ENERGY VALUE OF FOODS

. . . basis and derivation

by

Annabel L. Merrill

Bernice K. Watt

Human Nutrition Research Branch

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Agriculture Handbook No. 74

Slightly revised February 1973

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price $1.25 domestic postpaid or $1.00 GPO Bookstore Stock Number 0100–02770

PREFACE

The kilocalorie, which has been defined as the amount of heat energy needed to raise the temperature of a kilogram of water 1° C., is the unit that has been used traditionally for expressing the energy value of foods. Recently the International Bureau of Weights and Measures has recommended that the joule, a unit of energy applicable to electrical, work, and chemical energy, be adopted as the preferred unit for all forms of energy. The joule is derived from basic units in the International System of Units (SI) and is defined as a measure of force (newtons) times distance (metres).

In the interest of uniform nomenclature, some nutritionists have proposed that the kilojoule replace the kilocalorie. The conversion factor for expressing kcalories as kjoules, as recommended by the Committee on Nomenclature of the International Union of Nutritional Sciences, is 1 kcalorie equals 4.184 kjoules, based on the kcalorie determined at 14.5° to 15.5° C.

Use of kjoules in place of kcalories as the unit of measure for energy in no way invalidates the principles underlying the Atwater system for determining energy value of foods and the energy needs and energy expenditures of man.

The Atwater system is based on the demonstrated principle that the oxygen used, the carbon dioxide formed, and the energy evolved in oxidizing foods are the same whether this oxidation takes place in the body of man or in a bomb calorimeter. Furthermore, Atwater has clearly shown that by applying appropriate factors, which allow for metabolic losses, to the contents of protein, fat, and carbohydrate in a food, the physiologically available energy value of that food can be calculated with outstanding accuracy. The results obtained by this procedure are in excellent agreement with data from measurements made by bomb calorimetry on food and metabolic products. Results of studies by Atwater and others could be expressed either in kcalories or in kjoules.

CONTENTS

Text Tables

Appendix Tables

Energy value of foods

. . . basis and derivation[1]

INTRODUCTION

Accurate evaluation of the energy value of foods is essential for dealing with problems of normal nutrition, undernutrition, or obesity. The classic investigations of Professor W. O. Atwater and his associates at the Storrs (Conn.) Agricultural Experiment Station some 50 years ago provided the basis used in this country for measuring the energy values of food. The general calorie factors 4, 9, 4 developed from that work gained widespread acceptance, and until recently they were used for calculating the calories shown in official food composition tables. Properly applied, these general factors provide a satisfactory measure of available energy in average diets and food supplies in this country. Following Atwater's period little attention was given to methods of calculating food energy and to the details of Atwater's procedure.

However, in recent years attention has again turned to the important problems of determining and meeting man's energy needs. In attempts to alleviate food shortages experienced during and following World War II consideration was given first to meeting energy needs in stricken areas. Maynard, who represented this government in various interallied food-planning groups, pointed out the necessity of understanding the bases of the different methods for estimating energy values in use in Canada, the United Kingdom, and in this country. On several occasions he called attention to the correct application of the general calorie factors 4, 9, 4 and pointed out their limitations and misuse when applied to individual foods and different types of diets (*114, 115*).[2]

The Food and Agriculture Organization, faced with the urgency of assessing energy values of food supplies in various countries and population groups, convened an ad hoc committee of experts in 1947 to study the problems involved and to make recommendations. While endorsing the Atwater method as one that in the light of present knowledge is suitable if properly used, the committee pointed out the limitations of the use of general factors and the need for more specific calorie factors (*55*) when dealing with individual foods.

These developments have pointed to the need for summarizing the kinds of information Atwater used, the steps followed in his procedure for determining fuel values of food, and the need for revising caloric data for foods to take account of additional research accumulating since his time. This publication has been prepared to provide more background information on food energy data than that given in current textbooks and food tables and to show the basic data drawn upon in deriving the revised calorie factors now used in tables of food composition in this country. Except for a few recent revisions, factors derived as shown in this publication have been used in U. S. Department of Agriculture Handbooks No. 8 (*185*) and No. 34 (*100*) and in various other sources, including food tables published by the Food and Agriculture Organization (*36*).

PART I. SOURCES OF FOOD ENERGY

The chief food sources of energy to the human body are fat, carbohydrate, and protein. Fats and carbohydrates contain carbon and hydrogen which can be oxidized to their end products, CO_2 and H_2O, both in the bomb calorimeter and in the body. In addition, protein contains nitrogen. This nitrogen together with some carbon and hydrogen leaves the body chiefly in the form of urea. Thus protein is incompletely oxidized in the body, whereas it can be completely oxidized in the calorimeter. The heat released by oxidation of food in the bomb calorimeter is its heat of combustion and is a measure of its gross energy value.

Rubner (*147*), as early as 1885, realized that each of these broad groups of energy-yielding components of foods consisted of substances of more or less unlike composition and that the heat values for pure protein, neutral fat, and pure

[1] The authors express appreciation to Mildred Adams for her review of the manuscript and her invaluable suggestions; to William Kunerth for his generous help in translating numerous articles from German; and to Blanche C. Spears for her collaboration in various phases of the study.

[2] Italic figures in parentheses refer to Literature Cited, p. 51.

carbohydrate might not be applicable to foods. He also recognized that methods of determining how much of each is present in a food were not entirely satisfactory. Innumerable improvements in methods and techniques for separating and determining the fractions making up these three main sources of energy in food have been made in the intervening years, but many of the limitations of determining and dealing with the main sources of energy in food that were pointed out in 1890 by an ad hoc Committee of the Association of Official Agricultural Chemists (*5*) still remain. In the following sections the terms as they are used today in tables of food composition are discussed so that their meaning and limitations will be better understood.

Fat

Determination of fat content

The fat content of foods usually is determined by one of three general methods: (1) simple extraction with a solvent, (2) acid hydrolysis with extraction, and (3) saponification with extraction.

The fat content reported for foods in American tables of composition refers as a rule to the weight of crude fat and is obtained by simple extraction with a solvent, usually ether. Included with the fatty acids and the true fats (triglycerides) thus extracted are other materials having similar solubility, such as the sterols, and chlorophyll and some other pigments. Special precautions are necessary to insure complete extraction; carbohydrate-containing foods, particularly those high in starch, present additional problems (*61, 66, 105, 154*).

A method based on acid hydrolysis before extraction gives, in addition to substances listed above, fats which are in combination or which for other reasons are not removed by the usual fat solvents. Egg and yeast have been shown to contain appreciable amounts of fat not extracted without preliminary hydrolysis (*78*).

The third procedure used in determining the fat content of a food, saponification, is usually followed by extraction and titration of the fatty acids. The data obtained by this method are translated into terms of total fat on the assumption that all the fatty acids are present as triglycerides.

The determination of fat in foods is fraught with complications. Particular care is necessary to avoid oxidation of fat during sample preparation and analysis, loss of volatile fatty acids, and the possible formation of esters of fatty acids with alcohol.

Heat of combustion

The heat of combustion of the ether extract from a food depends on the particular fatty acids making up the triglycerides and on the components and proportions of the other ether-extractable materials present. The triglycerides of beef, mutton, and pork fat have been found to have heats of combustion of 9.50 or 9.51 calories per gram; butterfat, 9.27; and the fats from several common plant sources, about 9.3. Lower figures for heats of combustion have been found for total ether extract, indicating that the extractable matter other than the glycerides has a lower heat value than the glycerides alone.

Atwater (*17*) applied the heat of combustion factors determined for triglycerides to crude fat on the assumption that the error resulting from the use of the higher heat of combustion factors would in some measure offset the error resulting from the incomplete extraction of fat in the determination of the fat content of the food. The table containing the data which Atwater assembled from the literature and from his own work and the heat values he considered best suited to apply to the fat content (ether extract) has been reproduced here as table 1.

TABLE 1.—*Average determined heats of combustion of fats and oils as assumed factors for fat of different groups of food materials*

Kind of material	Heat of combustion per gram	
	Determined	Assumed or calculated
	Calories	*Calories*
Beef fat	9.50	
Beef "ether extract"	9.24	
Mutton fat	9.51	
Mutton, "ether extract"	9.32	
Pork fat	9.50	
Pork, "ether extract"	9.13	
Lard	9.59	
Cottolene	9.32	
Butterfat	9.27	
Wheat oil	9.36	
Wheat, "ether extract"	9.07	
Rye oil	9.32	
Rye, "ether extract"	9.20	
Maize oil	9.28	
Oats, "ether extract"	8.93	
Barley, "ether extract"	9.07	
Nut oil (except cocoanut)	9.49	
Olive oil	9.47	
Cocoanut oil	9.07	
Fat of meat, fish, eggs, etc		9.50
Fat of dairy products		9.25
Fat of cereals		9.30
Fat of vegetables and fruits		9.30

NOTE.—This table appears as table 7 in The Availability and Fuel Value of Food Materials (*17*).

Carbohydrate

Determination of carbohydrate content

The difference between 100 and the sum of the crude protein and fat, moisture, and ash is called "total carbohydrate" or "carbohydrate by difference," a practice used by Atwater in his food tables and continued in this country. In addition to the true carbohydrates, this "difference" fraction may include such compounds as organic acids.

Foods of animal origin, except the milk products, contain little carbohydrate. Foods of plant origin, on the other hand, have a variety of carbohydrates. The principal ones are starch, sugars, and cellulose, but appreciable amounts of pentosans, dextrins, gums, and other carbohydrates also may be present. It has been generally assumed that the starches, at least when cooked, and the monosaccharides and disaccharides are well used by the body. Much less is known about the utilization of cellulose, pentosans, and other of the more complex carbohydrates.

"Carbohydrate by difference" has been shown to be generally satisfactory for estimating energy values of foods (*17*). However, for certain purposes, such as dietary planning for the diabetic, carbohydrate values are needed which exclude the fractions that are not potential glucose formers. For these purposes nitrogen-free extract, "carbohydrate by difference" minus fiber, may be calculated. As the digestibility of fiber may be very low, nitrogen-free extract is considered a much closer estimate of the sum of potential glucose formers than the "carbohydrate by difference." "Nitrogen-free extract," sometimes abbreviated to NFE or Nifext, has been used for classifying fruits and vegetables into different carbohydrate groups (*2*, *37*).

Another approach has been the determination of the sum of the sugars, starches, and dextrins measured as total reducing sugars but exclusive of pentoses and hemicelluloses. In such cases it is fairly common to report total reducing sugars expressed as glucose based on analyses in which copper was used. For routine determinations, this procedure is not entirely satisfactory since the extent of the reduction of the copper reagent differs for the various sugars, and mixtures of sugars may be present. In addition the determination may be complicated by the presence of noncarbohydrate reducing substances. Improvements have been made in procedures involving the use of copper reagents, and progress is also being made in the development of totally different methods which may some day provide the specific information needed. For example, differential fermentation, chromatographic separation, and differential spectrographic analysis give promise of quantitative determinations for specific carbohydrates.

Heat of combustion

Atwater assumed that 97 percent of the carbohydrate in flours and meals was composed of starch with a small amount of fiber, about 2 percent dextrin, and 1 percent sugar. As the heats of combustion of dextrin, 4.11, and of sucrose, 3.96, are not greatly different from that for starch, 4.2, he considered 4.2 calories per gram the suitable factor to use for carbohydrate in cereal foods. He also applied this figure to the carbohydrate content of foods consisting largely of starch, such as cornstarch and tapioca, and to dried legumes because he considered that the carbohydrate portion of the latter consisted mainly of starch.

In many vegetables the carbohydrate is largely starch and cellulose with more or less sugar. Atwater suggested the same calorie factor for vegetables that he had used for cereals and for legumes, 4.2 calories per gram. He thought that vegetables had a higher proportion of pentosans than the cereals and that the higher heat of combustion of pentosans as compared with polyhexoses might offset the lower heat value of the sugars.

In fruits a large proportion of the carbohydrate is present as sugar, especially monosaccharides, but some starch, cellulose, and pentosans also are present. Combining the lower heat of combustion of the sugars with the higher value for starch, Atwater considered that 4.0 calories per gram was probably not far from a correct figure for carbohydrate in fruits.

The main carbohydrate of animal source is milk sugar. Atwater found that figures on record for its heat of combustion were not in agreement and he used 3.9 calories per gram. Muscle meats and fish contain traces of glycogen, which in ordinary analyses is not taken into account. Oysters, other shellfish, and liver, however, may contain an appreciable amount of glycogen, which has a heat of combustion of 4.2 calories per gram. Since the amounts of these foods contained in ordinary diets were small, Atwater used 3.9 calories per gram of carbohydrate in all foods of animal origin for general dietary calculations.

The table prepared by Atwater summarizing data on heats of combustion to apply to carbohydrate is reproduced here as table 2.

TABLE 2.—*Average determined heats of combustion of different carbohydrates and assumed factors for carbohydrates of different groups of food materials*

Kind of material	Heat of combustion per gram	
	Determined	Assumed or calculated
	Calories	*Calories*
Pentoses [1]	3.72 to 4.38	
Dextrose	3.75	
Levulose	3.76	
Cane sugar	3.96	
Milk sugar	3.86	
Cellulose	4.20	
Starch	4.20	
Dextrin	4.11	
Glycogen	4.19	
Carbohydrates of animal foods, meats, dairy products, etc.		3.90
Carbohydrates of cereals		4.20
Carbohydrates of legumes		4.20
Sugars		3.95
Starches		4.20
Carbohydrates of vegetables		4.20
Carbohydrates of fruits		4.00

[1] Apparently includes not only the simple pentoses but also the pentosans.

NOTE.—This table appears as table 8 in The Availability and Fuel Value of Food Materials (*17*).

Protein

Determination of protein content

It is customary in this country to calculate the protein content of a product from the nitrogen present by applying a factor considered suitable for converting nitrogen to the protein in the particular food. The factors used are based on the nitrogen content of the predominating protein present in various foods. As a great many commonly occurring proteins contain approximately 16 percent nitrogen, 6.25 is the factor often used for general purposes. In the course of extensive investigations, however, Jones (*76*) found rather wide variation in the nitrogen content of different kinds of protein, for example, 13.4 percent for an alcohol-alkali-soluble protein preparation from avocado and 19.3 for amandin in almonds. He therefore prepared special factors for converting nitrogen to protein in those foods for which he considered there was sufficient information to justify their derivation. Table 3 lists these factors along with others obtained from him through personal communication.

TABLE 3.—*Factors for calculating protein from nitrogen content of food* [1]

Food	Factor	Food	Factor
Animal origin:		Plant origin—Con.	
Eggs	6. 25	Legumes—Con.	
Gelatin	5. 55	Beans—Con.	
Meat	6. 25	Soybeans	5. 71
Milk	6. 38	Velvetbeans	6. 25
Plant origin:		Peanuts	5. 46
Grains and cereals:		Nuts:	
Barley	5. 83	Almonds	5. 18
Corn (maize)	6. 25	Brazil	5. 46
Millets	5. 83	Butternuts	5. 30
Oats	5. 83	Cashew	5. 30
Rice	5. 95	Chestnuts	5. 30
Rye	5. 83	Coconuts	5. 30
Sorghums	6. 25	Hazelnuts	5. 30
Wheat:		Hickory	5. 30
Whole kernel	5. 83	Pecans	5. 30
Bran	6. 31	Pine nuts	5. 30
Embryo	5. 80	Pistachio	5. 30
Endosperm	5. 70	Walnuts	5. 30
Legumes:		Seeds:	
Beans:		Cantaloup	5. 30
Adzuki	6. 25	Cottonseed	5. 30
Castor	5. 30	Flaxseed	5. 30
Jack	6. 25	Hempseed	5. 30
Lima	6. 25	Pumpkin	5. 30
Mung	6. 25	Sesame	5. 30
Navy	6. 25	Sunflower	5. 30

[1] Adapted from table 5 of U. S. Department of Agriculture Circular 183, revised edition, February 1941 (*76*) and from unpublished data obtained by personal communication with the author. For groups of foods not included here, the conventional factor 6.25 should be used until more is known regarding their proteins.

