash or mineral matter in beans is characteristically different from that of the cereals In cereals, the ash consists largely of phosphoric acid, potash and magnesia, while in bean ash there is somewhat less phosphoric acid and more potash and alkaline matter. Since beans contain so much protein there is a larger amount of sulfur in the ash than in the case of the cereals, this is because sulfur is one of the elements contained in protein.

In beans, the nutrients, as a whole, are somewhat different in character from the same class of nutrients in cereals; the protein compounds are largely in the form of legumin instead of glutens; the ether extract contains lecithin and free fatty acids; the nitrogen free extract consists largely of bean starch which is characteristically different and forms larger granules from that found in the cereals, while the ash is richer in potash and alkaline compounds and sulfur. It is evident when beans form a portion of the diet that a different class and character of nutrients are supplied to the body than when only cereal products are used.

Amount of Beans in a Ration. In these digestion experiments, the men consumed about 500 grams or 1.1 pounds of baked beans daily. This is equivalent to about 7 ounces of raw beans. These experiments indicate that in an ordinary ration with four or five other food articles, not more than 4 ounces per day of uncooked beans or 6 ounces of baked beans should be consumed. Four ounces or a quarter of a pound of uncooked beans will furnish about .05 of a pound of digestible protein and .15 of a pound digestible carbohydrates. An average ration should contain from .20 to .30 of a pound, per day, of digestible protein and .7 of a pound to one pound carbohydrates depending upon the nature and amount of work performed. Hence a quarter of a pound of beans would furnish about one fifth of the total protein of the ration. Beans are valuable not only for the digestible



A B C D

Fig. No. 89. Showing influence of parboiling and removal of skins from beans, A, raw beans; B, beans after parboiling, skins removed, showing increase in volume due to water absorbed; C, moist bean skins removed from A; D, the dry bean skins.

protein which they contain, but also for the starch and carbohydrates which are more digestible than the protein compounds.

Notes on the Uses of Beans in the Dietary. The way in which beans are prepared as food has a great influence upon their digestibility and the ease with which they undergo the digestive processes. In these experiments, 80.22 per cent of the protein and 96.2 per cent of the total carbohydrates were digested. If, however, the bean skins had not been removed this high degree of digestibility of proteids and carbohydrates could not have been secured. Beans contain a high per cent of crude fiber, a large portion of which was removed in the skins. Digestion experiments have shown that the crude fiber of the vegetable foods has a low degree of digestibility. The high degree of digestibility secured in these experiments was due to the absence of the skins which carried nearly 40 per cent of crude fiber. Many vegetable foods contain so much cellulose or crude fiber as to reduce their food value because the nutrients are enclosed within the cellular tissues which renders them more indigestible because they are not so readily acted upon by the digestive fluids.

While beans are a valuable food, there are certain limits between which they can be used to advantage in the dietary. As previously stated, the nutrients in beans are different in character from the same class of nutrients in cereals and other vegetable foods; and are not as readily digested as those of many of the cereals. Hence beans are suitable for persons engaged in active outdoor work rather than for those of sedentary habits of life. Beans, when properly cooked, should not, however, be entirely excluded from the dietary of those of sedentary habits, but they cannot form such a large part of the ration as in the case of the active working man leading an outdoor life.

SUMMARY.

(1) Beans were found to be more digestible when combined in a ration with milk, butter and other foods, and the highest degree of digestibility was secured in a mixed ration.

(2) The carbohydrate nutrients of beans were found to be more digestible than any of the other nutrients. The protein was the most variable in digestibility; its range of digestibility varying between 72.26 and 86.81 per cent.

(3) When soda was used in the preparation of the beans it was found that 84 per cent of the soda remained in chemical combination with the proteid material, and 16 per cent was removed in the drain water. Less than .66 of one per cent of the total nitrogen of beans was lost in the water used in parboiling, while 99.33 per cent of the total protein remained in the beans.

(4) When the skins of beans were removed by parboiling in water containing a little soda about 6.5 per cent of

the total dry matter of the beans was removed in the skins. The skins contained a large amount of crude fiber and a relatively small amount of protein, about three per cent of the total protein in the beans was removed in the skins.

(5) When the skins of beans were removed there was less tendency for the formation of gas in the intestines during digestion. A small amount of germ adhered to and was removed with the skins; the germ and skin are the parts of the bean which are the most fermentable and produce sulfuretted gaseous products during digestion.

(6) Beans contain a large amount of protein and a small amount of fat. Hence, in their preparation as human food, fat is necessary in order to make a more balanced food.

(7) When the skins of the beans were removed, the beans were more readily acted upon by digestive solvents as pepsin, diastase, and pancreatin. In twelve hours, twenty-five per cent more of the protein nutrient was digested when the skins of the beans were removed than when the beans were baked in a similar way without the removal of the skins.

(8) At ordinary prices, beans are one of the cheapest foods for supplying protein in rations. A pound of beans costing five cents contained about a fifth of a pound of digestible protein and somewhat less than three fifths of a pound of digestible carbohydrates, mainly in the form of starch.

(9) The nutrients in beans are different in character from the same class of nutrients in cereal foods. The protein in beans is mainly in the form of legumin, while that in the cereals is in the form of glutens. Bean starch granules are larger in size and differ in microscopic structure from the cereal starch granules. Beans contain only a small amount of ether extract, a portion of which is in the form of lecithin and free fatty acids. The ether extract from beans, however, has about the same caloric or heat producing power as the ether extract from other foods.

(10) In these experiments, over a pound of baked beans was consumed per day by men engaged, part of the time, in active outdoor work. It is believed, however, that not more than four ounces of uncooked beans or six ounces of baked

beans should be consumed in the daily ration. While beans are slow of digestion, they cannot be considered as indigestible when the availability or total amount of nutrients actually utilized by the body is considered. In these experiments, over 90 per cent of the dry matter in the beans was digested and utilized by the body.

THE DIGESTIBILITY OF BUTTER AND OLEOMARGARINE.

Nature of the Work. Four digestion experiments with men were made to determine the comparative digestibility of butter and oleomargarine. In two of the experiments the ration consisted of beans, skim milk, oleomargarine and bread, similar to that used in the digestion experiment with beans. The experiments lasted two days and were then followed by similar experiments in which butter was substituted for oleomargarine. In the making of the bread and the baking of the beans, a known amount of oleomargarine was used in the first two experiments and a known amount of butter in the second two. The rations were alike in every respect except that during the two days of the first experiments oleomargarine was used in place of butter in the second experiments. The main source of the fat in the rations was butter or oleomargarine. The amount of fat in the skim milk used was small and the amount of fat supplied to the ration from the bread, other than that used in its making, was small. The object of these experiments was to determine the amount of energy actually available to the body from butter and from oleomargarine.

Caloric Value of Foods. Since the methods of chemical analysis do not allow as accurate determination of the amount of fat in foods as could be desired, it was deemed advisable in these experiments to base the comparisons between butter and oleomargarine entirely upon the energy actually available to the body. This energy is determined and measured by the calorimeter, and is expressed in terms of calories or heat units. The determination of the caloric or heat producing value of foods is one of the most accurate determiations in chemestry. A Berthelot calorimeter, modified by Atwater and Woods was used in these experiments. The complete apparatus is shown in Fig. No. 90. It consists of a steel bomb that is placed in a metal cylinder (Q) Fig. 91. (This illustration, No. 91, is from Conn. Storrs, Annual Report for 1897.) The bomb is surrounded by water as indicated in the illustration, and the cylinder containing the bomb and water, is placed within a double walled fiber receptacle, (T and U).

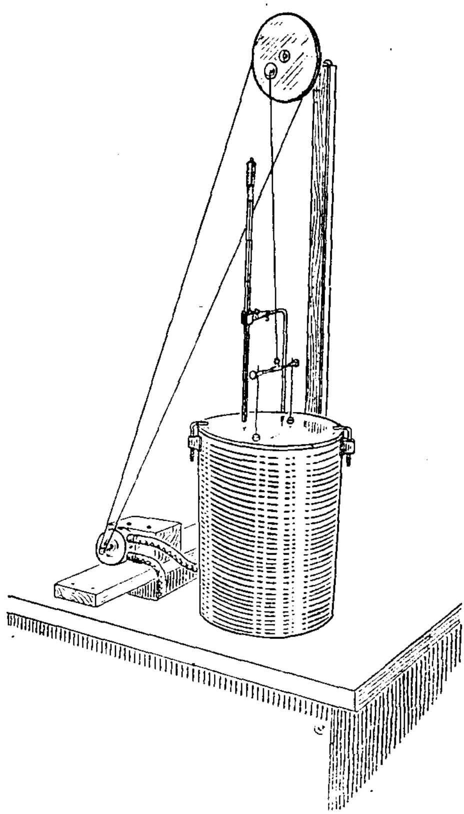


Fig. No. 90. The Bomb Calorimeter used for determining the caloric or heat producing value of foods.

The bomb itself consists of three parts; the cylinder which is lined with platinum, the cover, and a collar to hold the cover in place and tightly seal the bomb. These three parts of the apparatus are shown in Fig. 92.