The figures commonly reported in American tables of composition for protein actually represent crude protein, since as a rule the figures are derived by applying the appropriate factor to the total nitrogen present. This procedure involves the assumption that all of the nitrogen present is in the form of protein, which is not wholly valid because in this procedure counted with the true protein may be other nitrogenous compounds, such as nitrates, nitrites, purine bases, choline, and free amino acids.

Heat of combustion

The heat of combustion of the nitrogenous portion of food depends on the kinds of protein present and on the proportion of protein and nonprotein nitrogenous material—the latter usually having lower heat of combustion than the former.

Atwater's procedure for obtaining a figure for the heat of combustion for the total nitrogenous portion of a food may be illustrated by his figures for cereal grains having 17.5 percent nitrogen in their proteins. The protein would therefore be computed by multiplying the nitrogen by the factor 5.7. He assumed, from analyses of Teller (*4*), Snyder (*163*), and Wiley (*183*), that not less than 96 percent of the nitrogen of the seeds of cereals was in the form of protein and not over 4 percent as nonprotein material. One gram of cereal nitrogen, then, would be equivalent to 5.47 grams of protein (0.96 gm. N $\times$ 5.7) and, using asparagin (21.2 percent N) as a model of the nonprotein nitrogenous fraction, 0.19 grams of asparagin (0.04 gm. N $\times$ 4.7).

Applying to the protein portion the heat of combustion of the principal proteins in the cereals, about 5.9 calories per gram according to Atwater's data, and to the nonprotein portion, the heat of combustion of asparagin, 3.45 calories per gram, the total heat of combustion for the nitrogen-containing compounds in cereals was calculated as follows:

5.47 gm. protein $\times$ 5.9 cal./gm.=32.27 calories
.19 gm. asparagin $\times$ 3.45 cal./gm.=.655 calories
5.66 gm. nitrogenous compounds=32.9 calories
1.0 gm. nitrogenous portion=5.8 calories

For the heat of combustion of the nitrogenous portion of meat, Atwater felt the most satisfactory procedure was to use the value for the fat-free muscle tissue including the nonprotein extractives, as quantitative data on creatin and other nonprotein compounds were lacking. The heat of combustion for fat-free muscle meat was about 5.65 calories. He used this same factor for the protein of milk. He estimated the heat of combustion for the nitrogenous portion of egg to be 5.75 calories per gram, based on data for proteins in the white and yolk, assuming that very little nonprotein nitrogen is present.

Table 4 is a reproduction of one prepared by Atwater showing average determined heat of combustion of "proteids" and "nonproteids" and calculated heat of combustion of "protein." Atwater used the term "proteid" to cover the true proteins, and the term "protein" to cover both the nonprotein compounds, the extractives, amides, etc., and the true proteins. If Atwater's heat of combustion values for protein (as defined by him) is applied to protein as currently determined, that is, total N times a factor, some error will result because the heat of combustion of the true proteins is usually higher than that of other nitrogenous compounds. It has become the custom in this country, however, to apply heat of combustion factors to total nitrogen treated as protein without weighting the composition data according to the proportion of the different nitrogen-containing compounds present. This has been done because of the limited information available on the partition of nitrogen in foods between true protein and other forms. Although this procedure may result in an appreciable error in the calorie value of the protein of a food, the error in the total energy value is generally small, as most foods having a large proportion of their nitrogen as nonprotein nitrogen (mostly vegetables and fruits) contain relatively small amounts of total nitrogen.

TABLE 4.—*Average determined heats of combustion of proteids and nonproteids and calculated heat of combustion of protein*

Kind of material	Heat of combustion per gram	
	Determined	Assumed or calculated
	Calories	*Calories*
Beef, fat-free muscle	5.65	
Beef, fat-free muscle, extractives removed	5.73	
Veal, fat-free muscle	5.65	
Mutton, fat-free muscle	5.60	
Protein of meat		5.65
Egg albumin	5.71	
Egg, protein of yolk	5.84	
Vitellin	5.76	
Protein of egg		5.75
Milk casein	5.63 to 5.86	
Milk protein	5.67	
Protein of dairy products		5.65
Gliadin	5.92	
Glutenin	5.88	
Gluten of wheat	5.95	
Legumin	5.79	
Plant fibrin	5.89	
Protein of cereals (96% proteids)		5.80
Protein of legumes (96% proteids)		5.70
Protein of vegetables (60% proteids)		5.00
Protein of fruits (70% proteids)		5.20
Gelatin	5.27	
Creatin, as type of non-proteids of animal foods	4.27	
Asparagin, as type of nonproteids of vegetable foods	3.45	

NOTE.—This table appears as table 6 in The Availability and Fuel Value of Food Materials (*17*).

The effect of method of calculation on estimated energy values for the nitrogenous compounds in a food can be shown by using potatoes as an example—a food known to contain a considerable portion of nonprotein nitrogen. If 60 percent of potato nitrogen is attributed to protein and 40 percent to asparagin, the heat of combustion of the nitrogenous matter equivalent to 1 gram of nitrogen should be 28.2 calories and the heat of combustion per gram of nitrogenous compounds, 5.01 calories, as shown by the calculations below:

0.6 gm. N×6.25=3.75 gm. protein
0.4 gm. N×4.7=1.88 gm. asparagin
1.0 gm. N=5.63 gm. nitrogenous compounds

3.75 gm. protein×5.8 cal./gm.=21.75 calories
1.88 gm. asparagin×3.45 cal./gm.=6.49 calories
5.63 gm. nitrogenous compounds=28.24 calories

1.0 gm. nitrogenous compounds=5.02 calories

If, however, all of the nitrogen is assumed to be protein (6.25 gm. protein) and to this is applied the factor 5.02 calories (corrected as shown above for the lower heat of combustion for the nonprotein portion), an energy value of 31.4 calories per gram nitrogen results (1 × 6.25 × 5.02). This result is about 11 percent higher than that obtained in the first calculation because the content of protein is overestimated. If no correction is made for the presence of nonprotein nitrogenous compounds and if the higher heat of combustion of potato protein, 5.8 calories per gram, is applied, an energy value equivalent to 36.25 calories per gram of nitrogen would result (1 × 6.25 × 5.8). This result is nearly 30 percent higher than the first calculation because there has been overestimation in both the content of protein and the heat of combustion of the nonprotein fraction. This illustration shows that we should have data on the actual partition products, but until we do, it seems best to continue the rather arbitrary procedure shown here as the second calculation, namely, to apply a weighted calorie factor to total nitrogen treated as protein.

Determined versus calculated gross energy values of foods

Gross energy may be determined directly by burning a sample of food, or it may be calculated by applying previously determined heats of combustion to composition data on the energy-yielding components of food and obtaining the sum.

In view, however, of the diversity within the fractions of the so-called protein, fat, and total carbohydrate components of food pointed out in preceding paragraphs, and in view of the assumptions made in deriving heat of combustion values to apply to each fraction, Atwater recognized the importance of checking the gross energy values calculated for foods. He compared results for calculated and determined gross heats of combustion for 276 samples including foods of animal origin as well as a variety of plant products. He found that when he applied the heats of combustion he had worked out for protein (actually nitrogenous compounds), fat (as ether extract), and carbohydrate (usually determined by difference) to amounts present, the results were in good agreement with those obtained by bomb calorimeter. Although in a few cases discrepancies were as much as 5 or 6 percent, agreement was very much closer in most cases and justified the use of the calculated values.

The table in which Atwater summarized these comparisons has been reproduced here as table 5. Possibly the difficulties in getting satisfactory composition data for dried samples of high original water content was responsible for the larger discrepancies observed between the calculated and determined gross heats of combustion for fruits and vegetables. Differences might be expected for milk likewise and may have been observed for individual samples, but the averages for the 37 samples are in excellent agreement. With the improved techniques in moisture determinations now available, we would expect even better agreement between the gross heats obtained by calculation and the determined values.

TABLE 5.—*Comparison of calculated heats of combustion with results of direct determinations*

Kind of food material	Number of analyses included in average	Average heat of combustion per gram of water-free substance		Calculated results in percentages of those determined
		Determined	Calculated	
		Calories	*Calories*	*Percent*
Beef	55	6507	6619	101.7
Beef, canned	7	6197	6268	101.2
Mutton	10	7146	7316	102.4
Pork	10	7835	7944	101.4
Poultry	5	6310	6508	103.1
Fish	3	6317	6427	101.8
Eggs	10	7103	7160	100.8
Butter	20	8832	8918	101.0
Milk	37	5437	5413	99.6
Breakfast foods	3	4367	4360	99.8
Bread, crackers, etc	36	4536	4513	99.5
Corn (maize) meal and corn preparations	7	4580	4624	101.0
Rye preparations	6	4353	4343	99.8
Barley preparations	2	4352	4365	100.3
Rice	5	4390	4474	101.9
Oatmeal (rolled oats)	2	4834	4811	99.5
Oatmeal, cooked	6	4488	4480	99.8
Wheat, pastry	8	4579	4605	100.6
Legumes, fresh	8	4367	4361	99.9
Legumes, cooked	5	4312	4343	100.7
Vegetables, fresh	10	4195	4051	96.6
Vegetables, cooked	3	4057	4277	105.4
Vegetables, canned	2	4264	4102	96.2
Fruits, fresh	12	4389	4123	93.9
Fruits, canned	4	4078	4056	99.5
Average 276 samples	------	------	------	100.3

Note.—This table appears as table 9 in The Availability and Fuel Value of Food Materials (*17*). Figures for heat of combustion are in terms of small or gram calories rather than large or kilogram calories customarily used for foods.

We have compiled gross calorie data for a number of samples of wheat and flours produced in this country. For 15 samples of wheat or whole-wheat flour reported in the literature (*164, 166, 168, 183, 194, 195*) differences between determined and calculated gross heats varied from 0.1 percent to 1.9 percent and averaged only 0.6 percent. For 16 additional samples of wheat flour of varying degrees of refinement the average difference between gross calories obtained the two ways was slightly higher, 1.3 percent.

Other sources of energy

Two other sources of energy—organic acids and alcohol—are noted below since in some circumstances one or both may be important.

Organic acids

Occurrence of organic acids.—Organic acids are widely distributed in foods but for the most part in small concentrations. Among the various acids that have been identified are: Malic, citric, isocitric, ascorbic, oxalic, lactic, succinic, acetic, quinic, tartaric, benzoic, glyoxalic, salicylic, aconitic, and malonic. As explained earlier, figures for the total carbohydrate content of a food, that is, "carbohydrate by difference," include organic acids. In a very few foods the acids are sufficiently abundant that they should be determined separately for estimations of energy values of those foods, inasmuch as they are distinctly different chemically from carbohydrates and their heats of combustion are lower than for carbohydrates generally. Total free acid is commonly determined by titration against standard alkali and expressed as the predominant acid in the food. To the extent that the organic acids may be present in bound form the total acid value may be underestimated, but this error is ordinarily considered of little importance.

Fruits contain organic acids in more significant amounts than other food groups. In table 6 a number of fruits have been classified according to the total free organic acid content as reported in the literature. Citric and malic acids predominate in all fruits listed except grapes and tamarind. Tartaric acid accounts for most of the total in these two fruits. Other organic acids have been found present in small amounts in fruits. Of the fruits listed in table 6 only 7 have been reported to contain more than 2 percent organic acid; 15 contain from 1 to 2 percent; and more than 35 contain less than 1 percent. However, in proportion to the total solids, the organic acids may provide an appreciable percentage of the total energy value of some fruits. For lemon juice, it would amount to over half, but for peaches, only about a twentieth.

Less information is available on the acid constituents of vegetables, but the amounts in most vegetables tend to be less than 0.5 percent.

TABLE 6.—*Fresh fruits classified as to organic acid content* [1]

3 percent and over [2]	2 to 3 percent	1 to 2 percent	0.5 to 1 percent	Less than 0.5 percent
Lemons (C).	Cranberries (C).	Apricots (M).	Apples (summer) (M).	Apples (fall) (M).
Limes (C).	Currents, red, black, and white (C).	Carissa or natal plums (C).	Blackberries (C).	Apples (winter) (M).
Tamarind (T).	Gooseberries (C).	Cherries, sour (M).	Blueberries (C).	Bananas (M).
	Grandillas, purple, or passion fruit (C).	Grapefruit, all (C).	Cherries, sweet (M).	Cherimoya (C).
		Groundcherries (including poha and cape-gooseberry) (C).	Crab apples (M).	Feijoa (C).
		Kumquats (C).	Grapes, pulp or juice, American type, all (T).	Figs (C).
		Loganberries (C).	Grapes, European type, all (T).	Jujubes (C).
		Loquats (C).	Guavas (C).	Limes, sweet (C).
		Nectarines (M).	Mamey or Mammee apple (C).	Muskmelons (C).
		Oranges (C).	Mangos (C).	Papayas (C).
		Plums, excluding prunes (M).	Mulberries, black, white, and red (M).	Pears, all (C).
		Pomegranates (C).	Peaches, all (M).	Persimmons, Japanese or Kaki (M).
		Raspberries, red and black (C).	Pineapples (C).	Persimmons, native (M).
		Strawberries (C).	Plantains (M).	Prickly pears (M).
		Tangerines, other Mandarin type oranges (C).	Prunes (M).	Roseapples (C).
			Quinces (M).	Sapodilla or sapota (C).
				Sapote or Marmalade plum (C).
				Sugar apples or sweetsop (C).
				Watermelons (M).

[1] Total free acid expressed in terms of the predominating acid as malic (M), anhydrous citric (C), or tartaric (T) in the edible portion of fruit.
[2] Lemons and limes, 6 percent; tamarind, ripe, 13 percent.

Hartman and Hillig (*63*), reporting results from analyses of organic acids in a large number of food products, included a table of 29 vegetables which showed a total malic and citric acid content (free and combined) ranging from 0.1 to 0.8 percent. Only for lima beans, cauliflower, white potatoes (Idaho), and tomatoes were the values above 0.5 percent.

In certain types of processing by fermentation the total acidity of the product is increased several fold over the original content of the food. Cabbage, for example, contains only a fraction of a percent of acid as malic and citric, while sauerkraut has around 1.5 percent lactic acid. Similarly apples contain less than 1 percent acid expressed as malic, but vinegar made from apples averages about 4.5 percent acetic acid.

Some of the acid constituents of food are available to the body as a source of calories; others are known to be unavailable or of doubtful availability. Oxalic acid is probably excreted in the form of its insoluble calcium salt; tartaric acid is thought to be either excreted unchanged or destroyed by micro-organisms. Little is known about the availability of such acids as glyoxalic, malonic, and aconitic, but since they occur in insignificant amounts they would make a negligible contribution to the total energy value of the foods in which they are found.

Heat of combustion.—For the several acids found in appreciable amounts and considered available, the heats of combustion or gross calorie values per gram of acid calculated from gram-molecular weight data are as follows:

Acid:	*Calories per gram*
Acetic	3.488
Citric	2.471
Lactic	3.620
Malic	2.388

Organic acids contribute a very small portion of the total daily calorie intake, but in a few foods they are present in amounts that should not be overlooked as potential sources of energy. The gross energy value of organic acids in 100 grams of a few foods has been estimated as follows:

Food:	*Calories*
Lemons, limes	15
Currants, gooseberries	6
Fruits, 1–2 percent group (see table 6)	2.5 to 5
Apple vinegar	16
Sauerkraut	5

Alcohol

Alcohol, with a gross energy value of 7.07 calories per gram, is another source of energy which may be important in the diet of some individuals or some population groups. It is discussed in connection with the availability of energy from the various sources (p. 18) since the availability of its fuel value is the point of uncertainty.

PART II. DIGESTIBILITY AND AVAILABLE ENERGY OF FOODS

Definition of terms

Meanings of some of the terms necessary in a discussion of energy value of foods have changed over a period of years. In the following paragraphs terms of most importance are explained and attention is called to differences in past and present connotations.

Digestibility was the term Atwater used for the proportion of food material actually digested. If there had been a way to measure the undigested residue in the feces, digestible food would have been computed as the difference between the total food eaten and the undigested residue. However, as he pointed out, methods for distinguishing between metabolic products in the feces and undigested residue from the food were not sufficiently accurate to permit the determination of the undigested residue separately and he did not compute digestibility.

Availability was the term Atwater used to designate the quantity or proportion of the food or of the nutrients which could be used for building and repair of tissue and the yielding of energy. Some of the absorbed nutrients are used to form digestive juices and returned to the tract in the form of bile and other digestive secretions. Inasmuch as these metabolic products are not used for tissue building or as fuel, they are not available in the sense in which Atwater employed the term. He computed the amounts of available nutrients (protein, fat, carbohydrate) by subtracting the amounts in the feces from the amounts in the food. Availability as Atwater used the term is the same as *apparent digestibility* in more recent years and in current usage. He calculated the coefficient of availability, using nitrogen for illustration, as follows:

$$\frac{\text{N in food} - \text{N in feces}}{\text{N in food}} \times 100 = \text{coefficient of availability.}$$

According to present usage this would be called the coefficient of digestibility, meaning of course apparent digestibility, and it corrects only for total fecal losses.

Heat of combustion data are obtained by burning samples of food in a bomb calorimeter. The heat of combustion is a measure of the *gross energy value* of the food.

Available energy of a food takes into account both fecal and urinary losses. The total available energy of the food is its heat of combustion less that of the urinary and fecal residues. For fat and carbohydrate the available energy is the gross energy of the amounts absorbed (intake—fecal fat and carbohydrate) since each nutrient is assumed to be completely oxidized. The incompletely oxidized matter of the urine is assumed to be of protein origin and the available energy of protein is the gross energy of the absorbed protein (intake—fecal protein) less the gross energy of the urine. Available energy of a food may be obtained entirely from data on heat of combustion or it may be calculated in part from analytical data on nitrogen according to the following procedures:

1. Gross energy of food—(gross energy of urine+feces).
2. Gross energy of food—(gross energy in feces+net absorbed grams $N \times 7.9$).
3. Gross energy of food—(gross energy in feces+urinary N in grams$\times 7.9$).

If the subject is in nitrogen balance, no difference would be expected in the deduction for urinary loss between procedures 2 and 3. A discussion of the extent of the differences resulting from these methods of calculation under other conditions follows the section on calorie-nitrogen ratio of the urine, page 18.

Atwater distinguished between *physical* and *physiological* fuel values, the latter being the actual benefit gained by the body from the use of fuel for the different purposes served. This distinction was made in recognition of the possibility that the energy value of a gram of fat, for example, might be different for mechanical work from what it would be if used only for maintaining body heat. Atwater used the term fuel value as obtained by method 1, 2, or 3 described above to mean physical fuel value, not physiological fuel value. The latter term, however, has since been applied to his data and to his method of obtaining fuel values (*55, 111, 159*). Likewise, in the present publication physiological fuel value is the term used to connote energy value of a food obtained by subtracting energy lost in the excreta (feces and urine) from the total energy value of the food, no consideration being given to the specific functions served in the body.

Digestibility of fat, carbohydrate, and protein

On any diet some ether extractable matter, nitrogenous matter, and other organic matter are lost in the feces and must be taken into account in calculating the energy value of foods. The nitrogenous matter present in the feces may be due in part to undigested food residues, bacteria and their products, the residues of digestive juices, and mucus or particles of epithelium mechanically separated from the walls of the digestive tract. Numerous studies have been made to determine to what extent the nitrogenous matter in the feces under different kinds of dietary conditions is metabolic and to what extent it is undigested or unabsorbed food material. Some investigators have concluded that all the nitrogenous matter in the feces results from metabolic processes but that some foods cause greater loss than others (*104, 106, 147*). Other workers, including Murlin and coworkers (*40, 127, 128*) and Bricker, Mitchell, and Kinsman (*31*), as a preliminary step in obtaining biological values of proteins, have estimated the digestibility of foods with the assumption that part of the fecal nitrogen is metabolic in origin and part is from food eaten.

Since this publication is concerned primarily with estimation of energy value no attempt has been made to distinguish between metabolic and undigested food nitrogen appearing in the feces, because neither is available to the body as a source of energy. Actually, level of N intake may appreciably affect the apparent digestibility of protein; on low levels of protein intake the fecal N may represent chiefly metabolic N which, when charged against a specific test food, leads to low values for apparent digestibility of this food. Results reported in the literature in which digestibilities of test foods were measured under conditions of extremely low protein intake are therefore not satisfactory for application to a more normal level of protein intake. Even under conditions of higher protein intake, losses attributed to the protein of the test food by this method of calculation may actually be due to the influence of the test food on the digestibility of the entire diet. Similar problems occur in calculating the energy factors for carbohydrate and fat (*188, 190, 191*). More information or possibly an entirely different approach is needed to relate fecal losses directly to the test food.

Atwater assembled results of many digestion experiments on men in which the apparent digestibility of a food was studied. In some experiments a single food was fed and in others the test food was fed as part of a simple mixed diet. From these findings he developed tentative coefficients of digestibility. As they had been based largely on the digestibility of single foods in very simple diets, Atwater tested these tentative coefficients by applying them to the several foods in experiments in which ordinary mixed diets were eaten. In these latter experiments the amount of protein, fat, and carbohydrate in the feces was compared with that in the total food so that the "availability" measured applied to the whole mixed diet and not to nutrients in individual foods. The results found for these actual experiments were then compared with the calculated results in which the various tentative coefficients for each kind of food had been applied to the quantities of the respective foods in the diet.

Atwater reported that some adjustments in the tentative coefficients were necessary and he altered them slightly in the way he considered most probable. The resulting average coefficients of apparent digestibility (availability as Atwater used the term) for the nutrients in different food groups and for nutrients in a mixed diet were as follows:

Food group	Protein	Fat	Carbohydrate
	Percent	*Percent*	*Percent*
Animal foods	97	95	98
Cereals	85	90	98
Legumes, dried	78	90	97
Sugars and starches			98
Vegetables	83	90	95
Fruits	85	90	90
Vegetable foods	84	90	97
Total food [1]	92	95	97

[1] Weighted by consumption statistics based on a survey of 185 dietaries.

When these coefficients were applied to data in 93 digestion experiments on ordinary mixed diets very good agreement was found between calculated values and the results of actual determination. The calculated coefficient for protein in the whole diet was 93.6, and that found by actual determination, 93.3; for fat the calculated value was 94.5 and that found by determination, 95.0; for carbohydrate the calculated value was 98.1 and the actual value, 97.7. From this Atwater concluded that for average mixed diets the calculated coefficients were close enough to the determined so that the calculated could be used. But he pointed out that the calculated coefficients might not be applicable under all circumstances and might not apply to all foods in one class. Digestibility studies published since his time have indeed shown rather wide differences among foods within these groups.

A review of the literature shows that in most of the experiments very simple diets have been used in which the test foods made up a large proportion of the total diet. In experiments where the test foods were fed alone or contributed essentially all of the nutrients tested, the supplemental action of one food upon another cannot be observed. Woods and Merrill (*193*) reported that some of their early digestion experiments with men showed milk and bread to be more completely assimilated when fed together than when eaten separately. A similar conclusion was reached by Bryant (*32*) regarding milk and oatmeal when fed together and separately to infants. Unfortunately there is not adequate basis at this time for estimating how significant the differences in digestibility are under different conditions of diet intake.

Availability of energy from digested nutrients

Fat

Atwater illustrated his method of estimating the fuel value of fat (ether extract) with the fat of meat. The coefficient of digestibility (current usage) had been determined to be about 95 percent. As its heat of combustion was about

9.5 calories per gram, its fuel value was 9.0 calories per gram (9.5×.95=9.02).

Carbohydrate

The fuel value of carbohydrates was determined in like manner. For example, cereal carbohydrate was considered about 98 percent available (absorbed) for use in the body, and using the heat of combustion of 4.2 calories per gram, the fuel value was 4.1 calories (4.2×.98=4.12).

Protein

For protein (nitrogenous products), in addition to the use of the coefficient of digestibility, it was necessary to correct for the loss of incompletely oxidized nitrogen from the body. To do this Atwater determined the ratio of the nitrogen in the urine to the heat of combustion of the urine. The average of 46 determinations showed that for every gram of nitrogen present in the urine there was sufficient unoxidized matter to yield 7.9 calories, the equivalent of approximately 1.25 calories (7.9÷6.25) per gram of available (absorbed) protein. The heat of combustion of a gram of absorbed protein (nitrogenous compounds) was therefore reduced by 1.25 calories per gram to allow for incomplete metabolism. In the case of digestible meat protein, for example, the heat of combustion per gram is 5.65 calories. Of this number, 1.25 would be deducted for the heat of combustion of the unoxidized products in the urine. This figure was derived from the ratio of the calorie value of the urine to the nitrogen content of the urine on the assumption that the subjects were in N-equilibrium and that all of the nonmetabolized part of the available N was recovered in the urine. The fuel value, 4.40 calories, would then be applied to each gram of protein available as a source of fuel.

TABLE 7.—*Factors for heats of combustion and fuel values of nutrients in different groups of food materials and in mixed diet*

Kind of food material	Nutrients furnished by each group per 100 grams Total	Heat of combustion per gram	Proportion of total nutrient actually available	Total energy per gram in available nutrients	Fuel value		
					Per gram available nutrients	Per gram total nutrients	
	A	B	C	D = (B x C)	E [1]	F [2]	F revised [3]
Protein	*Grams*	*Calories*		*Calories*	*Calories*	*Calories*	*Calories*
Meats, fish, etc	43.0	5.65	0.97	5.50	4.40	4.25	4.27
Eggs	6.0	5.75	.97	5.60	4.50	4.35	4.37
Dairy products	12.0	5.65	.97	5.50	4.40	4.25	4.27
Animal food	61.0	5.65	.97	5.50	4.40	4.25	4.27
Cereals	31.0	5.80	.85	4.95	4.55	3.70	3.87
Legumes	2.0	5.70	.78	4.45	4.45	3.20	3.47
Vegetables	5.5	5.00	.83	4.15	3.75	2.90	3.11
Fruits	.5	5.20	.85	4.40	3.95	3.15	3.36
Vegetable food	39.0	5.65	.85	4.80	4.40	3.55	3.74
Total food	100.0	5.65	.92	5.20	4.40	4.00	4.05
Fat							
Meat and eggs	60.0	9.50	.95	9.00	9.50	9.00	9.03
Dairy products	32.0	9.25	.95	8.80	9.25	8.80	8.79
Animal food	92.0	9.40	.95	8.95	9.40	8.95	8.93
Vegetable food	8.0	9.30	.90	8.35	9.30	8.35	8.37
Total food	100.0	9.40	.95	8.90	9.40	8.90	8.93
Carbohydrates							
Animal food	5.0	3.90	.98	3.80	3.90	3.80	3.82
Cereals	55.0	4.20	.98	4.10	4.20	4.10	4.11
Legumes	1.0	4.20	.97	4.05	4.20	4.05	4.07
Vegetables	13.0	4.20	.95	4.00	4.20	4.00	3.99
Fruits	5.0	4.00	.90	3.60	4.00	3.60	3.60
Sugars	21.0	3.95	.98	3.85	3.95	3.85	3.87
Vegetable food	95.0	4.15	.97	4.00	4.15	4.00	4.03
Total food	100.0	4.15	.97	4.00	4.15	4.00	4.03

[1] Values for fats and carbohydrates, same as corresponding values in column B. Values for protein, same as corresponding values in column B minus 1.25.

[2] Values for fats and carbohydrates, same as corresponding values in column D. Values for protein, same as corresponding values in column D minus 1.25.

[3] Proportion of total nutrients available (column C) applied to heat of combustion values (column B). (Heat of combustion values for protein adjusted for energy loss in the urine by deduction of 1.25.)

NOTE.—This table appears as table 10 in The Availability and Fuel Value of Food Materials (*17*) with the exception of column F, revised. The figures in this column appear in tabular form in Investigations on the Nutrition of Man in the United States (*98, p. 18*).

The basic data needed for computing fuel value of a diet were brought together by Atwater and Bryant in a table, reproduced here as table 7. They presented two sets of factors for use in estimating energy values. In column E of their table they listed the factors to apply to a gram of available protein, fat, and carbohydrate in each of the various food groups and the average calorie factors per gram, 4.40, 9.4, and 4.15, to apply to the total amounts of protein, fat, and carbohydrate available in a mixed diet. The factors in column E were therefore to be applied to absorbed nutrients.

The fuel value factors listed in column F included a correction for digestibility loss and were to be applied to grams of ingested protein, fat, and carbohydrate in each of the food groups; the average factors rounded to 4.0, 8.9, and 4.0 calories per gram were to be applied to the total amounts of the nutrients in mixed diets. These then were the factors that they considered could be applied directly to representative data on the chemical composition of foods.

For some time after the publication of this work of Atwater and Bryant, apparently no consistent policy was followed with respect to the factors used to estimate energy values of foods (*6, 8, 10, 18, 19, 20, 68, 89, 157, 169, 171*). For a period of time the Atwater and Bryant general factors appeared in the literature as 4, 8.9, 4; then a reference to a further rounding of the factors to 4, 9, 4 was made in the 1910 revision of Farmers' Bulletin 142 (*11*). The 4, 9, 4 factors later came into widespread usage in estimating calorie values of food and not only were applied to the total amounts of protein, fat, and carbohydrate (by difference) of a mixed diet as Atwater and Bryant had originally intended but also were used in assessing the fuel value of individual foods.

Following the publication of the 1899 report, it was realized that for protein the number of calories calculated by applying factors in column E to absorbed nutrients was not identical with the number derived by applying factors in column F to total nutrients. Results obtained by the latter were too low. The error resulted from the misuse of the factor 1.25 derived from a gram of protein. It had been applied to protein which, after digestion loss was taken into account, was less than 1 gram. To illustrate: If a subject ingests 1.0 gram of protein the gross fuel value of which is 5.65 calories, and if only 0.97 gram is digested, the gross available calories are 0.97×5.65, or 5.48.

Since only 0.97 gram is available from each gram of ingested protein, only 0.97×1.25 or 1.21 calories should be deducted. Thus for 1 gram of ingested protein, the available energy value would be $5.48 - 1.21$, or 4.27 calories. This is the same as $0.97\ (5.65 - 1.25)$.

Corrected values for column F were written in file copies [3] of the report and have been included as column F revised here in table 7. The corrected values were also published by Langworthy and Milner in 1904 in a summary of investigations on the nutrition of man in this country (*98*). This publication may not have had wide circulation and has seldom been cited. The revised values make for consistency in the use of columns E and F. It should be pointed out that the revised figures for column F were unrounded in contrast to the values in columns D and E in the original table.

The calorie value per gram of urinary nitrogen.—Several questions have been raised on the advisability of applying 7.9, the calorie-nitrogen ratio in urine published by Atwater (*12, 17*), to energy calculations for which dietary conditions may be greatly different. Lusk (*101*) summarized data showing that the ratio was affected by the proportion of dietary protein, fat, and carbohydrate. Other questions have been raised concerning the effect of negative or positive nitrogen balance, and of high-fruit diets having more than the usual amount of organic acid.

Unfortunately, at the present time no record is at hand showing the specific experiments from which Atwater derived the ratio of 7.9 calories per gram of urinary nitrogen and from it concluded that 1.25 calories per gram of available protein should be subtracted for loss of incompletely oxidized material in the urine.

As early as 1897 Atwater and Benedict in the Storrs Agricultural Experiment Station report for that year (*12,. p. 167*), stated, " . . . the heat of combustion of the water-free substance of the urine will be 1.25 calories for each gram of digested (available) protein. This factor is the average found in a number of experiments in this laboratory, in which the heat of combustion of the water-free substance of the urine was determined."