The principle involved in determining the caloric value of a food is simple. A weighed quantity of the substance is burned in the calorimeter and the rise in temperature of the water that surrounds the calorimeter is noted. The combustion is carried on in an atmosphere of oxygen so as to be complete and all means possible are employed to secure accuracy of the results. The substance to be burned, if it is a material like flour, is made into a pellet by means of a press which exerts a power of about 10,000 pounds per square inch. (See Figure 94.) The object of making the material into the pellet is so that it will form a compact mass and burn evenly and not be scattered about in the calorimeter cylinder and be only partially burned. The pellet is placed in the small platinum cruci-

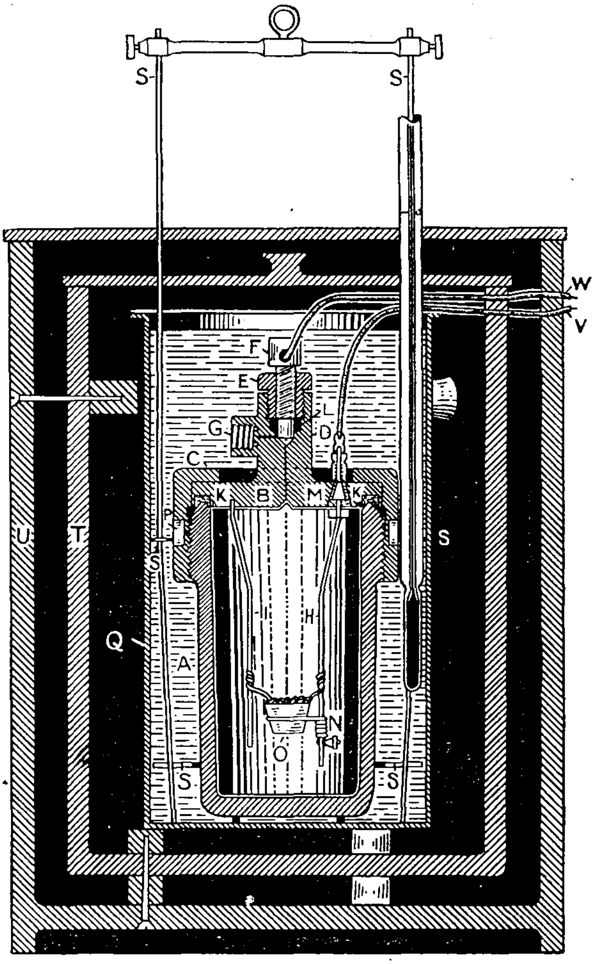
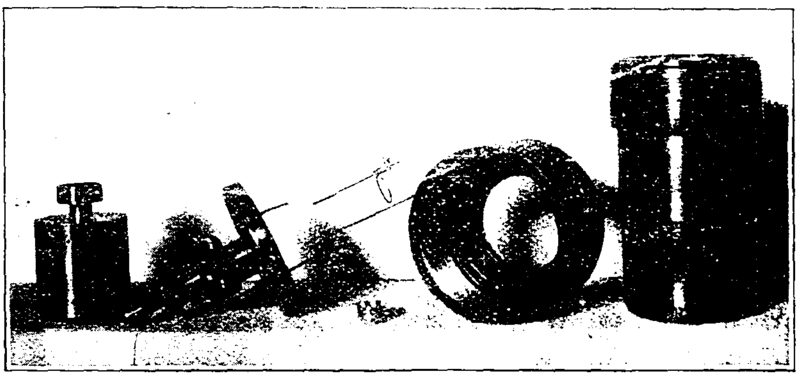


Fig. No. 91. The Bomb Calorimeter, showing interior structure and working of parts. [From Conn. (Stores) Ex. Station annual report 1897]. For description of the workings of calorimeter see page 140.

ble (O). Fig. 91. This crucible is supported by platinum wires attached to the cover of the calorimeter. Above the crucible a small coil of fine iron wire is stretched from the platinum wires. The cover is then screwed tightly upon the cylinder of the bomb and oxygen is admitted from an oxygen tank under pressure through valve (G) of the cover until a pressure of twenty atmospheres is secured, when the valve is securely closed. The bomb with the substance to be burned and charged with oxygen is placed in the metal cylinder (Q) containing a definite quantity of water, the temperature of which is carefully determined by means of a thermometer that reads to .005 of a degree C. The water is kept at an even temperature by means of the metal stirrer (S S) operated by a water motar. A connection is made with a storage battery which ignites the small iron wire that is suspended above the substance. The burning wire falls upon and ignites the material in the platinum crucible (O). The heat



A B C D E

Fig. No. 92. Part of Bomb Calorimeter and accessories. A, pellet mould. B, Cover to bomb. B, Platinum dish holding substance burned. D, Collar. E, Steel bomb—platinum lined.

from the combustion of the material raises the temperature of the water in the calorimeter cylinder. A number of readings are taken so as to secure the actual rise in temperature, caused by the combustion of the substance. Due allowances are made for the heat contributed by the combustion of the iron wire, the heat absorbed by the steel bomb and also for other factors that are known and under control. The heat that is produced is expressed in terms of calories. A calory is the amount of heat required to raise the temperature of a kilogram of water one degree C. or a pound of water nearly four degrees on the Fahrenheit scale.

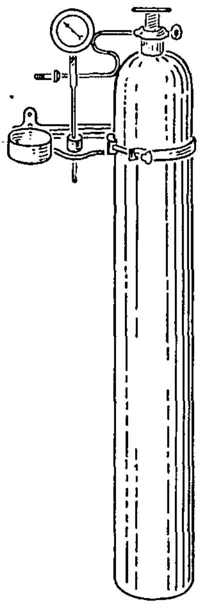


Fig. No. 93. Ogygen tank used in charging calorimeter bomb.

Object of Determining the Caloric Value of Foods.—One of the functions of the nutrients of foods is to produce heat within the body. The object of a calorimeter determination is to ascertain the amount of heat which a food or a nutrient is capable of producing. Since a portion of the food fails to undergo complete digestion, the total amount of heat that is produced by the combustion of a food in the calorimeter does not represent the amount of heat secured by the body from the digestion of the food; but when also the amount of heat produced by the undigested portion or feces is determined as well as the amount of heat that is present in the organic compounds as urea of the urine, the amount that is actually available for the use of the body is capable of being determined with a high degree of accuracy. In these experiments, the total amount of heat units in the separate foods consumed was determined and also the amount in the indigestible parts of the foods. The difference between the total amount of calories in the food and that which is indigestible, including the organic compounds of the urine, gives the amount available to the body.

Since the chemical methods for the determination of fat do not admit of as high a degree of accuracy as could be desired, it is not possible, by ordinary crude fat determinations, to obtain absolutely the digestibility of butter or oleomargarine, but since the calorimeter is capable of determining accurately the number of calories a substance yields it is thus possible to ascertain the completeness of the combustion or oxidation of food within the body. In these experiments the amount of fat or ether extract was determined in the ordinary way, but in the discussion of the results, the availability of the energy as obtained by the calorimeter, is taken as the standard for comparison.

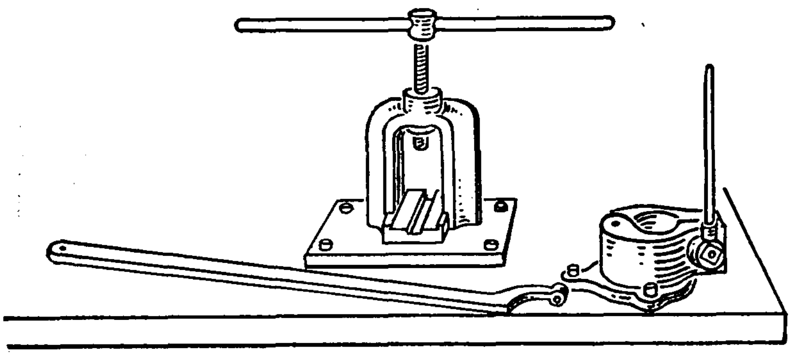


Fig. No. 94. Press used for making the pellet for combustion.

Comparative Composition and Digestibility of Butter and Oleomargarine.—The experiments were performed under conditions similar to those with bread, milk and beans. The same men were employed but Man No. 1, because of sickness, did not complete the second half of the experiment, that in which butter was used. The oleomargarine was of good quality and was obtained in the open market. The butter was made at the Experiment Station and was high grade June butter. The men were not restricted as to the quantity of either butter or oleomargarine consumed, but a record was kept of the amount eaten at each meal and also of the total amount for the period of the experiment. An average of four ounces per day of butter, and three ounces per day of oleomargarine was consumed.

TABLE No. 17.—Composition of Butter and Oleomargarine.

	Butter Per Cent.	Oleomargarine Per Cent.
Water	13.21	11.05
Fat	83.14	85.91
Crude Protein	.48	1.67
Ash	3.17	1.37

While butter and oleomargarine have a somewhat similar general composition, the character of the fats in the two is materially different. As is well known, butter contains the characteristic fat, butterine, which is not present in oleomargarine; the amounts of stearine and olein fats in the two are also different. The oleomargarine used contained but little volatile fatty acids. Oleomargarine is made chiefly from beef fat, tallow, cottonseed oil, etc., which are put through a refining process, churned with sweet milk, colored and made to resemble butter in appearance.

At the time of the experiment only one of the men was aware that oleomargarine was used in the ration. They knew that oleomargarine was to be used during the experiment but were not informed as to the time. One of the men commented upon the quality of the oleomargarine by saying that it was a "real good quality of butter." The results of the digestion experiments are given in the following tables:

TABLE No. 18.—Digestibility of Ration With Butter.

	Protein Per Cent	Fat Per Cent	Carbohydrates Per Cent	Available Calories
Man 2	92.71	96.46	97.00	91.80
Man 3	86.61	94.63	96.94	92.33
Average	89.66	95.54	96.97	92.06

Proportion of energy actually available to body in butter.

	Calories.
Man 2	98.79
Man 3	98.21
Average	98.50

TABLE No. 19.—Digestibility of Ration With Oleomargarine.