At the time this statement was published, results probably were available from the first 16 of a series of 55 experiments on the metabolism of matter and energy in the human body conducted under Atwater's supervision. We found the ratio of the heat of combustion of urine to urinary nitrogen when calculated for these 16 experiments to average 7.9 calories, or the equivalent of 1.26 calories per gram of absorbed protein ($7.9 \div 6.25 = 1.26$).

The study that included the 55 metabolism experiments was made at Middletown, Conn., during the years 1896–1902 under the auspices of the U. S. Department of Agriculture in cooperation with the Storrs (Conn.) Agricultural Experiment Station and Wesleyan University. The subjects were normal healthy men of similar weight, around 65 to 79 kg.

---

[3] A note on one of the marked copies on file in U. S. Department of Agriculture reads, "A copy showing corrections as made on slips sent to Magnus Levy in letter of July 6, 1904."

TABLE 8.—*Summary of data showing calorie-nitrogen ratio of urine based on early studies of energy metabolism and digestibility*

[Respiration experiments—food, drink, feces, urine, and respiratory products were weighed, measured, and analyzed. Metabolism experiments—same determinations as made for respiration and in addition measurements of heat given off and heat equivalent of work. Digestion experiments—food, drink, feces, urine, were weighed, measured, and analyzed.]

Kind of experiment	Experiment number	Date	Number of days duration	Subject	Activity	Daily nutrient intake: Gross energy	Protein	Fat	Carbohydrate	Nitrogen balance	Composition of daily urine: Nitrogen	Heat of combustion	Cal./N ratio
						Calories	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Calories*	
Respiration	[1] 1	Feb. 17–19, 1896	2¼	EO	Rest	3, 230	142	126	296	+2. 2	19. 6	150	7. 65
Do	[1] 2	Feb. 26–28, 1896	2¼	EO	do	2, 920	120	112	281	−. 4	18. 0	159	8. 83
Do	[1] 3	Mar. 16–21, 1896	5	OFT	do	2, 640	96	73	338	+. 7	13. 7	124	9. 05
Do	[1] 4P	Mar. 23–25, 1896	1⅝	AWS	do	2, 740	101	85	328	+. 7	14. 1	87	6. 17
Do	[1] 4A	Mar. 25–28, 1896	3	AWS	Mental work	2, 740	101	85	328	+1. 6	13. 1	101	7. 71
Do	[1] 4B	Mar. 28–31, 1896	3	AWS	Rest	2, 740	101	85	328	+2. 3	12. 5	126	10. 08
Do	[1] 4C	Mar. 31–Apr. 3, 1896	3	AWS	Work	2, 740	101	85	328	+. 7	14. 1	116	8. 23
Do	[1] 4S	Apr. 3–4, 1896	1⅝	AWS	Rest	2, 740	101	85	328	−1. 3	16. 1	84	5. 22
Digestion	[2] 37	Apr. 26–May 4, 1897	8	EO	do	2, 680	118	96	281	−. 1	17. 9	136	7. 60
Metabolism	[3] 5	May 4–8, 1897	4	EO	do	2, 660	119	95	276	−. 7	18. 1	128	7. 07
Digestion	[2] 39	May 14–18, 1897	4	EO	Work	3, 680	116	154	381	+6. 1	11. 2	96	8. 57
Metabolism	[3] 6	May 18–22, 1897	4	EO	do	3, 680	119	153	378	+1. 3	16. 3	125	7. 67
Digestion	[4] 41	June 3–8, 1897	5	EO	Rest	[5] 2, 470	104	69	192	−2. 5	17. 8	118	6. 63
Metabolism	[3] 7	June 8–12, 1897	4	EO	do	[5] 2, 460	104	68	190	−1. 9	17. 7	134	7. 57
Digestion	[2] 43	Nov. 4–8, 1897	4	EO	do	2, 930	122	102	311	+4. 1	14. 2	140	9. 86
Metabolism	[3] 8	Nov. 8–12, 1897	4	EO	do	2, 900	129	96	308	. 0	19. 5	152	7. 79
Average [6]						2, 870	112	98	304	+. 8	15. 9	124	7. 86
Minimum						2, 460	96	68	190	−2. 5	11. 2	84	5. 22
Maximum						3, 680	142	154	381	+6. 1	19. 6	159	10. 08
Digestion	[2] 45	Jan. 6–10, 1898	4	EO	Light	2, 710	116	69	342	−2. 2	19. 4	132	6. 80
Metabolism	[3] 9	Jan. 10–14, 1898	4	EO	Rest	2, 720	120	69	342	−. 6	18. 4	148	8. 04
Digestion	[4] 47	Feb. 11–15, 1898	4	EO	do	[5] 2, 700	120	32	299	+2. 4	16. 1	142	8. 82
Metabolism	[3] 10	Feb. 15–19, 1898	4	EO	do	[5] 2, 710	124	32	297	−1. 0	19. 4	147	7. 58
Digestion	[7] 49	Mar. 18–22, 1898	4	EO	Work	3, 860	121	128	488	+5. 1	12. 9	136	10. 54
Metabolism	[7] 11	Mar. 22–26, 1898	4	EO	do	3, 860	124	129	485	−. 2	17. 9	133	7. 43
Digestion	[4] 51	Apr. 8–12, 1898	4	EO	do	[5] 3, 950	120	163	307	+3. 4	14. 4	136	9. 44
Metabolism	[4] 12	Apr. 12–16, 1898	4	EO	do	[5] 3, 890	121	158	296	+. 1	18. 0	130	7. 22
Digestion	[2] 76	Nov. 4–8, 1898	4	EO	Light	2, 620	116	95	267	+. 3	18. 0	111	6. 17
Metabolism	[7] 13	Nov. 8–11, 1898	3	EO	Rest	2, 600	117	88	270	−1. 9	19. 5	173	8. 87
Digestion	[2] 78	Dec. 17–20, 1898	3	EO	Light	2, 450	92	81	280	−2. 8	16. 7	105	6. 29
Metabolism	[7] 14	Dec. 20–24, 1898	4	EO	Rest	2, 510	94	82	290	−2. 0	16. 2	142	8. 77
Digestion	[4] 80	Jan. 12–16, 1899	4	EO	Light	[5] 2, 640	102	40	269	+2. 9	13. 0	121	9. 31
Metabolism	[4] 15	Jan. 16–18, 1899	2	EO	Rest	[5] 2, 650	109	40	277	+1. 0	15. 6	128	8. 21
Do	[4] 16	Jan. 18–20, 1899	2	EO	do	[5] 2, 650	109	40	277	+1. 2	15. 4	126	8. 18
Do	[4] 17	Jan. 20–22, 1899	2	EO	do	[5] 2, 650	109	40	277	+1. 0	15. 6	128	8. 21
Digestion	[4] 82	Feb. 2–6, 1899	4	AWS	do	[5] 2, 670	94	72	253	−1. 4	15. 9	94	5. 91
Metabolism	[4] 18	Feb. 6–8, 1899	2	AWS	do	[5] 2, 780	97	72	250	−1. 9	16. 4	122	7. 44
Do	[4] 19	Feb. 8–10, 1899	2	AWS	do	[5] 2, 780	97	72	250	+. 1	14. 4	108	7. 50
Do	[4] 20	Feb. 10–12, 1899	2	AWS	do	[5] 2, 780	97	72	250	+. 4	14. 1	106	7. 52
Do	[7] 21	Feb. 12–15, 1899	3	AWS	do	2, 260	97	72	250	−. 9	15. 4	126	8. 18
Digestion	[4] 83	Mar. 9–13, 1899	4	EO	Light	[5] 2, 650	120	69	281	+2. 4	16. 1	142	8. 82

Metabolism	[4] 22	Mar. 13–16, 1899	3	EO	Rest	[5] 3, 040	123	69	276	+. 3	18. 4	137	7. 45
Do	[4,7] 23	Mar. 16–19, 1899	3	EO	do.	2, 550	124	69	279	−. 3	19. 0	141	7. 42
Do	[4,7] 24	Mar. 19–22, 1899	3	EO	do.	3, 060	124	69	409	+. 2	18. 3	136	7. 43
Average [9]						2, 870	111	85	303	+. 4	16. 3	127	7. 88
Minimum						2, 260	92	32	192	−2. 8	11. 2	84	5. 22
Maximum						3, 950	142	163	488	+6. 1	19. 6	173	10. 54
Digestion	[2] 147	Jan. 19–23, 1900	4	JFS	Light	2, 900	106	108	320	. 0	16. 6	129	7. 77
Metabolism	[7] 25	Jan. 23–26, 1900	3	JFS	Rest	2, 900	111	104	312	+. 2	16. 4	147	8. 96
Digestion	[2] 149	Feb. 10–14, 1900	4	JFS	Light	2, 520	97	97	264	−2. 0	16. 1	130	8. 07
Metabolism	[7] 26	Feb. 14–17, 1900	3	JFS	Rest	2, 490	100	95	247	. 6	15. 4	128	8. 31
Do	[4] 27	Feb. 17–20, 1900	3	JFS	do.	[5] 2, 490	99	40	247	. 9	15. 6	124	7. 95
Do	[4,7] 28	Feb. 20–23, 1900	3	JFS	do.	2, 490	99	40	375	−. 7	15. 3	128	8. 37
Digestion	[2] 153	Mar. 12–16, 1900	4	JFS	Work	3, 400	96	98	470	+. 1	15. 0	132	8. 80
Metabolism	[4,7] 29	Mar. 16–19, 1900	3	JFS	do.	3, 490	100	106	471	. 6	15. 8	134	8. 48
Do	[4] 30	Mar. 19–22, 1900	3	JFS	do.	[5] 3, 460	99	104	341	−1. 9	17. 1	140	8. 19
Do	[4,7] 31	Mar. 22–25, 1900	3	JFS	do.	3, 490	101	161	343	−. 1	15. 4	130	8. 44
Digestion	[2] 157	Apr. 16–20, 1900	4	JFS	do.	3, 490	96	152	362	. 8	15. 3	126	8. 24
Metabolism	[4,7] 32	Apr. 20–23, 1900	3	JFS	do.	3, 490	100	152	354	−. 4	15. 3	119	7. 78
Do	[4] 33	Apr. 23–26, 1900	3	JFS	do.	[5] 3, 490	100	99	355	−2. 2	17. 0	129	7. 59
Do	[7] 34	Apr. 26–29, 1900	3	JFS	do.	3, 490	100	99	478	−1. 5	16. 3	126	7. 73
Digestion	[2] 189	Dec. 5–9, 1900	4	JCW	Rest	2, 520	94	83	281	−1. 4	15. 9	137	8. 62
Metabolism	[10] 35	Dec. 9–13, 1900	4	JCW	do.	2, 520	98	86	278	1. 0	15. 8	135	8. 54
Fasting	[10] 36	Dec. 13–14, 1900	1	JCW	do					−11. 5	11. 5	95	8. 26
Digestion	[2] 192	Jan. 8–11, 1901	3	JCW	Light	2, 920	92	68	419	−5. 4	19. 4	177	9. 12
Metabolism	[10] 37	Jan. 11–15, 1901	4	JCW	Work	3, 710	100	69	601	1. 4	16. 6	133	8. 01
Do.*	[10] 38	Jan. 15–19, 1901	4	JCW	do.	3, 710	103	203	296	−4. 6	20. 3	155	7. 64
Fasting	[10] 39	Jan. 19–20, 1901	1	JCW	Rest					−16. 0	16. 0	131	8. 19
Digestion	[2] 195	Feb. 22–26, 1901	4	JCW	Work	4, 360	102	165	559	−. 8	15. 5	120	7. 74
Metabolism†	[10] 40	Feb. 26–Mar. 2, 1901	4	JCW	do.	4, 510	102	66	803	−1. 8	16. 8	143	8. 51
Do.*	[10] 41	Mar. 2–6, 1901	4	JCW	do.	4, 540	103	285	318	−4. 6	20. 0	158	7. 90
Fasting	[10] 42	Mar. 6–7, 1901	1	JCW	Rest					−14. 1	14. 1	108	7. 66
Digestion*	[2] 198	Mar. 25–29, 1901	4	JCW	Work	4, 260	96	264	320	−2. 4	16. 3	105	6. 44
Metabolism*	[10] 43	Mar. 29–Apr. 2, 1901	4	JCW	do.	4, 870	104	292	383	−3. 6	18. 8	147	7. 82
Do†	[10] 44	Apr. 2–6, 1901	4	JCW	do.	4, 930	104	67	902	−1. 7	16. 9	140	8. 28
Do*	[10] 45	Apr. 6–7, 1901	1	JCW	do.	4, 860	105	289	391	−3. 7	18. 9	150	7. 94
Digestion*	[2] 202	Apr. 29–May 3, 1901	4	JCW	do.	4, 830	102	294	374	−. 3	15. 0	132	8. 80
Metabolism*	[10] 46	May 3–7, 1901	4	JCW	do.	4, 840	103	302	367	−. 7	15. 9	144	9. 06
Do†	[10] 47	May 7–11, 1901	4	JCW	do.	4, 710	102	70	843	−1. 5	16. 1	145	9. 01
Do*	[10] 48	May 11–12, 1901	1	JCW	do.	4, 860	103	292	381	−2. 2	17. 2	162	9. 42
Digestion†	[2] 302	Mar. 23–27, 1902	4	JCW	do.	5, 370	104	86	977	−. 9	16. 0	137	8. 56
Metabolism†	[10] 49	Mar. 27–30, 1902	3	JCW	do.	5, 500	111	95	975	+1. 1	15. 5	135	8. 71
Do	[10] 50	Mar. 30–31, 1902	[11] 1	JCW	do.	2, 600	65	137	234	−3. 6	13. 5	118	8. 74
Fasting	[10] 51	Mar. 31–Apr. 2, 1902	2	JCW	Rest	10	3			−11. 5	12. 5	102	8. 16
Digestion*	[2] 305	Apr. 17–21, 1902	4	JCW	Work	5, 030	99	292	419	−. 6	16. 0	133	8. 31
Metabolism*	[10] 52	Apr. 21–24, 1902	3	JCW	do.	5, 480	106	334	436	+. 1	16. 0	128	8. 00
Metabolism†	[10] 53	Apr. 24–27, 1902	3	JCW	Work	5, 480	105	96	983	+. 7	14. 9	128	8. 59
Do*	[10] 54	Apr. 27–30, 1902	3	JCW	do.	5, 510	110	346	438	. 0	16. 6	132	7. 95
Do*	[10] 55	Apr. 30–May 1, 1902	1	JCW	do.	5, 510	109	334	435	+. 7	17. 4	145	8. 33
Digestion*	[12] 614	Apr. 23–27, 1903	4	JCW	do.	(13)	(13)	(13)	(13)		[14] 14. 4	[14] 128	[14] 8. 89
Metabolism*	[12] 56	Apr. 27–30, 1903	3	JCW	do.	5, 570	112	347	450	+1. 2	15. 7	138	8. 79
Digestion†	[12] 616	May 3–7, 1903	4	JCW	do.	(13)	(13)	(13)	(13)		[14] 12. 6	[14] 123	[14] 9. 76
Metabolism†	[12] 57	May 7–10, 1903	3	JCW	do.	5, 530	107	86	1, 002	+. 4	14. 7	128	8. 71
Digestion†	[12] —	Nov. 7–10, 1903	3	HF	Rest	(13)	(13)	(13)	(13)		5. 6	58	10. 36

See footnotes at end of table.