	Protein Per Cent	Fat Per Cent	Carbohydrates Per Cent	Available Calories
Man 2	91.69	94.61	97.01	90.71
Man 3	84.12	93.79	97.02	91.89
Average	87.90	94.20	97.01	91.30

Proportion of energy actually available to body in oleomargarine.

	Calories.
Man 2	97.54
Man 3	97.21
Average	97.37

Discussion of Results.— From the tables it will be observed that in the ration with butter, the crude fat was 95.54 per cent digestible and 92.06 per cent of the total caloric value of the ration was available to the body. In previous experiments, it was found that 88.8 per cent of the energy measured as calories in the bread, milk and beans was digested and available to the body. In the same ration in which oleomargarine took the place of butter, crude fat was 94.2 per cent digestible and 91.3 per cent of the total calories were available to the body. When the availability of the energy from the butter alone was calculated, an average of 98.5 per cent was found available and of the oleomargarine 97.37 per cent. While the difference in digestibility is not large, it is in favor of the butter to the extent of 1.13 per cent.

In these digestion experiments it appeared that not only was the energy from the butter more available to the body but also the protein was more available to the extent of 1.76 per cent in the ration that contained butter instead of oleomargarine.

Similar digestion experiments with butter and oleomargarine were made by Mayer at Wageningen in Holland, in which the ration consisted of bread, peas, potatoes, condensed milk, egg albumin, sugar and cheese. Mayer's results show that 98.7 per cent of the butter was digested and when oleomargarine was substituted for butter 96.7 per cent of the oleomargarine was digested. The butter was found to be two per cent more digestible than oleomargarine (Bul. No. 21. U. S. Dept. Agri. Office of Experiment Stations.) While the difference in the digestibility between butter and oleomargarine is not large, it is in favor of the butter. Mayer concluded that the butter of the ration was entirely digested, that the small amount of indigestible ether extract consisted of biliary coloring matters and impurities, and that the butter fat itself was all assimilated.

Food Value of Butter.—These experiments show that butter has a high degree of digestibility. Of the total energy or fuel value of the butter consumed, 98.5 per cent was available to the body, and only one and a half per cent failed to undergo digestion or oxidation. The part which failed to undergo digestion probably consisted largely of casein and non fatty materials; the butter used in these experiments contained 3.65 per cent of ash and casein. The pure butter fat itself has undoubtedly even a higher degree of digestibility than butter containing 4 or 5 per cent of non fatty solids. When butter is used as human food practically all of the butter fat is available to the body for the production of heat and energy.

Oleomargarine and Butter.—It is often difficult without resorting to chemical tests to distinguish oleomargarine from butter. When sold as butter and at the same price as it frequently is, it is a dishonest competitor for it is then purchased by persons who prefer to use pure butter; and they are denied the privilege of purchasing what they desire. Oleomargarine, is not as digestible as butter. The fact that it cannot be readily distinguished from butter emphasizes the importance of some distinguishing feature to prevent its being sold as butter.

CHEESE.

Nature of the Work.—Three digestion experiments were undertaken to determine the digestibility and nutritive value of cheese. The ration consisted of cheese, and bread and milk. For the purpose of this investigation a large amount of cheese was consumed, three fourths of a pound per day, which resulted unsatisfactorily in two of the experiments, as the ration proved to be very constipating in character. The digestibility of bread and milk had been determined in a former experiment with the same subject.

Composition of Cheese.—The best quality of Minnesota cheese, of good taste and flavor and well cured, was used. The analysis showed that the cheese had been made from a good quality of milk containing from four to four and a half per cent of fat.

TABLE No. 20.—Composition of Cheese.

	Per cent
Water	34.38
Fat	36.85
Carbohydrates	1.71
Protein	23.68
Ash	3.38

Compared with other foods, cheese is characteristically rich in both fat and protein. Ordinary cheese is composed of about a third each of water and fat, and about a fourth of its weight is crude protein in the form of casein. The mineral matter, milk, sugar, acids and other compounds present in small amounts make up the balance of the composition. The percentage amounts of protein and fat in cheese vary with the amount of water left in the cheese and the composition of the milk used. A large amount of water in the cheese decreases the amounts of both fat and protein, and a cheese made from poor milk contains proportionally less fat than one made from milk containing from four to

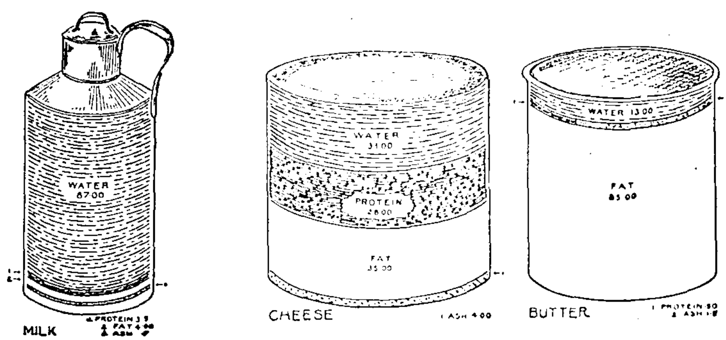


Fig. No. 95. The Relative Composition of Milk, Cheese and Butter.

five per cent of fat. When properly made from a good quality of milk, cheese is fairly constant in composition.

Digestibility of Cheese.—Since only one digestion experiment was satisfactorily completed a detailed discussion is not attempted. The digestibility of the entire ration and of the cheese alone are given in the following table:

TABLE No. 21.—Digestibility of Cheese and Bread and Milk Ration.

	Per cent digested	Prct. dig't of Cheese alone
Protein	92.69	93.36
Fat	94.55	94.5
Carbohydrates	96.55	
Available Energy	88.08	92.59

The table shows that as far as completeness of digestibility is concerned, the nutrients of cheese have a high degree of digestibility, the protein being 93.36 per cent and the fat 94.50 per cent digestible. Ordinarily cheese is considered indigestible, but it is not indigestible in the sense of lack of completeness of the digestion processes. It is slow of digestion and has a tendency to cause constipation if used in excessive amounts or if not properly combined with other foods. Experiments have shown that when cheese is used to the extent of one to three ounces per day, it does not unfavorably affect the digestion, but, if anything, it favorably influences the process of digestion. Koenig has shown that when cheese is consumed in small amounts with other foods it is valuable not only because of the nutrients present but because it tends to make the foods with which it is combined more digestible. He found that when cheese was added to a ration consisting of maize (corn) meal, the digestibility of the protein was increased from 58 to 93 per cent.

Digestibility of Cheese in Pepsin and Pancreatin Solutions.—Experiments were made to determine the digestibility of cheese in both pepsin and pancreatin solutions. Three samples of cheese were selected for this purpose, namely: the best quality of Minnesota, Wisconsin and New York cheese that could be obtained in the market.[1] The cheese samples were found to have the following composition upon analysis:

	Water Per cent	Protein Per cent	Fat in Dry Matter Per cent
Minnesota	28.66	23.56	47.84
Wisconsin	32.18	21.98	47.40
New York	30.37	24.61	45.40

The methods for determining the digestibility of a food in pepsin and pancreatin solutions are described on page 130 of this bulletin. In brief the process consists in placing a weighed quantity of food, in a fine state of division, in contact with acid pepsin solution at a temperature of 98.6° F. for a given length of time. The pepsin solution is of about the same strength as that present in the stomach. The object is to determine the amount of protein peptonized, and the amount left in insoluble forms. After treatment with acid pepsin solution, the portion of the food that fails to

NOTE—1 These samples were selected and secured by Mr. W. W. P. McConnell, State Dairy and Food Commissioner of Minnesota.

dissolve is treated with an alkaline pancreatin solution of about the same strength as that found in the pancreas and intestines.

When the samples of cheese were subjected to the pepsin and pancreatin digestion processes it was found that from 47.4 to 52.9 per cent of the total protein, namely, casein was digested and rendered soluble by the action of the peptic ferments, and that from 44 to 49.2 per cent of the remaining protein was dissolved in the alkaline pancreatin solution. The results are given in the following tables:

TABLE No. 22—Digestibility of Cheese in Acid Pepsin Solution.

Kind of Cheese	Amount Ch'se used Grams	Protein in Cheese Per cent	Protein in indiges'ble Per cent	Protein in Digested Per cent
1. Minnesota	5.05	1.19	.56	52.9
2. Wisconsin	5.28	1.16	.61	47.4
3. New York	5.06	1.25	.60	52.0

TABLE No. 23.—Digestibility of Cheese in Alkaline Solution.

Kind of Cheese	Amount of Cheese Used Grams	Protein in Cheese Per cent	Protein indigest'le Per cent	Digested Per cent
1. Minnesota	5.10	1.20	.038	96.9
2. Wisconsin	5.04	1.11	.037	96.6
3. New York	5.03	1.24	.032	97.3

The digestibility of cheese by the natural and artificial methods give nearly identical results. Man No. 3 digested 96.55 per cent of the cheese proteids while 96.9 per cent was digested by the pepsin and pancreatin solutions. This is a closer agreement than has been found in any other of these experiments. In some of the trials, notably with beans, the differences between the results obtained by the two methods were large.

The digestion with pepsin and pancreatin solutions show that a large part of the work is carried on by the pancreatin solution. If the peptones present in the cheese were deducted it would be found that the larger part of the work of digestion takes place in the alkaline pancreatin solution. These artificial digestion trials emphasize the fact that the main portion of the work of digestion of cheese is carried on in the intestines rather than in the stomach. This is probably the reason why cheese is characterized as a "hearty food" and frequently causes digestion troubles when eaten. In such cases the amount of cheese consumed should be reduced to correspond with the digestive capacity of the individual. Cheese should be consumed in small amounts and by so doing the digestive powers of an individual can be strengthend and not impaired.