493-791 O - 73 2

TABLE 8.—*Summary of data showing calorie-nitrogen ratio of urine based on early studies of energy metabolism and digestibility*—Continued

Kind of experiment	Experiment number	Date	Number of days duration	Subject	Activity	Daily nutrient intake: Gross energy	Daily nutrient intake: Protein	Daily nutrient intake: Fat	Daily nutrient intake: Carbohydrate	Nitrogen balance	Composition of daily urine: Nitrogen	Composition of daily urine: Heat of combustion	Composition of daily urine: Cal./N ratio
						Calories	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Calories*	
Metabolism	[11] 58	Nov. 10–13, 1903	3	HF	Rest	1, 500	40	27	252	−2. 2	8. 5	76	8. 94
Digestion	[12] 619	Jan. 21–27, 1904	6	BFD	do	(13)	(13)	(13)	(13)		15. 1	133	8. 81
Metabolism	[11] 60	Jan. 27–30, 1904	3	BFD	do	2, 510	101	51	356	−. 6	15. 7	130	8. 28
Do	[12] 61	Jan. 30–31, 1904	1	BFD	Work	3, 610	100	163	376	−1. 6	16. 5	138	8. 36
Digestion	[12] 622	Apr. 12–16, 1904	4	ALL	do	(13)	(13)	(13)	(13)		15. 3	126	8. 24
Metabolism	[12] 62	Apr. 16–19, 1904	3	ALL	do	4, 640	101	115	731	−. 8	15. 4	131	8. 51
Do*	[12] 63	Apr. 19–22, 1904	3	ALL	do	4, 750	103	300	323	−2. 0	17. 8	136	7. 64
Do*	[12] 64	Apr. 22–23, 1904	1	ALL	do	5, 390	117	365	337	+2. 4	15. 7	128	8. 15
Do†	[12] 65	Apr. 23–24, 1904	1	ALL	Rest	2, 370	96	30	389	−9. 4	24. 0	176	7. 33
Do	[12] 66	Apr. 24–25, 1904	1	ALL	do	2, 060	88	30	324	−9. 0	22. 3	157	7. 04
Do†	[12] 67	Apr. 25–27, 1904	2	ALL	Light	2, 110	68	29	371	−7. 2	17. 4	130	7. 47

[1] Atwater, W. O., Woods, C. D., and Benedict, F. G. U. S. Dept. Agr., Off. Expt. Sta. Bul. 44, 1897. (*23*)

[2] Atwater, W. O. Fourteenth Ann. Rept. of the Storrs Agr. Expt. Sta. 1901, pp. 179–245, 1902. (*7*)

[3] Atwater, W. O., and Benedict, F. G. U. S. Dept. Agr., Off. Expt. Sta. Bul. 69, 1899. (Rev. ed.) (*13*)

[4] Atwater, W. O., and Benedict, F. G. Natl. Acad. Sci. Sixth Mem. Vol. 8, 1902. (*15*)

[5] Included 512 calories from 72.5 grams alcohol.

[6] Average of the 16 experiments believed used by Atwater to obtain his first estimate of the calorie-nitrogen ratio 7.9 in 1897.

[7] Atwater, W. O., and Benedict, F. G. U. S. Dept. Agr., Off. Expt. Sta. Bul. 109, 1902. (*14*)

[8] 512 calories supplied by 72.5 grams alcohol on last day of experiment.

[9] Average of all metabolism and their preliminary digestion experiments made in period 1896–1899. These 41 experiments believed to be included in the 46 experiments used by Atwater to confirm 1897 estimate of calorie-nitrogen ratio.

[10] Atwater, W. O., and Benedict, F. G. U. S. Dept. Agr., Off. Expt. Sta. Bul. 136, 1903. (*16*)

[11] Experiment discontinued at end of first day, subject became nauseated and able to consume only part of food, worked 5 hours instead of customary 8 hours.

[12] Benedict, F. G., and Milner, R. D. U. S. Dept. Agr., Off. Expt. Sta. Bul. 175, 1907. (*27*)

[13] Amount not reported, but essentially same as in following experiment.

[14] Results for last two days of period.

*High fat diet, fat supplying one-half to two-thirds of the total calories.

†High carbohydrate diet, carbohydrate supplying two-thirds or more of the total calories.

A complete outline of the work, and the procedures followed were given in considerable detail by Atwater and Benedict (*16*). Those aspects of the study thought to have a direct bearing on the calorie-nitrogen ratio of the urine will be referred to here. Some additional details are given in the section on alcohol (p. 18). Selected data from the 55 experiments have been summarized in table 8 along with data from a later series in which Benedict and Milner continued the study.

Atwater designated the first four experiments of the series as "respiration experiments;" for these, analyses were made of food intake, drink, feces, urine, and respiratory products. No determinations were made of the heat given off from the body nor of the heat equivalents of external work in these experiments. He called the remaining experiments, Nos. 5 through 55, "metabolism experiments." They included measurements of energy in addition to the data obtained in the respiration experiments. Each metabolism experiment had two parts, a digestion experiment in which the subject lived under ordinary conditions and the metabolism experiment proper in which the subject lived in a respiration chamber. Digestibility data were available from the second part as well as from the first part of each metabolism experiment.

The respiration calorimeter, described in detail in U. S. Department of Agriculture Bul. 63 (*21*), was especially designed for this series of experiments. It included among other equipment a bed and a stationary bicycle with an ergometer for measuring external muscular work, thus providing for the study of metabolism of matter and energy under conditions of rest and strenuous activity.

In the so-called work experiments, the activity of the subject varied but in most cases he rode the stationary bicycle for 8 hours daily. During the preliminary digestion period, prior to the work periods within the calorimeter, the activity of the subject was sometimes comparable to that during the work period and sometimes was only his normal activity with some additional light exercise. This latter activity was designated as "light" in table 8 to differentiate it from the more strenuous activity of pedaling the stationary bicycle for 8 hours daily, referred to as a "work" experiment. In the "rest" experiments the subject remained quiet, avoiding all muscular activity as far as it was practical.

Certain precautions were taken to minimize errors in the nitrogen and energy determinations. The urinary nitrogen was determined in 6-hour intervals throughout the day, using the Kjeldahl method. A portion of each collection was reserved as part of a composite sample for the day. Nitrogen and the heat of combustion were determined on a portion of this composite and the remainder was preserved by adding formalin or thymol. This became a part of the composite sample for the whole period of usually 3 to 4 days. The analysis of the total composite sample checked closely with results obtained when the urine was analyzed each day. This assured the investigators that no significant error occurred from nitrogen or energy loss in the urine during storage.

The heats of combustion were determined by the Kellner method. A weighed absorption block of cellulose of known heat of combustion was saturated with a known amount of urine, dried at about 60° C., and burned in a bomb calorimeter. The results were corrected for the heat of combustion of the absorption block. This latter factor was an average of determinations for a number of similar blocks. The method was given in detail by Atwater and Snell, 1903 (*22*).

The investigators took into account the possibility that a lag in nitrogen excretion by the subjects would introduce some error in urinary estimations in the relatively short experimental periods of 3 to 4 days. This possible error was reduced by having periods on the same diet run consecutively. In addition to the incompletely oxidized matter lost in the urine the perspiration losses should be recognized. However, as nitrogen losses have been shown by 25 work experiments of Atwater and Benedict (*16*) to be small, averaging only 0.29 gram per day, and as data on comparable energy loss in the perspiration were lacking, the data in table 8 apply to urinary losses only.

The series was planned to study metabolism (1) while fasting, (2) when the proportions of fat and carbohydrate of an ordinary diet were varied, and (3) when a moderate amount of alcohol replaced fat and carbohydrate isocalorically. In the first 16 experiments rather simple mixed diets were used as shown in table 9. For these experiments the amounts of protein, fat, and carbohydrate, and the gross calories found by determination were reported. The amounts of other nutrients present in the diet have been calculated from tables of nutrient composition; these calculated values are shown in table 10.

In the annual report for 1899 (*17*) Atwater continued to use the same factor, 1.25 calories per gram of digested protein, in his calculations of available energy, although he recognized that this deduction was not accurate for all foods. Some error is introduced when this correction, based on the factor 6.25 to convert nitrogen to protein, is used with proteins or with nonproteins containing more or less than 16 percent nitrogen. In the same publication he mentioned briefly the derivation of the basic figure 7.9 calories per gram of urinary nitrogen. He stated that the figure was based on the average of 46 determinations. They were mainly from his laboratory with a few from Chas. D. Wood of the Maine Experiment Station. In addition to the first 16 experiments conducted prior to the 1897 report, the next 25 of the series may have been completed before the 1899 report was prepared. Possibly these 41 experiments, together with 5 unpublished from the Maine Experiment Station, made up the 46 experiments to which Atwater referred in the 1899 report.

TABLE 9.—*Daily food intake in the experiments from which Atwater originally obtained the calorie-nitrogen ratio of 7.9 for urine*

Food item	Respiration experiments				Metabolism experiments				Digestion experiments			
	1	2	3	4 [1]	5	6	7	8	37	39	41	43
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Beef, fried	121	121	96	96	120	100	169	150	121	100	170	150
Beef, dried					25		25		25		25	
Ham, deviled						50				52		
Eggs	98	101	100		95	54	141	95	107	52	144	103
Milk, whole (assumed raw)	1,000	500	660	650	775	850	575	850	775	850	575	850
Cheese	75	75										
Butter	35	35	20	45	35	75	15	35	34	75	15	35
Bread, brown				250								
Bread, white				150		450				450		
Bread, rye	250	228	275		325		150	325	316		150	328
Crackers, milk	100	100										
Oatmeal				40								
Wheat breakfast food									6			
Sugar	20	40	46	20	35	50	45	40	38	50	45	40
Beans, baked				120	125	125	125	125	125	125	125	125
Potatoes, boiled in skins	150	150	270	100								
Apples			85	125				200				200
Peaches			140									
Pears, canned			210		150	300	150		150	300	150	
Alcohol							72.5				72.5	

[1] Includes experiments 4P, 4A, 4B, 4C, and 4S. (See table 8.)

In the 25 additional published experiments in this series conducted prior to 1900, the diet was modified somewhat as compared with the first 16. It consisted of beef, whole or skim milk, butter, bread, cereal breakfast foods, graham crackers, ginger snaps, and sugar. The estimated nutrient intake was similar to that of the preceding experiments except that the ascorbic acid content was lower, probably only between 10 and 20 milligrams per day. The average calorie-nitrogen ratio for the 41 experiments, 7.88 (table 8), is not different from that found for the first 16 alone, 7.86.

The calorie-nitrogen ratio of the urine in these 41 experiments showed a wide variation with a range from 5.22 to 10.54. As the number of experiments under any one set of conditions was limited, it is scarcely feasible to conclude from this series how different factors such as level of intake, extent of digestibility, type of diet, and degree of activity influenced the calorie-nitrogen ratio of the urine. To the data in table 8 already mentioned, we have added data selected or calculated from the rest of the 55 metabolism experiments completed after 1899, and data from a series of metabolism experiments, numbers 56–67 by Benedict and Milner (*27*), which was actually a continuation of the earlier series of Atwater and Benedict. Benedict and Milner resumed the investigations of matter and energy in 1903. We have included data from these studies for reference since copies of the various publications in which the experiments were reported are no longer readily available and they furnish much valuable basic data.

The diets of the experiments conducted in 1900 and later showed very wide variations in gross calories and in the levels of protein, fat, and carbohydrate. The urinary calorie-nitrogen ratio for these experiments varied from 6.44 to 10.36. Both extremes were within those observed for experiments conducted prior to 1900; the average was 8.32, a little higher than for the preceding experiments.

Many other studies have been made in which data on urinary nitrogen and energy have been reported. To facilitate further study of this problem, some of these are noted below.

Rubner (*148*) determined the calorie-nitrogen ratio in urine on a variety of mixed diets, reporting an average ratio of 8.5. But a number of years later in a paper with Thomas (*151*) he reported that the ratio was between 7 and 8, although he had found variations outside this range. Among other problems Rubner (*148*) studied the influence of level of fat, single foods, and periods of rapid growth on calorie-nitrogen ratio of the urine and summarized the results as follows:

Food	Calories per gram N	Duration of experiment
		Days
Mother's milk	12.10	7
Cow's milk, infants	6.93	7
Cow's milk, adults	7.71	7
Diet poor in fat	8.57	2
Do	8.33	4
Diet rich in fat	8.87	2
Do	8.44	4
Boys' mixed diet	6.42	4
Boys' mixed diet rich in fat	7.50	4
Meat	7.69	1
Potatoes	7.85	1

TABLE 10.—*Daily nutrient intake in the experiments from which Atwater originally obtained the calorie-nitrogen ratio of 7.9 for urine*

Nutrient	Respiration experiments				Metabolism experiments				Digestion experiments			
	1	2	3	4[1]	5	6	7	8	37	39	41	43
Gross energy...calories	3, 230	2, 920	2, 640	2, 740	2, 660	3, 680	[2]2, 460	2, 900	2, 680	3, 680	[2]2, 470	2, 930
Protein...grams	142	120	96	101	119	119	104	129	118	116	104	122
Fat...grams	126	112	73	85	95	153	68	96	96	154	69	102
Carbohydrate...grams	296	281	338	328	276	378	190	308	281	381	192	311
Calcium...milligrams	1, 882	1, 290	962	1, 394	1, 137	1, 269	891	1, 224	1, 145	1, 214	895	1, 230
Iron...milligrams	15. 3	14. 4	15. 1	16. 4	17. 9	13. 0	17. 0	17. 9	18. 2	13. 5	17. 3	18. 1
Vitamin A value...International Units	4, 700	3, 940	3, 620	3, 040	3, 520	4, 490	3, 050	3, 820	3, 620	4, 460	3, 090	3, 900
Thiamine...milligrams	1. 26	1. 02	1. 35	1. 06	1. 17	1. 04	. 90	1. 26	1. 20	1. 05	. 86	1. 27
Riboflavin...milligrams	2. 87	2. 12	2. 06	1. 89	2. 29	2. 35	2. 02	2. 43	2. 35	2. 33	2. 04	2. 43
Niacin...milligrams	14. 6	13. 7	15. 6	16. 4	15. 4	13. 8	14. 4	16. 2	14. 8	14. 0	14. 4	15. 3
Ascorbic acid...milligrams	42	32	67	35	21	25	16	29	21	25	16	29

[1] Includes experiments 4P, 4A, 4B, 4C, and 4S. (See table 8.)

[2] Includes about 500 calories from 72.5 gm. alcohol in diet.

Rubner and Thomas (*151*) found the urinary calorie-nitrogen ratio for a subject on a diet solely of potatoes to be 9.04, 11.92, and 10.09 for the 1st, 4th, and 6th days respectively—ratios which were much higher than Rubner had observed in earlier experiments except for the infant on mother's milk. Sherman (*156*) reported a series of metabolism experiments on very simple diets of crackers and milk and in some cases butter. In one series periods of restricted and liberal intakes were alternated. Experimental periods of 3 to 5 days followed consecutively, two series for 12 days each and a third series for 20 days, to provide a better basis for following and interpreting changes in the composition of the urine. There was no apparent difference in the calorie-nitrogen ratios found for the periods on restricted and liberal intakes. The range was 7.39–8.00. In general the ratio was somewhat lower than that found by Atwater and coworkers for subjects on mixed diets.

Benedict made an extensive investigation of nitrogen and energy losses in the urine under fasting conditions, reporting his results in two publications (*25, 26*). When body material is metabolized the calorie-nitrogen ratio appears to be even more variable than that found for different kinds of mixed diets but the average ratio is higher. He reported ratios in the range of 8 to 10 for the first day of fasting, increasing with each successive day until after several days some were in the range of 14 to 18.

Several investigations have been made in which calories and nitrogen in the urine of children have been reported, notably those of Macy (*111, 112*). Her studies provided data on a group of children ranging from 4 to 12 years of age over an extended period of time. From the composition of the urine reported the calorie-nitrogen ratio has been calculated for each child. The ratio does not appear to differ appreciably from that obtained by Atwater for adults. Related problems have been studied by Folin (*54*), Rubner (*149*), Rubner and Heubner (*150*), and Tangl (*180*).