Cost of Nutrients in Cheese.—Cheese should be used in the dietary regularly and in reasonable amounts, rather than irregularly and then in large amounts as it frequently is. Cheese is not a luxury, but ordinarily it is one of the cheapest and most nutritious human foods that can be procured. A pound of cheese, costing fifteen cents, will contain nearly a quarter of a pound of protein and over a third of a pound of fat. For the same amount of money it is possible to secure a larger amount of digestible nutrients and available energy from cheese costing fifteen cents a pound than from meats costing ten cents per pound. In the use of cheese in the dietary, the same precautions should be observed as are exercised by successful feeders of animals, namely: to begin gradually and not to use a concentrated food in excessive amounts. The amount of cheese that can be used in a ration can be determined only by the individual.

THE DIGESTIBILITY AND FOOD VALUE OF OATMEAL.*

Nature of the Work.—Four digestion experiments were made to determine the digestibility and nutritive value of oatmeal. Rolled oats of good quality, obtained in bulk, were used in the digestion and cooking experiments. For the digestion experiments the oatmeal was prepared by cooking a weighed quantity of rolled oats for four hours in a double boiler. The influence of long and short periods of cooking upon the composition and solubility of the nutrients of oatmeal was also studied. The use of oatmeal in the dietary, and the cost of nutrients in oatmeal are considered,

* A part of this subject is reported in U. S. Dept. Agr., Office of Experiment Stations, Bul. No. 101, which gives full details of the digestibility of oatmeal.

Composition of Rolled Oats.—The oats used had the following composition.

	Per Cent
Water	5.97
Ash	1.87
Protein	18.13
Fat	7.30
Carbohydrates	66.73

As a food, rolled oats are characteristically rich in crude protein and fat; there are larger amounts of these two nutrients in rolled oats and oatmeal than are present in nearly any other cereal product. There are less carbohydrates in oatmeal than in average cereals, and of the carbohydrates about one per cent is crude fiber. The main portion of the carbohydrates of oatmeal is in the form of oat starch. See Fig. 96 for illustration of the characteristics of oat starch.

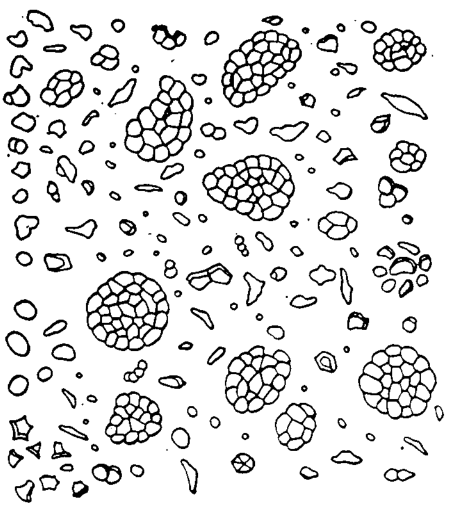


Fig. No. 96. Oat Starch Granules.

Digestibility of Oatmeal.—In two of the rations oatmeal and milk were used in large amounts; in fact an effort was made to consume as much of these foods as possible; in two other trials, oatmeal and milk were used in more moderate amounts. The object of these two series of tests was to determine the influence which large and small amounts of the same kind of foods would have upon the completeness of digestion. The men, while engaged in the experiment, were employed at average farm labor. The large ration gave some discomfort in its digestion but the more moderate ration was digested without any inconvenience, in fact, the subjects stated that they were better able to perform their work on the oatmeal and milk ration, and with a greater degree of comfort than when any other two articles of food were used. The subjects, however, were both strong, healthy young men. The following results were obtained:

TABLE No. 24.—Digestibility of Oatmeal.

	Per Cent of Nutrients Digested.			
Full Ration.	Protein Per cent	Ether Ex't Per cent	Carbohydrates Per cent	Available Energy Per cent
Man A	82.7	68.9	94.4	85.5
Man B	79.4	70.1	95.7	86.2
Moderate Ration.				
Man A	96.	91.7	97.2	92.3
Man B	94.6	94.3	95.6	91.4

Discussion of Results.—These results show that when oatmeal is used in reasonable amounts, the nutrients have a high degree of digestibility. When excessive amounts of food were consumed, a smaller percent of all of the nutrients was digested than when a moderate ration was used. As far as completeness of digestion is concerned, oatmeal appears to be a food that is quite completely digested. As in the case of experiments with other foods, particularly beans, a difference was observed in the extent to which the various nutrients were digested by different individuals. Man A digested a larger amount of the protein nutrient but a smaller amount of fat than man B. There was less difference in the completeness of digestion of the carbohydrates than of any other nutrient. The figures given for the digestibility of oatmeal represent the extreme conditions that would be met with. In the case of the moderate ration, undoubtedly the smaller amounts of food consumed and the favorable action of the large amounts of milk taken have increased the digestibility of the various nutrients, making the figures as high as would be obtained for the digestiblity of oatmeal under favorable conditions. On the other hand, the figures obtained for the digestibility of the full or excessive ration are probably lower than under normal conditions because of the unfavorable influence which the large amount of food has exerted upon the completeness of the digestion process. Even on the basis of the digestible nutrients obtained in the full ration, oatmeal has a high degree of digestibility, as 81 per cent of protein, 70 per cent of fat, and 95 per cent of the carbohydrates were completely digested.

The digestion experiments, as a whole, show that oatmeal, when properly cooked, is a food with a large amount of digestible nutrients but it does not have the high food value which is frequently claimed by the manufacturers.

Digestible Nutrients in Oatmeal.—Since oatmeal contains such relatively large amounts of protein and fat and these nutrients are quite completely digested, the total amounts of these nutrients available to the body are large. The total digestible nutrients are obtained by multiplying the percentage amounts by the amount digested. The rolled oats contained 18.13 per cent crude protein of which 81 per cent was digested; this is equivalent to 14.68 per cent of digestible crude protein. (18.13 x 81=14.68) That is, in every 100 pounds of rolled oats, as purchased, there are 18.13 pounds of the crude protein nutrient of which 14.68 pounds are digested and used by the body while 3.45 pounds are indigestible. Like calculations for the ether extract or crude fat show that there is 7.3 per cent of the nutrient present in the original food of which 5.1 pounds are digested, and 2.2 pounds are undigested. The rolled oats contained 66.73 per cent of carbohydrates, 95 per cent of which was digested and 5 per cent was indigested. Oats, when used as human food, supply a large amount of both total and available nutrients to the body. This high food value, however, was secured by thorough cooking of the oatmeal.

Cost of Nutrients in Oatmeal.—When oatmeal or rolled oats are purchased in bulk a large amount of nutrients can be procured for a small sum. At three cents per pound, ten cents will procure three and one half times more protein and two and two thirds more fat and nearly ten times the energy that can be procured for the same sum invested in round steak at twelve cents p r pound. Compared with meats oatmeal is a much cheaper food. Oatmeal contains nearly as much, pound for pound, of the protein nutrient as meats, and while it contains less fat, the difference is more than made up by the earbohydrates which are present to the extent of 65 per cent and more in oatmeal and are present only in slight traces in meats. A pound of rolled oats, costing three cents, will contain about two ounces of digestible protein, one half ounce of digestible fat, and about ten and a half ounces of digestible carbohydrates. In oatmeal there is about one part of digestible protein to every fifth and one tenth parts of non-nitrogenous material. This is a much larger proportional amount of protein than is found in ordinary cereals or cereal products.

Notes on the Use of Oatmeal in the Dietary.—Oatmeal is a food, like beans and cheese, slow of digestion and requiring much intestinal work for the digestion process. Therefore, like beans, it is not suitable in large amounts for an individual with weak digestion. As usually milled, rolled oats contain some crude fiber, (1.1 per cent) which makes it a food that encourages peristaltic action, and hence it is slightly laxative in character. Oatmeal requires thorough cooking, otherwise it is not easily digested; unless it is well prepared and thoroughly cooked it is not a suitable food for persons of sedentary habits; and if well prepared and thoroughly cooked is a much more suitable food for persons of all habits.

As frequently prepared by cooking for a few minutes only, it is difficult to digest because of the large amounts of glutinous material which surround the starch grains and prevent their disintegration, except by long and thorough cooking. When thoroughly cooked the protecting action of the mucelagenous proteid material is overcome, and the compound starch granules are sufficiently disintegrated to allow the digestive juices to act. The ease of digestion of oatmeal depends upon the completeness of the cooking process. This fact is particularly noticeable when the results of long and short periods of cooking are considered.

Influence of Long and Short Periods of Cooking Upon the Digestibility of the Nutrients of Oatmeal.—Experiments were made to determine the influence of long and short periods of cooking upon the digestibility of the nutrients of oatmeal. One lot of rolled oats was cooked for thirty minutes while another lot was cooked for four hours. The soluble carbohydrates, and the water, salt, and alcohol proteids of the original rolled oats, and of the two lots of cooked oats were determined. The results, on the basis of the dry matter, are given in the following table.

TABLE No. 25.—Influence of Cooking Upon the Solubility of the Nutrients of Oatmeal.

First trial.	Rolled Oats Per cent	Rolled Oats Cooked 30 min'tes Per cent	Rolled Oats Cooked 4 hours Per cent
Soluble Carbohydrates	1.35	1.89	2.01
Water Soluble Nitrogen		.44	,45
Salt " "	.26	.41	.32
Alcohol " "	.44	.34	.37
Second trial			
Soluble Carbohydrates	1.35	1.78	1.91
Water Soluble Nitrogen			.43
Salt " "	.26	.34	.32
Al'ohol " "	.44	.41	.37

No material change in total solubility of the carbohydrate and proteid nutrients was observed whether the rolled oats were cooked for one half or four hour periods. There was a slight increase in the soluble carbohydrates when the oats were cooked four hours, while the water, salt, and alcohol soluble nitrogen in the oatmeal cooked for one half and four hour periods are practically the same as in the original material. The cooking evidently has not materially changed the total solubility of the nutrients.

While the nutrients of the rolled oats have not suffered a measurable chemical change by the process of cooking the physical changes that have taken place have affected the composition of the material; while the starch has not been changed to soluble carbohydrates, it has undergone hydration and other changes so that chemical action can more readily take place.

The disintegration of the rolled oats, and the hydration of the starch and proteids by prolonged cooking, have resulted in making the material more readily digested. This fact was observed when a dilute solution of malt was allowed to act upon rolled oats cooked for one half hour and four hour periods. When the rolled oats cooked for one half hour were acted upon by a malt solution for ten minutes 6.11 per cent of starch was rendered soluble. When the same weight of rolled oats (dry matter basis) cooked for 4 hours was acted upon by the malt solution for 10 minutes, 20.36 per cent of the starch was dissolved. In the same length of time over 3.3 times more starch was rendered soluble by the action of malt upon the rolled oats cooked four hours, than upon those cooked only one half hour.

While the cooking of the rolled oats for four hours has not increased the percentage amounts of soluble carbohydrates and proteids, it has changed the material physically so that it is more susceptible to the action of solvents. That is, when rolled oats are cooked for four hours the carbohydrates are more readily converted into soluble forms by the action of the diastase ferment than when the rolled oats are cooked for only one half hour.

COMPARISON OF THE NUTRITIVE VALUES OF GRAHAM, ENTIRE WHEAT, AND STANDARD PATENT ROLLER-PROCESS FLOURS.*

Nature of the Work.—The food value of any material depends not only upon the amounts of nutrients which are present, as indicated by chemical analysis, but also upon the proportion of those nutrients which can be digested and and made available to the body. In order to determine and compare the actual nutritive values of graham, entire-wheat and standard patent roller-process flours, not only were complete analyses of these materials made and heats ofcombustion determined, but a series of digestion experiments with men were conducted, in which a considerable portion of the diet consisted of bread made of the different flours. It is to be observed that the "graham" flour is unbolted wheat meal, while the so-called "whole-wheat" or entire-wheat flour contains all of the kernel except a portion of the bran. The "patent," "straight" and clear grades of flour contain practically none of the bran or episperm and very little of of the germ or embryo of the wheat kernel.

* The complete report upon this subject with analysis, tabular statements of results and conclusions is given in bulletin No. 101, U. S. Dept. of Agriculture, office Experiment Stations, from which this summary of results is compiled. These digestion experiments were carried on under the supervision of the Office of Experiment Stations, U. S. Dept. of Agriculture, at the Chemical Laboratory of the College of Agriculture, University of Minnesota.

Flours all Milled From the Same Lot of Wheat.—While numerous analyses have been made of different kinds of flour, and the digestibility of bread has been studied by several investigators, the results, although valuable, were not sufficient for an accurate comparison of the nutritive values of different grades of flour in general because they were not all milled from the same lot of wheat and there was probably a considerable variation in the composition of the wheat from which the different flours were milled. Consequently in these investigations the different kinds of flour were all made from one lot of wheat. The protein in samples of flours purchased in the open market has been found to range from 7 to 14 per cent. In some cases the proportion of protein is higher and in other cases lower in standard patent than in entire-wheat or graham flours. That these differences in the protein content of different samples of flour are due to variations in the composition of the wheat from which the various flours were ground is indicated by the figures for analyses of wheat given in the report of Jenkins and Winton on the composition of American feeding stuffs. The average protein content of 310 samples of wheat is there given as 11.9 per cent, the range being from 8.1 to 16.6 per cent. While such extreme variations are found occasionally, a range from 11 to 15 per cent is not exceptional. If wheat with 15 per cent of protein were made into ordinary white flour and wheat with 11 per cent of protein were made into entire-wheat or graham flour, the white flour would contain appreciably more protein than the entire-wheat or graham, but if the wheat with 15 per cent of protein were made into entire-wheat or graham flour and that with 11 per cent into ordinary white flour the result would be the reverse.

It is evident from such facts as these that a fair comparison of the nutritive values of the different kinds of flour—graham, entire-wheat, and standard patent—can be made only when the three kinds of flour have been milled from the same lot of wheat. This was done in the investigations here reported, a hard, Scotch Fife spring wheat being used.

Careful milling of the wheat so as to secure representative samples of the three kinds of flour from the same lot

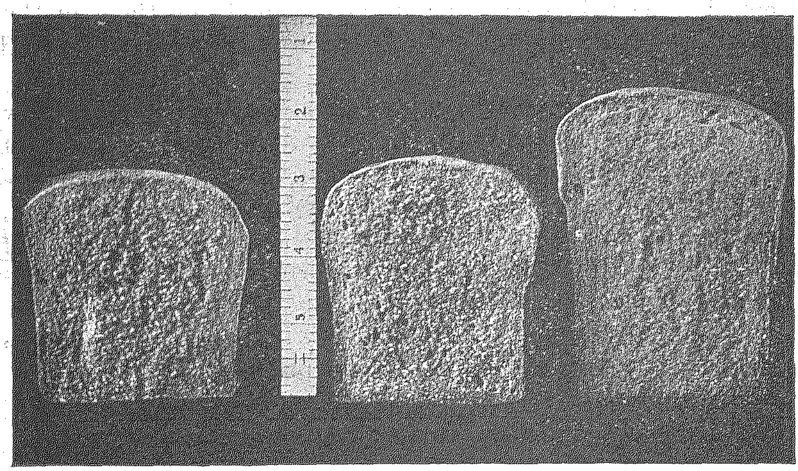
NOTE—1 U. S. Dept. Agri., Office of Experiment Stations Bul. 11.

was of considerable importance. This work was done under the supervision of Mr. C. E. Foster, of the Northwestern Consolidated Milling Company of Minneapolis, Minn., in one of the large mills of the company. Hard Scotch Fife spring wheat, plump and of good quality, weighing 60 lbs. per bu., was used; 72.6 per cent of the cleaned wheat was secured as straight grade patent flour.

TABLE No. 26—Composition of Wheat and Flour Products.

	Water Per cent	Protein (Nx5.7) Per cent	Fat Per cent	Carbohydrates Per cent	Ash Per cent
Wheat..........	8.50	12.65	2.36	74.69	1.80
Graham flour............ ..	8.61	12.65	2.44	74.58	1.72
Entire-wheat flour..	10.81	12.26	2.24	73.67	1.02
Straight grade or patent..	10.54	11.99	1.61	75 36	.50
First patent flour..........	10.55	11.08	1.15	76.85	.37
Second patent flour........	10.49	11.14	1 20	76.75	.42

Digestibility of Bread.—Only that portion of the food that is digested is useful to the body as nourishment. For



A B C

Fig. No. 97. Bread from the same weight of A, Graham, B, Entire wheat, C, Standard Patent Flour.

an accurate comparison of the actual nutritive values of graham, entire-wheat, and standard patent flours it is necessary to determine what proportions of the nutrients in each will be digested. To gain information on this point, a series of nine digestion experiments with three subjects was carried on, in which the diet consisted of milk and bread made from the different grades of flour. At the same time, to determine whether there is any difference in the digestibility of different grades of patent flour, three experiments with another subject were made with first patent, second patent, and standard patent flours, instead of with graham, entire-wheat, and standard patent. The subjects were young men in good health, designated in these experiments as Nos. 1, 2, 3, and 4. In so far as possible, the experiments were alike, except as regards the kind of flour from which the bread consumed was made. All the food consumed and feces excreted were weighed and samples analyzed. The separation of the feces for the experimental period was made by the use of charcoal, which was given to the subjects in capsules with the last meal before and the first meal after each period; the charcoal coloring the feces. The digestibility of the bread and milk diet as a whole was measured by the difference between the total nutrients in the diet and those in the feces. Then the digestibility of the nutrients in the bread alone was estimated.

Each experiment lasted two days, and was preceded by a preparatory meal similar to that eaten in the experiment proper. In each case the bread eaten consisted only of the moist crumb. It was found necessary to remove the crust, because when the latter was included accurate sampling of the bread was difficult, and the determinations of ether extracts were interfered with.

Summary of Results.—The following table summarizes the results of the digestibility of the bread alone:

TABLE No. 27—Digestibility of Nutrients and Availability of Energy of Bread Alone.

Subject No.	Kind of Food	Protein Per cent	Fat Per cent	Carbohydrates Per cent	Energy Per cent
1	White bread (standard patent)..	86.7	65.2	97.4	90.0
2	Do..........	86.3	52.6	97.9	90 8
3	Do................	82.8	51.3	97.1	89 5
	Average of 3......	85.3	56.4	97.5	90.1
1	Entire-wheat bread..	78.1	55.6	93 5	84.4
2	Do............................	83.9	48.1	94.6	86.1
3	Do......................... ..	79.1	63.6	94.1	84.1
	Average of 3	80.4	55.8	94.1	85.5
1	Graham bread..................	81.0	67.8	88.1	81.8
2	Do......	80.6	55.1	88.7	81 6
3	Do............................	71.1	51.2	88.5	78.6
	Average of 3.....	77.6	58.0	88.4	80.7
4	White bread (first patent).......	90.5		98.0	92.8
4	Do (second patent)	91.4		98.7	93.5
4	Do (standard patent)......	90.3		97.4	92.2
	Average of 3......	90.7		98.0	92.8

Standard patent grade flour contains 11.99 per cent protein, 85.3 per cent of which is digestible; the proportion of digestible protein in standard patent flour would then be (11.99 per cent x 85.3=) 10.2 per cent. In like manner the digestible carbohydrates and available energy may be calculated. Such calculations have been made for standard patent flour, entire-wheat flour, and graham flour on the basis of the composition of the flour as milled. The following table shows these results. In the case of the protein the results have been calculated by the two factors, namely nitrogen x 6.25, and nitrogen x 5.70. This is because both factors are in use for calculating this nutrient.