In view of the wide variation observed for the calorie-nitrogen ratio of the urine, the use of an average calorie value per gram of nitrogen may be questioned. Data providing a measure of the magnitude of the discrepancies when the available energy of the whole diet is calculated by the three procedures outlined on page 8 have been brought together in table 11. The experiments selected represent the more extreme conditions on record as follows: (1) Those in which the actual calorie-nitrogen ratio of the urine was considerably above or below the average; (2) those in which the subject was in different states of N-balance; and (3) those in which the subjects had diets of widely different composition with respect to proportions of calories from fat, protein, and carbohydrate.

The data show that although the amount of energy lost in the urine is highly variable, on the whole it is small compared with the gross energy of the food eaten. This is not surprising since less than a third of the gross calories from the digestible protein is involved, and digestible protein makes up only 10 to 25 percent of the total calories in these diets. Consequently, an error introduced by the use of an average calorie value per gram of either urinary nitrogen or net absorbed nitrogen does not affect greatly the calculated available energy of the whole diet.

For individual high-protein foods such as lean meat and some defatted nut and legume products, urinary loss might be a much more significant factor in determining available energy. If suitable data were available not only for foods of high nitrogen content but for all foods having some nonprotein nitrogen, and if data were available on the digestibility and utilization of the various nitrogenous compounds, a more accurate procedure for calculating available energy could be developed. Such data are not available and we are continuing to use Atwater's correction of 1.25 calories per gram of available protein (nitrogen content 16 percent).

For purposes for which the calculation of urinary energy loss from nitrogen in the usual way is not satisfactory, attention is called to the work of Rubner (*149*) and of Benedict (*25, pp. 490–492*). Benedict found less variability in the ratios of calories to either carbon or organic matter than in the ratio of calories to nitrogen. He found closer relationship when he related the energy to carbon but in view of the difficulty in determining carbon he suggested as a more feasible procedure, using the somewhat less constant calorie-organic matter ratio of the urine. The latter was largely proportional to the carbon content of the urine and far more readily determined. Benedict's suggestion for making the urinary energy deduction on this basis rather than using the more variable calorie-nitrogen ratio in estimating available calories in foods should be given further consideration.

Alcohol

The perplexing subject of the energy value of alcohol has been investigated from time to time for more than 50 years. Investigations have included such problems as the extent to which alcohol can spare protein for building or maintenance of body tissue, and the use of alcohol for muscular activity, deposition of fat, and generation of heat for maintenance of body temperature. Particularly controversial has been the question of the body's use of alcohol for muscular work.

The gross energy value of alcohol is 7.07 calories but its physiological energy value has been assessed variously by different groups of investigators. Daniel, 1951 (*45*) suggested using about 5.0 calories per gram, since from animal experiments and various biochemical studies it

TABLE 11.—*Comparison of data for available energy obtained by direct determination only and in part by calculation* [1]

Experiment number and kind (See table 8)	Average gross energy per day			Nitrogen absorbed (net) per day	Nitrogen in urine per day	Heat of combustion of urine per gram urinary N	Daily N-balance	Available energy obtained from data in preceding columns—			Deviation from values obtained by direct determination, of values calculated by—	
	Food	Feces	Urine					By direct determination Procedure 1 (2)−[(3)+(4)]	In part by calculation Procedure 2 (2)−[(3)+7.9 (5)]	In part by calculation Procedure 3 (2)−[(3)+7.9 (6)]	Procedure 2	Procedure 3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Calories	*Calories*	*Calories*	*Grams*	*Grams*	*Calories*	*Grams*	*Calories*	*Calories*	*Calories*	*Percent*	*Percent*
65 (Metabolism)	2, 369	92	176	14. 5	24. 0	7. 33	−9. 5	2, 101	2, 162	2, 087	+2. 9	−0. 7
66 (Metabolism)	2, 062	92	157	13. 3	22. 3	7. 04	−9. 0	1, 813	1, 865	1, 794	+2. 9	−1. 0
67 (Metabolism)	2, 114	92	130	10. 1	17. 4	7. 47	−7. 3	1, 892	1, 942	1, 885	+2. 6	−. 4
41 (Metabolism)	4, 539	231	158	15. 4	20. 0	7. 90	−4. 6	4, 150	4, 186	4, 150	+. 9	0
38 (Metabolism)	3, 708	153	155	15. 7	20. 3	7. 64	−4. 6	3, 400	3, 431	3, 395	+. 9	−. 1
43 (Metabolism)	4, 867	224	147	15. 1	18. 8	7. 82	−3. 7	4, 496	4, 524	4, 494	+. 6	0
45 (Metabolism)	4, 860	256	150	15. 2	18. 9	7. 94	−3. 6	4, 454	4, 484	4, 455	+. 7	0
198 (Digestion)	4, 258	246	105	13. 9	16. 3	6. 44	−2. 4	3, 907	3, 902	3, 883	−. 1	−. 6
48 (Metabolism)	4, 856	280	162	15. 0	17. 2	9. 42	−2. 2	4, 414	4, 458	4, 440	+1. 0	+. 6
48 (Respiration)	2, 741	120	84	14. 8	16. 1	5. 22	−1. 3	2, 537	2, 504	2, 494	−1. 3	−1. 7
8 (Metabolism)	2, 897	117	152	19. 5	19. 5	7. 79	0	2, 628	2, 626	2, 626	−. 1	−. 1
25 (Metabolism)	2, 896	111	147	16. 7	16. 5	8. 91	+. 2	2, 638	2, 653	2, 655	+. 6	+. 6
76 (Digestion)	2, 622	71	111	18. 3	18. 0	6. 17	+. 3	2, 440	2, 406	2, 409	−1. 4	−1. 3
49 (Metabolism)	5, 499	172	135	16. 6	15. 5	8. 71	+1. 1	5, 192	5, 196	5, 205	+. 1	+. 3
80 (Digestion)	2, 638	96	121	15. 9	13. 0	9. 31	+2. 9	2, 421	2, 416	2, 439	−. 2	+. 7
43 (Digestion)	2, 935	158	140	18. 3	14. 2	9. 86	+4. 1	2, 637	2, 632	2, 665	−. 2	+1. 1
49 (Digestion)	3, 860	198	136	18. 0	12. 9	10. 54	+5. 1	3, 526	3, 520	3, 560	−. 2	+1. 0
39 (Digestion)	3, 684	192	96	17. 2	11. 1	8. 65	+6. 1	3, 396	3, 356	3, 404	−1. 2	+. 2

[1] Data selected from more extensive list of experiments shown in table 8. The reader is referred to that table for further information and for source of original publication.

appears that only 65 to 70 percent is available for muscular work. The Food and Agriculture Organization Committee on Calorie Conversion Factors and Food Composition Tables did not publish a review of the literature but suggested in their report (*55*) that alcohol be omitted in computations of energy value of diets for two reasons—it is seldom possible to estimate alcohol consumption accurately, and little is known regarding its physiological energy value.

The gross potential energy value of alcoholic beverages was estimated by Atwater and Benedict to be as much as 500 calories per day for an individual's consumption described as "moderate." Statistics based on alcohol tax receipts in this country indicate that the average per capita consumption (man, woman, and child) of alcoholic beverages in recent years is approximately equivalent to 76 calories (gross value) per day. Were children and all other nonusers eliminated, the average consumption for users would be much higher. For numerous purposes, therefore, some assessment must be made of the energy value of alcohol.

The question is still being debated whether the energy of alcohol can be used for various physiological processes to the same extent as the organic constituents of food or whether its use is limited entirely or partially to providing heat. Reviews of the different aspects of alcohol utilization have been published by Carpenter (*35*), Mitchell and Curzon (*122*), Keys (*80*), and Klatzkin and others (*82*).

To be accurate, the assessment of food energy should take into account the site of the energy conversion and physiological destination of the nutrients. Up to the present no such additional refinements have been attempted in any common method of estimating energy values of foods. Attempts to do so with a view to obtaining calorie values to apply to foods under real life situations would be very complex. To illustrate, Keys (*81*) pointed out that when starch is hydrolyzed to glucose in the gastro-intestinal tract, approximately 14 calories per 100 grams are released in the body. This is available only as body heat and for no other purpose. If the hydrolysis occurs during cooking, these calories are lost before ingestion. In estimating calorie values of starch this type of difference is not taken into account. Of more importance, he pointed out, is the demonstration that, calorie for calorie, fat is about 12 percent less efficient for production of external muscular work than carbohydrate, yet there is no difference if calories are needed solely to maintain body temperature.

The potential energy of moderate amounts of alcohol may have a more limited usefulness in body metabolism than energy from proteins, fats, and carbohydrates. In view of the fact that in estimating calorie values, differences in availability and efficiency of use of the energy from these common sources are not considered, it does not seem necessary at present to discount the energy value of alcohol, particularly since there is considerable evidence that when intake is moderate a large part may be available for muscular work and that all of it may serve as a source of body heat.

The calorie factor for alcohol used in the tables in this publication is the one proposed by Atwater and Benedict (*15*), 6.9 calories per gram, based on respiration calorimeter studies in which they found that 98 percent of the heat of combustion (7.07 calories per gram) was utilized by the human body in its combined needs for energy in muscular work, building tissue, and maintaining body temperature.

Altogether Atwater and Benedict conducted 26 experiments, each lasting 2 to 4 days, in which they compared the metabolism of man on diets with and without alcohol. These experiments were part of the long series already referred to and are included in table 8.

In three groups of the first experiments, the periods with and without alcohol were not as directly comparable as in the six groups of later experiments, owing largely to lack of means for providing a food supply of uniform composition. By the time the later experiments were conducted, ways of preserving considerable quantities of food by canning and by cold storage had been devised. Three men in good health and with apparently normal digestion served as subjects in these 26 rest and work experiments. The respiration calorimeter used (see p. 15) was so constructed and equipped as to permit measurement and sampling for analysis of ventilating air, food, and excreta, and also for measurement of heat given off and external work performed by the subject.

The experimental plan for these 26 experiments was in general the same as that for the other experiments in the entire series. One difference was that in this group of experiments all periods were more than 1 day.

A preliminary digestion experiment of 3 or 4 days preceded each metabolism experiment. Each subject was on the experimental diet he was to have in the following period in the respiration chamber. During this preliminary period the subject made adjustments considered necessary in the diet and controlled his activity as much as possible to that he would have during the metabolism experiment in the calorimeter. The amounts, heats of combustion, and composition of food, feces, and urine were determined.

During the metabolism experiment these determinations were continued and in addition determinations were made of the water and carbon dioxide content of the ventilating air entering and leaving the respiration chamber, the heat given off by the body, and the heat equivalent of the muscular work performed during the work experiment. These data made it possible to determine the carbon, nitrogen, and hydrogen balance, the potential energy of food and unoxidized excreta, the kinetic energy of heat given off, and the external work performed.

Each subject had a rather simple diet consisting of such ordinary foods as meat, milk, bread, cereals, butter, sugar, and in some cases, coffee. During the rest experiments the diet supplied about 2,500 calories and during the work experiments, about 3,900 calories. In the rest experiments the subject performed as little activity as possible in addition to the necessary motions of dressing, undressing, handling of samples, recording of data, and the daily setting up and taking down of his cot. Most of the day was spent sitting, reading, or writing. In the work experiments he rode a stationary bicycle for a total of 8 hours a day.

Alcohol was substituted for either carbohydrate or fat or a mixture of both in 13 experiments, including rest and work experiments. About 72 grams (about 500 calories) were given in 6 small doses, 3 with meals and 3 at regular intervals between meals. Thus it furnished about a fifth of the calories during the rest experiments and between a seventh and an eighth of the calories during the work experiments.

The data showed that alcohol had no practical effect on digestibility except possibly in the case of protein. The coefficient of apparent digestibility of protein was a little larger in the experiments when the diet included alcohol than in comparable experiments without alcohol, 93.7 percent as compared with 92.6 percent.

The amounts of unoxidized alcohol given off by the kidneys, lungs, and skin were measured and deducted from the amount ingested. The difference was taken as the amount of alcohol oxidized in the body. Previous research by another worker had indicated that alcohol was not excreted by way of the intestine even when considerable quantities were taken. Therefore, no analysis of feces for alcohol was made. In these experiments only small amounts of unoxidized alcohol (0.7 to 2.7, averaging 1.3 grams) were recovered. The authors concluded that not more than about 2 percent would be given off unoxidized when taken in amounts comparable to those in these experiments. They suggested using 98 percent of the gross heat of combustion as the value of alcohol.

From these results Atwater and Benedict compared the energy of the daily net income and the outgo for subjects on diets with and without alcohol. The net income was the energy of the material actually oxidized in the body, and was determined by adjusting the available energy (gross food energy minus total calories in urine and feces) for calorie equivalent of loss or storage of body protein and fat. The total heat outgo was the energy measured by the apparatus as the heat given off plus the heat equivalent of the work performed by the subject. Whether or not the diet contained alcohol, the average energy outgo was equal to the average amount of energy of the net income. Atwater and Benedict concluded that the energy of alcohol oxidized was transformed completely into kinetic energy and appeared either as heat or as muscular work, or both.

Atwater and Benedict made some deductions concerning the protecting effect of alcohol on body material, based on the carbon, nitrogen, and hydrogen balances of the subjects. From these balances they estimated the daily gains and losses of body fat and protein, assuming that the glycogen stores for each individual at the beginning and end of the experiment were the same. They found some gains and some losses of body fat on either kind of diet but on the average there was a gain. This gain was slightly larger when the subjects were on the diets including alcohol than when on the ordinary diets; 2.4 grams daily as compared with 1.1 grams of fat in comparable experiments with and without alcohol. Storage and loss of body protein also was calculated. Comparisons made between the ordinary and alcohol periods indicated that alcohol was slightly inferior to carbohydrate or fat in protecting body protein; that is, a larger average daily loss, 6.9 grams, of body protein occurred in the alcohol periods than the average loss, 3.5 grams per day, for the ordinary periods.

Loss of the energy of alcohol by radiation of heat seemed to account for only a small proportion of the calorie value. Atwater and Benedict found that the radiation of heat from the body was only slightly greater with the alcohol diet than with the ordinary diet, and amounted to not more than 6 percent of the energy of alcohol.

Some of the results of the six groups of experiments (totaling 15 balances on 2 men) in which the alcohol and nonalcohol periods were more nearly comparable are shown in table 12. As the protein intake within each group of comparable experiments with and without alcohol is nearly constant, these data indicate approximately the effect of alcohol on both the apparent digestibility of protein and on the retention or loss of digested protein. There was a small increase in apparent digestibility and also some increase in urinary nitrogen excretion when the diets included alcohol. The heats of combustion which Atwater and Benedict applied in experiments 9 and 10 to changes in body protein and fat were 5.65 and 9.54 calories per gram, respectively. In their later experiments they changed the figure for body fat as they considered 9.4 calories per gram more nearly correct. The net effect of alcohol on gain or loss of body protein and fat in terms of total energy change is shown in column 13. The last two columns of the table show excellent agreement between energy expenditures obtained in two entirely different ways: by adjusting available energy of food intake for changes in amounts of body protein and fat, and by direct measurements of the heat given off by the body plus the heat equivalent of the muscular work performed (in the work experiments).