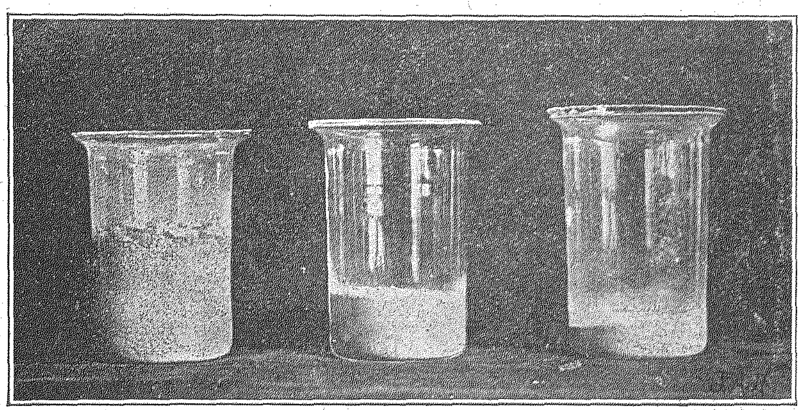
TABLE No. 28—Proportions of Total and Digestible Nutrients and Available Energy in Different Grades of Flour as Milled.

Flour	Protein.				Carbohydrates				Heat of combust'n pr grm	
	N x 5 70		N x 6 25		N x 5 70		N x 6 25			
	Total	digestible	Total	digestible	Total	digestible	Total	digestible	total	Available
	Pr ct.	Per ct.	Per ct.	Per ct	Pr ct	Pr ct.	Per ct.	Per ct.	calo's	caloric
Standard Patent...	11.99	10.2	13.14	11.2	75.36	73.5	74.21	72.3	4.050	3.650
Entire-wheat....	12.26	9.9	13.44	10:8	73.67	69.3	72.49	68.2	4.080	3.445
Graham..	12.65	9.8	13.86	10.7	74.99	66.3	73.78	65.2	4.150	3.350

From this table it will be observed that according to composition the graham flour contained the largest proportion of protein and the largest amount of energy, while the standard patent flour contained the smallest proportion of protein, but a little more energy than the entire-wheat flour. According to the results of the digestion experiments, however, the amount of digestible protein and the amount of energy actually available to the body were greater in the standard patent flour than in the entire-wheat or graham flour. Graham contained the least digestible protein and available energy.

In the three experiments with subject No. 4, in which first patent, second patent, and standard patent flours were used, the digestibility of these three flours was found to be practically the same. This will be observed from the results in table No. 27. It will also be noticed that the digestibility of the protein of the standard patent flour was somewhat greater with subject No. 4 than with either subject No. 1 or 2, while with subject No. 3 it was least of all. These differences are doubtless due largely to individual peculiarities of the different men.

Coarse Particles Escape Digestion.—A comparison of the feces from the different flours is also interesting. The



A B C

Fig. No. 98. Relative amounts of dry feces from A, graham flour, B, entire-wheat and C, standard patent flour. All of the indigestible material from the breads consumed are present in the feces.

feces from a given amount of graham and entire-wheat flour breads were more bulky, and weighed more than those from the same weight of standard patent flour bread. Figure No. 76 shows the relative amounts of dry feces produced in two days from the different breads.

A microscopic examination of the feces of the various digestion experiments was made, with the following results: The feces from bread made from standard patent flour contained very small particles of disintegrated starch, which gave the color reaction with iodin. The feces from graham and entire-wheat breads contained masses of material containing wheat-starch grains in practically the same form as

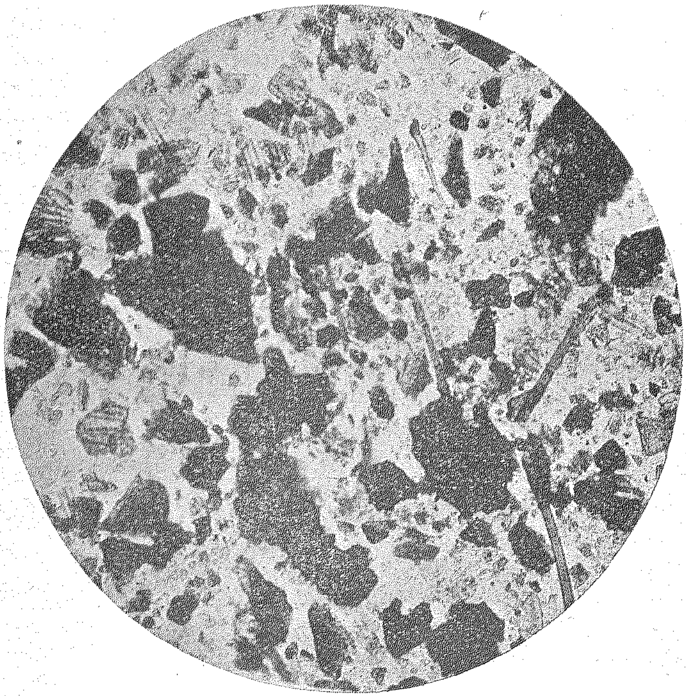


Fig. No. 99. Indigestible residue from feces of Graham bread magnified showing wheat starch granules which have escaped digestion.

in the original graham and entire-wheat flour breads.

The comparatively small amount of digestible protein and available energy in the feces from the bread made from the patent flour as compared with the same nutrients in the feces from the entire wheat and graham flour bread is doubtless due to the fact that the patent flour is much more finely ground. Results of a similar general character were obtained in an experiment at the Minnesota Experiment Station, [1] when pigs were fed whole and ground wheat. The ground wheat was 10 per cent more digestible than the whole wheat. Other experiments with animals have shown that when foods are ground, the nutrients are from 3.3 to 14 per cent more digestible than in unground foods.[2] Fineness of division of the particles, evidently, has a material influence upon both completeness and rate of digestion of a food.

Artificial Digestion of Bread. Artificial digestion experiments were made by treating samples of bread with digestive ferments under conditions of temperature, etc., approximating those of the body. While, as previously explained, the results of such experiments are not absolute it is believed that they may be satisfactorily compared with one another when obtained by the same method. For purposes of comparison, samples of the breads from the different kinds of flour used in the experiments with men were digested artificially by means of an acid pepsin solution. The proportions of dry matter and nitrogen in the samples used are shown in the following table.

TABLE No. 29.—Dry Matter and Nitrogen in bread of Different Kinds.

Kind of Bread.	Dry mat'r Per cent	Nitrogen Per cent
Bread from standard patent flour	58.90	2.22
" " entire-wheat flour	58.31	2 32
" " graham flour	56.68	2 37

In each artificial digestion experiment 25 grams of the bread were kept for four hours in 225 cubic centimeters of acid pepsin solution at a temperature of 38° C. The insoluble residue was filtered off, washed and dried, and the nitrogen content determined. The results of these experiments are as follows:

(1) Minn. Sta. Bul. 36, p 147.
(2) U. S. Dept. of Agr. Office of Ex. Sta. Bul. 77

TABLE No. 30—Results of Artificial Digestion Experiment With Breads of Different Kinds.

Kind of Food.	In Bread grams.	Nitrogen in undigested residue. gram	Digested Per cent
Bread from standard patent flour...	0.33	0.06	82
Bread from entire-wheat flour.......	.34	.08	76
Bread from graham flour...........	.34	.14	58

From the results it will be observed that bread from standard patent flour was most completely digested in the acid pepsin solution; bread from entire wheat flour was less digested; and bread from graham flour was least digested of all of the three. These results agree with those obtained in the experiment with men.

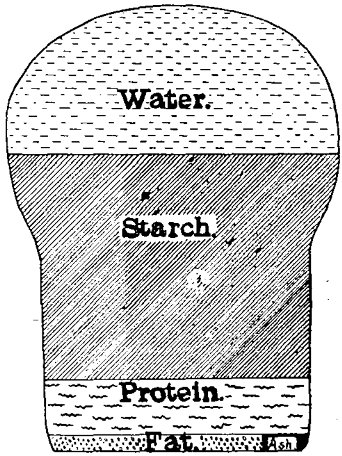


Fig. No. 100. Composition of a slice of bread made from standard patent flour.

Conclusions of Lawes and Gilbert. — In general, these results are in accord with the following conclusions concerning the nutritive values of the different grades arrived at by Lawes and Gilbert[3] who have made extensive experiments with wheat. The physiological action of the different kinds of flour is also well illustrated in the following quotations:

"The higher percentage of nitrogen in bran than in fine flour has frequently led to the recommendation of the coarser breads as more nutritious than the finer. We have already seen that the more branny portions of the grain also contain a much larger percentage of mineral matter. And, further, it is in the bran that the largest proportion of fatty matter —the non-nitrogenous substance of the highest respiratory capacity which the wheat contains—is found. It is, however, we think, very questionable whether upon such data

NOTE—(3) On some points in the composition of the wheat grain of the product in the mill and bread. Reprint.

alone a valid opinion can be formed of the comparative values of bread made from the finer or coarser flours ground from one and the same grain. Again, it is an indisputable fact that branny particles, when admitted into the flour in the degree of imperfect division in which our ordinary milling processes leave them, very considerably increase the peristaltic action, and hence the alimentary canal is cleared much more rapidly of its contents. It is also well known that the poorer classes almost invariably prefer the whiter bread, and among some of them who work the hardest and who consequently soonest appreciate a difference in nutritive quality (navvies, for example) it is distinctly stated that their preference for the whiter bread is founded on the fact that the browner passes through them too rapidly; consequently, before their systems have extracted from it as much nutritious matter as it ought to yield them. * * * In fact, all experience tends to show that the state as well as the chemical composition of our food must be considered; in other words, that the digestibility and aptitude for assimilation are not less important qualities than its ultimate composition."

"But to suppose that whole-wheat meal as ordinarily prepared is, as has generally been assumed, weight for weight more nutritious than ordinary bread flour, is an utter fallacy founded on theoretical text-book dicta, not only entirely unsupported by experience but inconsistent with it. In fact, it is just the poorer fed and the harder working that should have the ordinary flour bread rather than the whole meal bread as hitherto prepared, and it is the overfed and the sedentary that should have the whole-wheat bread. Lastly, if the whole grain were finely ground it is by no means certain that the percentage of really nutritive nitrogenous matter would be higher than in ordinary bread flour, and it is quite a question whether the excess of earthy phosphates would not then be injurious."

CONCLUSIONS.

The digestibility of first and second patent flours was not appreciably different from that of standard patent flour. The degree of digestibility of all of these flours is high, due largely to their mechanical condition—that is, to the fact that they are finely ground.

According to chemical analysis of graham, entire-wheat, and standard patent flours milled from the same lot of hard Scotch Fife spring wheat, the graham flour contained the highest and the patent flour the lowest percentage of total protein. But according to the results of the digestion experiments with these flours the proportions of digestible or available protein and available energy in the patent flour were larger than in either the entire-wheat or graham flour. By digestible nutrients is meant the difference between the amounts of the several nutrients consumed and the amounts excreted in the feces. The lower digestibility of the protein of entire-wheat and graham flours is due to the fact that in both of these flours a considerable portion of the protein is contained in the coarser particles (bran), and so resists the action of the digestive juices and escapes digestion. Thus, while there actually may be more protein in a given amount of graham or entire-wheat flour than in the same weight of patent flour from the same wheat, the body obtains less of the protein and energy from the coarse flour than it does from the fine, because, although the including of the bran and germ increases the percentage of protein, it decreases its digestibility.

THE COMPARATIVE DIGESTIBILITY OF BREAD AND TOAST.

Nature of the Work.—Four experiments were made to determine the comparative digestibility of bread and toast made from the same kind of bread. The rations consisted of bread and milk, and toast and milk. The bread was made from straight grade patent flour, the toast was prepared from the bread after it was about twelve hours old. The toast was first dried in the oven and then prepared in the usual way in a wire toaster. The main difference in the composition of the bread and toast was in moisture content because of the removal of the water during the drying and toasting process. The bread and toast had the following composition on the basis of the dry matter:

TABLE No. 31.—Composition of Bread and Toast.

	Bread Per Cent	Toast Per Cent
Protein	13.44	13.37
Ether Extract (1)	.16	1.02
Carbohydrates	85.71	84.37
Ash and Salt	.69	.94

Chemical Changes Caused by Toasting.— As is well known, the toasting process changes the form and solubility of the nutrients, particularly of the carbohydrates, to a much greater extent than it does the percentage amounts. During the toasting process, a portion of the starch was changed to dextrine, a soluble carbohydrate. The proteid compounds also suffered changes in composition, but opposite in character from the carbohydrates; tests showed that the proteids were rendered less soluble, while the carbohydrates were rendered more soluble.

Digestibility of Bread and Toast.—In the following table, No. 32, a summary is given of the results of the digestion experiments with bread and toast. By the digestibility of a food is meant the completeness, expressed in percentage amounts, with which it undergoes the digestion process and is absorbed and utilized by the body. This is determined by the difference between the amounts in the food consumed and the amounts excreted in the feces.

TABLE No. 32.—Comparative Digestibility of Bread and Toast.

	Bread Per Cent	Toast Digested
Man No. G.		
Protein	88.6	86.42
Carbohydrates	97.7	97.53
Available Energy	91.8	....
Man No. D.		
Protein	85.5	82.98
Carbohydrates	97.2	97.06
Available Energy	91.5	....

NOTE.—(1) The Ether extract or crude fat content of bread is discussed on page 32, Bul. No. 67, U. S. Dept. Agr. Office of Experiment Stations.

Discussion of Results.—From the table it will be observed that Man G digested 2.2 per cent more protein and practically the same amount of carbohydrates when the nutrients were in the form of bread as when they were consumed as toast. In the case of Man D, 2.6 per cent more protein was digested in the form of bread than in the form of toast. There appears to be no great difference in the amount of nutrients utilized by the body whether the food was consumedlin the form of toast or bread. If anything, the toast appeared to be slightly less digestible than the bread, as 2.4 per cent more protein failed to digest in the toast ration than in the bread ration. The difference in the digestibility of the carbohydrates was small. These figures do not represent the rate of digestion, or the comparative ease with which the two foods are digested. These facts were ascertained by artificial digestion experiments.

Comparative Action of the Diastase Ferment upon Bread and Toast.—The work of digestion of the carbohydrates is carried on largely by the soluble ferments or enzemes present in the intestines. Diastase, one of the ferments of malt, is particularly active in the digestion of starch. Ten grams of dry sterilized toast were placed in a flask containing a dilute solution of malt, and after digestion for three quarters of an hour, 14.68 per cent of starch was rendered soluble from the bread, while 21.38 per cent was dissolved from the toast. When the toast and bread were acted upon by the diastase ferment under the same conditions, about a half more starch was rendered soluble from the toast than from the bread. The human digestion experiments showed that the protein of the toast was slightly less digestible than that of the bread and that the carbohydrates in each have practically the same total digestibility. Experiments with the malt solutions show that toast is more readily acted upon by the diastase ferment than is bread; that by toasting bread, a food is produced that is more readily but not quite as completely digested as bread. The fact that toast is somewhat more readily but not quite as completely digested as bread does not detract from its value as a food for invalids and others who require a sterilized food, but it suggests that as far as the availability of the nutrients is concerned, the bread is to be preferred to the toast. When dry toast is used to any considerable extent in the dietary, it has a tendency to cause constipation, particularly if used with tea, as it frequently is; the tannic acid of the tea together with the toast form a combination with costive properties. This tendency, however, is overcome when the toast is prepared with unboiled milk.

Toast is a sterile food while some breads contain various ferment bodies which have not been destroyed in baking, as the interior of the loaf is not heated above the boiling point of water. The ferment and fungus bodies present in unclean flour undergo incubation during the process of digestion, particularly if the digestion is in any way impaired. In the case of normal digestion, however, these bodies do not develope to any appreciable extent because the digestive tract disinfects itself. Microscopic examination of the feces, particularly of those when the diet consisted of graham or entire-wheat breads, showed that these fungus bodies had undergone the incubation process during digestion. The patent grades of flour produced by the roller process of milling contain less of these ferment bodies than either graham or entire wheat flour. This is because the bran and germ parts of wheat which are included in the graham and entire-wheat flours are the parts which contain the ferment bodies. In figure No. 98 some of these growths are shown. In case it is necessary to use a sterilized food, as toast, in the dietary it is more economical to prepare it at home from flour of good quality than it is to purchase it in the form of so-called health foods.

Action of Heat on Animal Foods.—Experiments with animals have shown that when grains and other foods are prepared by cooking,[1] the proteids of the cooked foods are from one to six per cent less digestible than in the uncooked foods, while the carbohydrates have practically the same digestibility, the difference being slightly in favor of the uncooked foods. It would appear that the prolonged action of heat in the preparation of foods lessens the digestibility of the protein but not of the carbohydrates. The two classes of nutrients in foods, proteids and carbohydrates are evidently affected in a different way, as far as the total digestibility is concerned, the carbohydrates being made more easy to digest and the proteids less completely digestible by the prolonged action of heat. Since in many of our foods, particularly the grains, the carbohydrates are by far the most abundant class of nutrients, the action of heat in their preparation has a favorable influence in making food more easy of digestion rather than affecting the completeness of the process.

SUMMARY.

The carbohydrates of toast were more readily acted upon by the diastase ferment than were the carbohydrates of bread. The protein of bread was 2.4 per cent more completely digested than that in toast. There was but little difference in the total digestibility of the carbohydrates, but in the same length of time about a half more of the starch was rendered soluble by the diastase ferment from toast than from bread. In the dietary of a working man less nutrients are secured from toast than from bread.

INFLUENCE OF THE ENZEMES OR CHEMICAL FERMENTS OF MILK UPON THE DIGESTIBILITY OF FOODS.

Nature of The Work.—Two series of digestion trials were made to determine the nutritive value of milk and its influence upon the digestibility of other foods. In two of the trials, the ration consisted of bread, butter, beans, potatoes, eggs and milk, and in two other trials, the same foods were used except that the milk was omitted. It was the aim to have a variety of food articles supplied in liberal amounts, and then to determine the influence which the presence or absence of milk had upon the digestibility of the ration. The eggs were cooked in their shells and the washed unpealed potatoes boiled. Mixed milk from the college herd was used. The butter was made at the experiment station. The bread was from standard patent spring wheat flour. The two series of experiments were alike in every respect except that in one milk was used while in the other it was omitted.