TABLE 12.—*Effects on energy metabolism of replacing portions of dietary carbohydrate and fat by alcohol*

Subject, diet, and experiment number	Activity	Daily intake		Daily N excretion		Nitrogen balance	Gross heat values						Energy value of material oxidized in body	
							Determined for—			Calculated for gain or loss of body tissue [1]				
		Protein	Energy	Feces	Urine [1]		Feces	Urine	Excreted alcohol	Protein	Fat	Net change	Energy of net income 4−(cols. 8+9+10+13)	Body heat loss plus heat equivalent of work
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
EO on a mixed diet:		*Grams*	*Calories*	*Grams*	*Grams*	*Grams*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*
9 Without alcohol [2]	Rest	119. 6	2, 717	1. 3	18. 4	−0. 6	142	149		−20	+174	+154	2, 272	2, 309
10 With alcohol replacing 520 calories from the diet (37 gm. fat, 45 gm. carbohydrate). [3]	do	123. 5	2, 709	1. 4	19. 5	−1. 1	127	147	8	−38	+200	+162	2, 265	2, 283
EO on a mixed diet:														
11 Without alcohol [4]	Work	124. 1	3, 862	2. 2	18. 1	−. 5	219	133		−17	−374	−391	3, 901	3, 932
12 With alcohol replacing 512 calories mainly from carbohydrate.[5]	do	120. 6	3, 891	1. 3	18. 2	−. 2	136	130	11	−6	−302	−308	3, 922	3, 927
EO on a mixed diet:														
24 Without alcohol [4]	Rest	123. 6	3, 061	1. 3	18. 2	+. 3	116	136		+10	+561	+571	2, 238	2, 272
22 With alcohol replacing 509 calories of sugar.[5]	do	123. 2	3, 044	1. 1	18. 5	+. 2	114	138	15	+8	+589	+597	2, 180	2, 258
JFS on a mixed diet:														
26 Without alcohol, supplement of 63.5 gm. butter, supplying 508 calories.[4]	do	99. 6	2, 490	1. 1	15. 4	−. 6	106	128		−20	+233	+213	2, 043	2, 085
28 Without alcohol, supplement of 128 gm. cane sugar, supplying 507 calories.[4]	do	98. 6	2, 489	1. 2	15. 3	−. 7	112	128		−26	+208	+182	2, 067	2, 079
27 With alcohol [5]	do	98. 6	2, 491	1. 1	15. 7	−1. 0	97	124	6	−35	+174	+139	2, 125	2, 123
JFS on a mixed diet:														
31 Without alcohol, supplement of 63.5 gm. butter, supplying 511 calories.[4]	Work	100. 9	3, 495	. 8	15. 6	−. 3	91	129		−13	−151	−134	3, 439	3, 420
29 Without alcohol, supplement of 128 gm. sugar, supplying 507 calories.[4]	do	100. 1	3, 487	. 8	16. 0	−. 8	93	134		−28	−227	−255	3, 515	3, 589
30 With alcohol supplement (72 gm.), supplying 509 calories.[5]	do	99. 2	3, 458	. 7	17. 3	−2. 1	71	140	5	−74	−163	−237	3, 479	3, 470

JFS on a mixed diet:														
32 Without alcohol, supplement of 63.5 gm. butter, supplying 510 calories.[4]	do	100. 5	3, 487	1. 2	15. 7	−. 8	142	119		−14	−333	−347	3, 573	3, 565
34 Without alcohol, supplement of 128 gm. sugar, supplying 507 calories.[5]	do	99. 7	3, 493	1. 2	16. 7	−1. 9	126	126		−54	−334	−388	3, 629	3, 587
33 With alcohol supplement (72 gm.), supplying 509 calories.[5]	do	99. 7	3, 486	1. 2	17. 3	−2. 5	125	129	5	−76	−366	−442	3, 669	3, 632

[1] Includes 0.2 gm. nitrogen per day from loss in perspiration for work experiments 11, 12, 29, 30, 31, and 0.4 gm. nitrogen per day for work experiments 32, 33, and 34. No correction for nitrogen loss in perspiration during rest experiments.

[2] In these experiments the heats of combustion used by Atwater and Benedict were 5.65 calories per gram of body protein, and, except in experiments 9 and 10, 9.40 calories per gram for body fat; in experiments 9 and 10, 9.54 calories per gram of body fat was used.

[3] Atwater, W. O., and Benedict, F. G. U. S. Dept. Agr. Off. Expt. Stas. Bul. 69, 1899. (Rev. ed.) *(13)*

[4] Atwater, W. O., and Benedict, F. G. U. S. Dept. Agr. Off. Expt. Stas. Bul. 109, 1902. *(14)*

[5] Atwater, W. O., and Benedict, F. G. National Academy of Science Sixth Mem., vol. 8, 1902. *(15)*

A comparison of the experiments with and without alcohol (column 13) indicates that within each group, when 72 grams of alcohol (509 calories) replaced an approximate calorie equivalent of fat and/or carbohydrate, the calculated net gain or loss of energy value in the form of body tissue was sometimes a little larger and sometimes a little smaller than the change calculated for the comparable experiments when no alcohol was included. In these six groups of experiments the calculated calorie change of body tissue varied from an additional gain of 83 calories to a larger loss of 95 calories as compared with the corresponding nonalcohol experiment. Under the conditions of these experiments Atwater and Benedict concluded that alcohol must have been used by the body about as efficiently as the nutrients from ordinary food it replaced. In the most extreme case, alcohol calories were only about four-fifths as well used as the food calories which alcohol replaced. These experiments do not prove but suggest that under the conditions comparable to those in these experiments much of the energy of alcohol can be used in the body for internal or muscular work.

PART III. DERIVATION OF CURRENT CALORIE FACTORS

Since Atwater first proposed his individual food group factors and his general factors for estimating the fuel value of mixed diets as a whole (*17*), enough data for a number of foods have accumulated to make possible some revisions and additions. For other foods more data are urgently needed.

Prior to 1947 the Bureau of Human Nutrition and Home Economics had summarized the available information on digestibility by man of bread made from wheat of three levels of extraction and had compiled preliminary material for potatoes. Since then, study of the scientific literature has been continued, permitting the addition of coefficients of digestibility for many more items. Data from the digestibility studies reviewed are given in appendix tables 23 and 24. The resulting summary of data on human digestibility and heat of combustion needed for deriving specific calorie values of individual items of food or of small food groups is given in table 13. Where further information was lacking, Atwater's data were taken from the revised figures for column F in table 10 of his report cited above and reproduced as table 7, page 10. The figures in columns 4, 7, and 10 are the specific factors to be applied to the grams of protein (nitrogenous material), fat (usually ether extract), and carbohydrate (determined by differences) in the food to obtain the physiological energy value.

Before discussing the derivation of the specific calorie factors shown in table 13, a few general observations should be made regarding the basis of the data.

The basis for the coefficients of digestibility in table 13 could have been broadened greatly, if the large volume of work with experimental animals in the literature had been included. Some work has been done to compare digestibilities of man and experimental animals. Brierem and Nicolaysen (*30*) compared utilization of protein and dry matter in wheat and rye brans by man with utilization by sheep and swine. Later Crampton and others (*43*) compared man's use of several grain products with that of rats, sheep, and swine. However, there is insufficient evidence at present for concluding that digestibility of nutrients by experimental animals can be used to predict that of man. If a relationship could be established, research in this field could proceed more economically and more rapidly.

The energy factors shown in table 13 do not rest on equally reliable information. The number of subjects for different foods varied considerably. In general, no information was available on the possible departure of the test diet from the previous dietary pattern. Lack of uniformity was observed in the experimental procedures used, including lengths of the preliminary and experimental periods, choice of marker, and the relative proportion of the diet furnished by the test food. The foods tested, expecially in the early digestion experiments, were not always adequately described, nor was the chemical composition of the sample always reported. In some cases, reasonable assumptions could be made as to the identity of the samples. For a few foods neither descriptive nor composition data were reported by the investigators, and energy factors derived from digestibility data in those experiments may be shown by future work to need considerable revision. Grain products of various degrees of milling as described some 50 years ago have presented particularly knotty problems. Although the products were identified by extraction and other recognized milling terms, composition data in addition were necessary to classify them in terms of the most nearly comparable products on the market today.

TABLE 13.—*Data used for calculating energy values of foods or food groups by the Atwater system* [1]

Food or food group	Protein			Fat			Carbohydrate		
	Coefficient of digestibility	Heat of combustion less 1.25 [2]	Factor to be applied to ingested nutrients	Coefficient of digestibility	Heat of combustion	Factor to be applied to ingested nutrients	Coefficient of digestibility	Heat of combustion	Factor to be applied to ingested nutrients
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Eggs, Meat products, Milk products:	*Pct.*	*Cal./gm.*	*Cal./gm.*	*Pct.*	*Cal./gm.*	*Cal./gm.*	*Pct.*	*Cal./gm.*	*Cal./gm.*
Eggs	97	4.50	4.36	95	9.50	9.02	98	3.75	3.68
Gelatin	97	4.02	3.90	95	9.50	9.02			
Glycogen	----	----	----	----	----	----	98	4.19	4.11
Meat, fish	97	4.40	4.27	95	9.50	9.02	----	----	(3)
Milk, milk products	97	4.40	4.27	95	9.25	8.79	98	3.95	3.87
Fats, separated:									
Butter	97	4.40	4.27	95	9.25	8.79	98	3.95	3.87
Other animal fats	----	----	----	95	9.50	9.02	----	----	----
Margarine, vegetable	97	4.40	4.27	95	9.30	8.84	98	3.95	3.87
Other vegetable fats and oils	----	----	----	95	9.30	8.84	----	----	----
Fruits:									
All (except lemons, limes)	85	3.95	3.36	90	9.30	8.37	90	4.00	3.60
All fruit juice (except lemon, lime) unsweetened	85	3.95	3.36	90	9.30	8.37	[4] 98	4.00	[4] 3.92
Lemons, limes	85	3.95	3.36	90	9.30	8.37	[4] 90	2.75	[4] 2.48
Lemon juice, lime juice, unsweetened	85	3.95	3.36	90	9.30	8.37	98	2.75	2.70
Grain products:									
Barley, pearled	78	4.55	3.55	90	9.30	8.37	94	4.20	3.95
Buckwheat flour, dark	74	4.55	3.37	90	9.30	8.37	90	4.20	3.78
Buckwheat flour, light	78	4.55	3.55	90	9.30	8.37	94	4.20	3.95
Cornmeal, whole ground	60	4.55	2.73	90	9.30	8.37	96	4.20	4.03
Cornmeal, degermed	76	4.55	3.46	90	9.30	8.37	99	4.20	4.16
Dextrin	----	----	----	----	----	----	98	4.11	4.03
Macaroni, spaghetti	86	4.55	3.91	90	9.30	8.37	98	4.20	4.12
Oatmeal, rolled oats	76	4.55	3.46	90	9.30	8.37	98	4.20	4.12
Rice, brown	75	4.55	3.41	90	9.30	8.37	98	4.20	4.12
Rice, white or polished	84	4.55	3.82	90	9.30	8.37	99	4.20	4.16
Rye flour, dark	65	4.55	2.96	90	9.30	8.37	90	4.20	3.78
Rye flour, whole grain	67	4.55	3.05	90	9.30	8.37	92	4.20	3.86
Rye flour, medium	71	4.55	3.23	90	9.30	8.37	95	4.20	3.99
Rye flour, light	75	4.55	3.41	90	9.30	8.37	97	4.20	4.07
Sorghum (*kaoliang*), whole or nearly whole meal	20	4.55	.91	90	9.30	8.37	96	4.20	4.03
Sorghum (*feterita, kafir, milo*), 80–85 percent extraction	[4] 50	4.55	[4] 2.28	90	9.30	8.37	[4] 97	4.20	[4] 4.07
Wheat, 97–100 percent extraction	79	4.55	3.59	90	9.30	8.37	90	4.20	3.78
Wheat, 85–93 percent extraction	83	4.55	3.78	90	9.30	8.37	94	4.20	3.95
Wheat, 70–74 percent extraction	89	4.55	4.05	90	9.30	8.37	98	4.20	4.12
Wheat, flaked, puffed, rolled, shredded, whole meal	79	4.55	3.59	90	9.30	8.37	90	4.20	3.78
Wheat bran (100 percent)	40	4.55	1.82	90	9.30	8.37	56	4.20	2.35
Other cereals, refined	85	4.55	3.87	90	9.30	8.37	98	4.20	4.12
Wild rice	78	4.55	3.55	90	9.30	8.37	94	4.20	3.95
Legumes; Nuts:									
Mature dry beans, cowpeas, peas, other legumes; nuts	78	4.45	3.47	90	9.30	8.37	97	4.20	4.07
Immature lima beans, cowpeas, peas, other legumes	78	4.45	3.47	90	9.30	8.37	97	4.20	4.07
Soybeans, dry; soy flour, flakes, grits	78	4.45	3.47	90	9.30	8.37	97	4.20	4.07
Sugars:									
Cane or beet sugar (sucrose)	----	----	----	----	----	----	98	3.95	3.87
Glucose	----	----	----	----	----	----	98	3.75	3.68
Vegetables:									
Mushrooms	70	3.75	2.62	90	9.30	8.37	85	4.10	3.48
Potatoes and starchy roots	74	3.75	2.78	90	9.30	8.37	96	4.20	4.03
Other underground crops [5]	74	3.75	2.78	90	9.30	8.37	96	4.00	3.84
Other vegetables	65	3.75	2.44	90	9.30	8.37	85	4.20	3.57
Miscellaneous foods:									
Alcohol [6]	----	----	----	----	----	----	----	----	----
Chocolate, cocoa	42	4.35	1.83	90	9.30	8.37	32	4.16	1.33
Vinegar	----	----	----	----	----	----	98	2.45	2.40
Yeast	80	3.75	3.00	90	9.30	8.37	80	4.20	3.35

[1] In a few cases values in columns 4, 7, and 10 are slightly different from those shown in table 7, column F, revised, because of different methods of rounding figures.

[2] The correction, 1.25 calories, has been subtracted from the heat of combustion. This gives values applicable to grams of digested protein and identical with Atwater's factors per gram of available protein.

[3] Carbohydrate factor, 3.87 for brain, heart, kidney, liver; 4.11 for tongue and shellfish.

[4] Revision made since 1955.

[5] Vegetables such as beets, carrots, onions, parsnips, radishes.

[6] Coefficient of digestibility, 98 percent; heat of combustion, 7.07 calories per gram; factor to apply to ingested alcohol, 6.93 calories per gram.

Physiological Fuel Values of Foods of Animal Origin

For determining physiological fuel values of foods of animal origin, Atwater's factors for the different categories are still being used with only slight changes. His coefficient of digestibility of 97 percent for the protein of meat, fish, eggs, and dairy products has been used without change in this publication (see table 7).

Many items of animal origin contain small amounts of carbohydrate to which Atwater applied the energy factor 3.82 calories per gram. He obtained this using 3.90 calories as heat of combustion and a coefficient of digestibility of 98 percent. Some small revisions in this factor are indicated in view of current information on the form of carbohydrate predominating in the different kinds of foods of animal origin. These revisions, which are very minor, are noted in the following paragraph.

For the carbohydrate of milk and milk products, we have used for the physiological energy factor, 3.87 calories per gram. This is based on the heat of combustion for lactose, 3.95 calories per gram, and Atwater's coefficient of digestibility, 98 percent.

Eggs contain a small amount of carbohydrate, chiefly glucose, bound in a large complex. The energy factor used in this publication, 3.68 calories per gram, was obtained by applying the coefficient of digestibility, 98 percent, to 3.75, the heat of combustion of glucose. Perhaps this figure is too low for simple sugars which require no digestion.

Appreciable amounts of glucose and glycogen have been found in tissue of brains, heart, and glandular organs, the relative amounts varying according to metabolic conditions at the time of slaughter and conditions of storage. For heat of combustion, 3.95 calories per gram, a figure intermediate between the heats of combustion of glucose and glycogen, has therefore been selected, resulting in a physiological energy factor of 3.87 calories per gram.

Analyses have shown glycogen to be the main carbohydrate constituent of tongue and some kinds of shellfish. Hence, to derive an appropriate energy factor, we applied the coefficient of digestibility, 98 percent, to 4.19, the heat of combustion of glycogen, and the resultant factor was 4.11 calories per gram.

For animal fats we have used Atwater's energy factors, 8.79 calories per gram for fats in dairy products and 9.02 for fats from other animal sources.