NOTE—1 Bul. No. 77 U. S. Dept. of Agr. Office of Experiment Stations p 93.

Enzemes in Milk.—Investigations made during recent years by European and American Scientists, have shown that milk normally contains a number of characteristic enzemes or chemical ferments. Enzemes are chemical substances produced by the activity of animal or plant bodies. Enzemes are lifeless chemical bodies, which are products of life processes and are capable of producing chemical changes. Babcock and Russell have shown that among the chemical or soluble ferments of milk, there is a tryptic-like ferment capable of digesting casein. Enzemes, similar in character, are present in the digestive tract, and they are the active agents which promote digestion of the proteids and other nutrients of foods. Since milk contains a tryptic-like ferment as well as other enzemes, experiments were undertaken to determine their influence upon the digestion of foods.

Digestibility of Foods Used.—The digestibility of the bread, butter, beans and milk, and of the bread, beans and milk had been determined in former trials and is reported in this bulletin. In a former report, Bul. No. 43, U. S. Dept. of Agr., Office of Experiment Stations, the digestibility of potatoes and eggs is given. While the digestibility of all of the foods used in these trials had been previously determined, no attempt had been made, except with the beans, to show the extent to which one food influenced the digestibility of another.

Digestibility of Rations.—The digestibility of the rations with and without milk is given in the following table:

TABLE No. 33.—Influence of Milk Upon the Digestibility of Food.

Ration,—Bread, Milk, Butter, Potatoes, Beans and Eggs						
	Dry Matter Per cent	Protein Per cent	Ether Extract Per cent	Carbohydrates Per cent	Ash Per cent	Cal. Per cent.
Man 6.......	94.69	89.84	97.12	96.44	74.62	91.00
Man 7........	95.11	91.85	96.28	97.11	72.55	91.56
Digestibility of same rati'n without milk.						
Man 6........	91.42	81.65	95.55	94.63	48.42	89.42
Man 7..	93.31	84.64	96.29	95.76	65.81	90.89

From this table it will be observed that in the rations with milk the nutrients are more completely digested, particularly the crude protein, than in the same ration without milk; in the case of man No. 6 the difference in the protein is 8.20 per cent, and with man No. 7 it is 7.20 per cent in favor of the ration with milk.

Discussion of Results. In the ration with milk the results show that the milk is entirely digested and that the other foods in the ration are also more digestible than in the same ration without milk. To illustrate, in the ration with milk, for man No. 6, there are 281.75 grams of protein; 61.40 grams being supplied by the milk, and 220.35 grams by the other foods. If the protein in the milk is considered entirely digestible, and the indigestible protein in the feces as coming entirely from the other foods it would make the protein of the mixed ration exclusive of the milk 86.98 per cent digestible. The actual amount digested when the milk was omitted was 81.65 per cent. That is, in the ration with milk, the protein of the milk was entirely digested and that of the other foods was made 5.33 per cent more digestible. Similar calculations for man No. 7, show that the protein of the milk was entirely digested and that of the other foods were made 4.50 per cent more digestible by the milk. In the ration with milk the carbohydrates are also more digestible.

Somewhat similar experiments treating of the beneficial influence of milk upon the digestibility of a single food, bread, are reported in Bul. No. 53, U. S. Dept. of Agr., Office of Experiment Stations. It is stated that when bread and milk were used alone they had a different and lower degree of digestibility than when used together. Bread and milk in combination were more completely digested than either bread or milk alone. "The average of ten digestion experiments with an exclusive milk diet showed 92.1 per cent of the protein and 86.3 per cent of the carbohydrates to be digested. Five experiments made with an exclusive bread diet or with bread and sugar showed 82 per cent of the protein and 99 per cent of the carbohydrates digested. Five experiments with a diet of bread and milk showed 97.1 per cent of the protein and 98.7 per cent of the carbohydrates digested. In other words the protein in milk alone or in bread alone seems to be much less completely digested than when the two are eaten together." In the experiment quoted, the influence of milk upon the digestibility of a single food as bread is quite marked. No comments, however, are made as to the cause of the increased digestibility of the bread in the presence of milk. In the case of a mixed ration, as in this experiment, the effect is equally marked.

Digestive Action of the Enzymes Ferments in Milk. The fact that when milk was used in a mixed ration, the protein was from 4.50 to 5.33 per cent more digestible than when the milk was omitted suggested that the soluble or chemical ferments of milk were the active agents which had caused this increase in digestibility. Direct experiments were made to determine the action of milk as a digestive fluid and the extent to which the soluble ferments of milk were capable of acting upon foods. A dilute solution of fresh milk was used in place of the pepsin solution as described in preceding experiments.

Ten grams of bread toast were digested with 10 cc of milk and 90 cc of water for two hours at a temperature of 98.5° F. The nitrogen content of the milk, toast, and the water soluble nitrogen of the toast were all determined in duplicate. As a check upon the work, a blank test with 10 cc of milk and 90 cc of water was made. Toast was used because it was desired to have a thoroughly sterilized food and also a material from which the soluble nitrogen could readily be filtered. Duplicate digestion trials were made, and also tests with Pasteurized milk. The results are given in the following table:

Table No. 34. Digestive Action of Milk.

Soluble before digestion.	Trial 1. Standard c. c.	Trial 2. acid used c. c.	Protein grams Average
10 cc milk	11.4	11.4	.346
10 grams toast water soluble nitrogen	2.8	3.0	.088
Total in milk and water soluble nitrogen	14.2	14.4	.434
Soluble after digestion.			
10 grams toast, 10 cc milk 90 cc water	15.8	15.9	.493
Amount digested	1.6	1.6	.059
Per cent digested			12.25

When fresh milk was used as a digestive fluid, 12.25 per cent of the total protein of bread toast was digested. Similar tests were made with rolled oats but the results are not given because of difficulties experienced in filtering the soluble nitrogen from the starchy mass. The pasteurized milk (157°F) did not digest as much protein as the fresh milk; while the fresh milk digested 12.25 per cent, the pasteurized milk digested 7.6 per cent. Because of the coagulation of the albumin, experiments could not be made with sterilized milk. The soluble ferments of milk evidently exert a material influence as digestive agents, and fresh milk is a digestive fluid, as well as a food of high nutritive value.

Experiments by Babcock, Russell, Van Slyke and others have shown that normal milk contains soluble or chemical ferments which unaided by other ferment bodies are capable of carrying on the ripening process in cheese making. The curing or ripening process in cheese making is distinctly a digestion process. It is the favorable action of the enzymes or soluble ferments in milk upon the other foods with which it is combined that gives milk its unique value as a human food enabling a larger amount of the nutrients in a mixed ration to be utilized by the body for food purposes. The fact that the chemical ferments in milk assist in the digestion of food is also emphasized by experiments made by Patterson and others which have shown that sterilized or cooked milk is less digestible than unsterilized milk.

Value of Milk in Animal Rations. Experiments with animals show that whole milk and skim milk are valuable in making other foods more digestible. In the case of pigs it has been shown that when skim milk is used in a ration the gain in weight is more rapid than when the same total amount of nutrients in the form of grains has been substituted for the skim milk, 6 pounds of skim milk are equal in pork producing value to about one pound of grain. When the nutrients in six pounds of skim milk and one pound of shorts, for example, are compared, it will be found that there is nearly the same amount of protein in each but that there is a quarter of a pound more carbohydrates in a pound of shorts than in six pounds of skim milk; nevertheless a pig is capable of making as much gain in weight from six pounds of skim milk containing less total nutrients as from a pound of shorts containing more nutrients. This is because skim milk causes the grains with which it is combined to be more completely digested, and the animal is enabled to utilize a larger proportional amount of the nutrieuts from the grain. Milk appears to have the same characteristic value in making other foods more completely digestible in animal rations as in human rations.

Cost of Nutrients in Milk. Milk at ordinary prices, 4 to 6 cents per quart, is one of the cheapest foods that can be procured. Ten cents worth, or 4.16 pounds of average milk at five cents a quart, will contain as much protein and fat and more fuel value than ten cents worth of sirloin steak or any meat at the low price of twelve cents per pound. Milk should not be considered as a luxury but more as an economical food. Dietary studies made at the Maine State College by Professor Jordon, have shown that when milk was liberally used the cost of food was appreciably lessened.

Notes on the Use of Milk in the Dietary. When milk is used quite extensively in the dietary it has occasionally a tendency to cause constipation. This can be largely avoided by dissolving a little salt in the milk or by using some solid food as bread or crackers with the milk to prevent the formation of coagulated, indigestible masses. When used, even in liberal amounts, with other foods in a mixed ration, milk has no tendency to cause digestion disorders provided it contains no preservatives and is pure and wholesome. The purity of the milk supply, which is a sanitary and bacteriological problem, as well as a chemical one, is a matter of great importance. It is questionable whether the soluble ferments of milk are capable of exercising their maximum digestive powers in the presence of the numerous micro organisms which are so abundant in impure milk. The purity of the milk supply is too frequently given but scant attention.

CONCLUSIONS.

1. When milk was used in a ration, with bread, butter, beans, eggs, and potatoes, all of the protein of the milk was digested and in addition 4.91 per cent more of the protein of the other foods with which it was combined was digested than when the milk was omitted.

2. Milk is valuable, not only for the nutrients which it contains, but also because the soluble ferments which are present make the foods with which it is combined more completely digestible. Fresh milk acts as a digestive fluid; 12.25 per cent of the protein of toast was digested in two hours by the enzymes or chemical ferments of fresh milk.