Physiological Fuel Values of Plant Products

Separated fats of plant origin are important items today but were practically unknown 50 years ago. For them we have used the digestibility coefficient, 95 percent, that Atwater used for butter and other animal fats. For the heat of combustion of fat in plant products, whether or not separated, we have continued the use of Atwater's factor, 9.3 calories per gram.

Margarine as manufactured in the United States of America may be made of either animal or vegetable fats, and a few States have laws requiring a specified high proportion of animal fats. However, as most margarine in this country is made with vegetable oils, the factor 8.84 calories per gram for fat in margarine shown in table 13 was based on heat of combustion of 9.3 calories per gram and a coefficient of digestibility of 95 percent. Margarine of either type and butter contain small amounts of protein and carbohydrate carried over from the milk in which the fats were blended or churned. The calorie factors for protein and carbohydrate of milk were used for those constituents of margarine.

For fat as it occurs in cereals and other plant sources Atwater assumed the apparent digestibility to be 90 percent and we have continued this practice. The energy factor for fat in plant foods is therefore assumed to be 8.37 calories per gram.

The revisions we have made in the Atwater factors for the physiological fuel values of protein and carbohydrate of plant products have resulted mainly from adding data from a comprehensive review of digestibility studies reported since 1875. For a few foods the revisions result from changes in the heat of combustion factors used. More specific energy factors, together with the average coefficients of digestibility and heats of combustion from which they were derived, are presented in table 13. The basis for the differences in these figures as compared with Atwater's factors for food groups is discussed in the remainder of this section. In some instances the values may prove to need further revision as the result of future research, but we believe them to be better approximations for individual foods than either the general, overall factors or the food group factors that were developed in 1899. The basic data on digestibility from which the factors were obtained have been compiled in table form (appendix table 23).

This compilation is not entirely complete for studies reported in foreign languages, but we believe it covers the bulk of early and recent research in which apparent digestibility of the test food was measured. Articles in which apparent digestibility was not reported or could not be calculated for the test food alone were not included. By this criterion, digestion experiments such as those of F. Erismann (*52*) were excluded. His coefficient of digestibility for protein has been quoted by various authors in early publications as applying to peas, but a translation of the original article shows that the coefficient was applied to bread made of 50 percent pea meal and 50 percent rye flour without adequate basis for calculating the digestibility of the pea meal alone. Included in the compilation are several experiments which contribute useful information although for various reasons they have been excluded from the data used for obtaining average coefficients.

The derivation of the energy factors in table 13 is discussed in the following paragraphs by food groups since foods within a group have certain characteristics and problems in common. Where no mention is made of the derivation of factors, Atwater's data considered most applicable to the particular item or small food group have been used.

Products of wheat

By far the largest proportion of the digestion experiments reported have been concerned with foods of the cereal group. Of the cereal foods wheat has been studied in most detail.

Flours

Digestibility of wheat flour was studied first by Rubner and other European scientists during the latter part of the 19th century. As milling practices and the terms used have changed over the years, we encountered problems in deciding how to combine and group the large volume of data on the digestibility of wheat flours. Wheat flours milled commercially and experimentally have been studied extensively since 1900, particularly in the United States and in Great Britain. For a great many of these flour samples, enough information is available so that the flours can be arranged in three groups according to degree of extraction from the kernel. These three groups were described by United States scientists in the early part of the 20th century as graham, entire wheat, and as straight or standard patent. Not all the terms used then still apply but the data are usable.

Graham was essentially whole-wheat meal, but may have had a very small amount of coarse material removed. The straight and standard patent flour group contained the first and second patent flours and the first clear flour and made up about 70 to 72 percent of the wheat kernel, which is in line with modern-day yields of straight grade flour. Data on the composition of the straight patent flours used in the early experiments when reported also indicated that from the standpoint of proximate constituents the straight patent flours were similar to those produced in recent years. In some instances the standard patent was blended with small amounts of the low-grade flours, second clear and red dog.

More variation existed in the flours included in those of the intermediate extraction. The so-called entire-wheat flour as described by Woods and Merrill (*194*) included patent, first clear, second clear, red dog, and shorts, indicating that it may have been somewhat more than 85 percent of the kernel. For comparison, the average milling yields from several commercial millings of cleaned wheat reported in 1941 by Sherwood and others (*160*) have been included here as follows:

Milled fraction:	*Percent yield*
Patent flour	63.0
First clear flour	7.0
Second clear flour	4.5
Red dog flour	4.0
Germ	.2
Shorts	12.3
Bran	9.0

If it could be assumed that the sum total of the fractions comprising the entire-wheat flour of the early experiments was comparable to the fractions reported by Sherwood, theoretically the yield of entire-wheat flour would have been close to 91 percent. Usually the entire-wheat flour was referred to as being of about 85-percent extraction. Probably this was a little low. Woods and Merrill (*194*) stated that 100 pounds of cleaned No. 1 wheat would make 85 to 88 pounds of entire-wheat flour, that the large mills gave rather larger yields than small mills, and that a starchy wheat yielded 1 to 3 pounds more than a hard wheat. They also stated that the ash content of the entire-wheat flour was about half that of the whole-wheat flour.

Snyder (*164, 166, 168*) also conducted experiments in that period and used entire-wheat flours, but the indications are that the flours he used were of somewhat longer extraction than those described by Woods and Merrill. The flours of longer extraction were obtained by removal of part of the coarser bran by screening and the inclusion of fine bran, shorts, and germ. The amount of coarse bran removed varied from a small proportion to over half the total amount present. Data he reported showed that the ash content of the entire-wheat samples ranged from 51 to 92 percent of that in the wheats from which they were milled. In view of this kind of information it is likely that entire-wheat flour represented about 90 percent of the cleaned wheat. The latter figure was also arrived at independently by a milling expert in the United States Department of Agriculture who estimated the probable extractions of a number of samples of entire-wheat flour from their ash contents in relation to the ash content of the whole-wheat from which each was milled.

Since such estimates may be more or less in error, and since the information on the milling and composition of the flours suggests that the entire-wheat flour was not always of uniform extraction, we have considered it preferable in this publication to assume that the data applied to flours within the range of 85- to 93-percent extraction. Likewise for flours designated as standard patent we have assumed that the data applied to flours of 70- to 74-percent extraction. With regard to the whole-wheat or graham flours used in the early studies, it has been assumed that flour so designated may have been of from 97- to 100-percent extraction, since there was some evidence that a small amount of the outer portion of the kernel may have been removed.

The average coefficients of digestibility of protein and of carbohydrate for wheat flours of these three extraction ranges are based on more than 70 digestibility trials on whole-wheat and near whole wheat flours, more than 50 trials on wheats of intermediate extractions, and over 100 digestibility trials on straight and patent flours. The average coefficients of digestibility are shown in table 14. The variation in digestibility found for the protein of wheat was much greater than that for the carbohydrate, and there was greater variation in the digestibility of longer extraction flours than for refined flours of shorter extraction.

The wheat samples used in the digestibility studies were largely hard wheats, both spring and winter varieties; a few soft wheats were included. Data on proximate composition were available for the whole-wheat flours used in 18 digestibility trials, for the flours of intermediate extraction in 22 trials, and for the straight and patent flours in 28 trials. Average values for the flours of known composition are shown in the first column of table 14. Within each of the three groups there was much variation. The protein content of the whole-wheat samples, for example, ranged from 8.5 to more than 15 percent, the majority containing over 12 percent. At present, data are inadequate to determine to what extent variation observed in digestibility within groups and between groups may have been due to differences in protein and carbohydrate content of the flours.

TABLE 14.—*Energy values of wheat flours calculated by use of specific energy factors for protein, fat, and carbohydrate*

Type of flour	Composition [1]	Coefficient of digestibility	Energy value of available nutrient	Energy factors to be applied to ingested nutrients (col. 3 × col. 4)	Available energy of food using specific factors (col. 2 × col. 5)
(1)	(2)	(3)	(4)	(5)	(6)
Essentially whole wheat [2] (97–100 percent extraction):	*Percent*	*Percent*	*Cal./gm.*	*Cal./gm.*	*Cal./100 gm.*
Protein (N × 5.83)	12.6	79	[3] 4.55	3.59	45.2
Fat	1.9	[4] 90	9.30	8.37	15.9
Carbohydrate by difference	71.8	90	4.20	3.78	271.4
Total					332.5
Intermediate extraction (85–93 percent): [2]					
Protein (N × 5.7)	12.0	83	[3] 4.55	3.78	45.4
Fat	1.8	[4] 90	9.30	8.37	15.1
Carbohydrate by difference	73.0	94	4.20	3.95	288.4
Total					348.9
Patent [2] (70–74 percent extraction):					
Protein (N × 5.7)	11.7	89	[3] 4.55	4.05	47.4
Fat	1.3	[4] 90	9.30	8.37	10.9
Carbohydrate by difference	74.5	98	4.20	4.12	306.9
Total					365.2

[1] Composition data are calculated to a 12-percent moisture basis.

[2] The ash content found for the wheat flours are 1.7 percent for essentially whole wheat, 1.2 percent for wheat of intermediate extraction, and 0.5 percent for patent flour.

[3] 1.25 calories have been deducted from the heat of combustion of 1 gram of protein to correct for loss of incompletely metabolized products in the urine.

[4] Assumed coefficient of apparent digestibility for fat in plant products, 90 percent, used because actual data for wheat were unsatisfactory.

The average digestibility of the protein and of the carbohydrate for any one type of flour of known chemical composition showed differences of less than 1 percent from average coefficients of digestibility obtained by using data from all of the samples of that type. The coefficients based on all the samples within the group, therefore, were used for deriving the energy factors shown in table 14. It is unlikely that the heat of combustion value would be the same for the nitrogenous portion of flours of different extraction rates. The relative proportions of protein and nonprotein nitrogen compounds and the composition of the protein fraction itself are each known to vary. These changes would be expected to affect the heat of combustion and hence the energy factors also. However, in preparing table 14, no attempt was made to adjust the heat of combustion data for differences in the heat values of the protein or fat mixtures in the flours of different extractions.

Energy values for flours at each of the three extractions have been worked out from the composition data of the known samples. The results, shown in the last column of table 14, are considered suitable for flours of the extractions and compositions specified.

From time to time calorie values for flours of other extractions are needed. To estimate coefficients of digestibility for protein and carbohydrate in such flours, the digestibility data estimated at the three extraction rates, 100, 90, and 70 percent, for the wheat flours just discussed were used. This was done inasmuch as the few scattered digestion experiments reported on flours of other specified extractions of wheat were so varied in conditions and methods that the results were not usable for this purpose. The relationship between the percent extraction and coefficient of digestibility of wheat can be expressed in the form of the equation $y=a+bx+cx^2$, where x=percent extraction and y=coefficient of digestibility. By the method of least squares the constants for this equation, fitting the three points based on average digestibility data for wheat of 100-, 90-, and 70-percent extraction, were as follows for protein and carbohydrate:

Equation constant	Value of constant	
	Protein	Carbohydrate
a	0. 890	0. 700
b	. 00233	. 00867
c	−. 0000333	−. 0000667

Digestibility coefficients (y) for other extraction percentages (x) were computed by solving the equation.

From this equation, coefficients of digestibility of protein and carbohydrate were calculated for flours of 95-, 85-, 80-, and 75-percent extraction. The values found are shown in table 15. Additional intervening points may be determined from the equation or read from a curve. For convenience the energy factors to apply to the protein and carbohydrate in wheat flours of the specified extractions are also included in table 15.

Degree of extraction has been accepted here as the most important influence on digestibility of wheat flour. To test this assumption an estimate was made of the extent to which rate of extraction was associated with coefficients of digestibility. The relationship of these two, based on those subjects for whom data were available at each of three extraction rates, was found to be represented by an equation of the form $y=a+bx+cx^2$, where the extraction rate is the independent variable. R^2, the variance, was 44 percent, showing that almost half of the variation in the coefficient of digestibility was associated with variation in extraction. This indicates that the assumption was warranted since 56 percent of the variation remained to be distributed among such factors as level of protein intake, level and nature of carbohydrate, length of experimental period, the variation characteristic of each subject, and fineness of grind of the flour.

TABLE 15.—*Apparent digestibility and physiological fuel value of wheat flours*

Percent Extraction	Coefficient of digestibility		Specific energy factor	
	Protein	Carbohydrate	Protein	Carbohydrate
	Percent	*Percent*	*Cal./gm.*	*Cal./gm.*
100	79	90	3. 59	3. 78
95	(81)	(92)	3. 69	3. 86
90	83	94	3. 78	3. 95
85	(85)	(96)	3. 87	4. 03
80	(86)	(97)	3. 91	4. 07
75	(88)	[1] (98)	4. 00	4. 10
70	89	98	4. 05	4. 12

[1] 97.5 by calculation from equation, page 29.

Since 1945, when the relationship between coefficient of digestibility and degree of extraction were worked out rather hastily for wheat of 100-, 90-, and 70-percent extractions, some additional data have been located in the literature and others have become available as the result of more recent research. The inclusion of these additional values did not warrant any change in the coefficients of digestibility published earlier (*55, 118*), and we have continued to use them.

Methods of determining energy values used in Great Britain.—McCance and his associates have given special attention to assessing the energy values of cereals (*102, 104, 108*). They differentiated between available and physiological calories and as both procedures differ from the one used in this country and as certain of the terms have different meanings we include here a brief discussion of their work—particularly as it relates to wheat.

The consideration given carbohydrate has been an important difference between the systems for estimating energy used by English and American scientists. Data on carbohydrate in British tables of food composition are based on "available carbohydrate," which includes sugars, starches, and dextrins—carbohydrates assumed to be fully utilized by the body, but exclude as unavailable, fiber and nonfermentable sugars or pentoses. The analytical determination of available carbohydrate has been discussed by McCance and Lawrence (*103*).

Available calories as calculated by McCance are the sum of the gross calories in the available carbohydrate fraction of the food, plus the calories from fat after deduction for fecal lipids, plus the calories from protein after deduction for fecal and urinary losses of nitrogenous matter. In principle this procedure is similar to that used in this country but the method for determining available calories from carbohydrate is different; also there are some differences in the actual calorie factors selected for protein and fat.

To illustrate how the calorie factors for the calculation of available calories are obtained, data are presented here from a study of McCance and Walsham (*104*). Digestion and utilization of calories of two samples of whole-wheat flour, one made from a low-protein English wheat and the other from a high-protein Canadian wheat were determined for adult subjects. The calorie factors for protein were found by applying the coefficients of apparent digestibility of protein found in these digestion experiments to the factor 4.35 calories per gram (5.65 less 1.3 calories per gram for urinary loss) used by Sherman (*158*) for the heat of combustion of protein in a mixed diet. The apparent digestibility of protein was found from the experiment to be 84.9 percent for the Canadian flour and 74.2 percent for the English flour.

The calorie factor for fat was obtained by applying 58 percent, the coefficient of apparent digestibility found for fat, to 9.45 calories the heat of combustion per gram of fat in a mixed diet (*158*). From these experimental data the calorie factors to be applied to analytical data on the content of protein and fat to obtain the calories from these nutrients in the two samples of flour were thus found to be 3.65 and 5.5 calories per gram, respectively, for the Canadian and 3.21 and 5.5 calories per gram for the English wheat flours. Calories from carbohydrates were obtained by applying the gross calorie factor for starch, 4.2, to data on content of "available carbohydrate" expressed as starch for each wheat.

Physiological calories as calculated by McCance include only the gross calories from those fractions of the nutrients which definitely may be considered usefully available. Provision is made for excluding urinary calories, a loss resulting from incomplete combustion of protein, but no deduction is made for nitrogenous matter in feces; likewise no deduction is made for fecal fat. The fraction of the carbohydrate measured is considered completely available. It is treated in the same way for determining physiological calories as in the determination of available calories—the fraction of questionable value as a source of energy is excluded and a gross heat value is used with the data on available carbohydrate content. For use in food tables physiological calories are the values McCance considers most suitable (*102*, *104*, *108*), because, as he has pointed out (*107*), it is unusual to make allowance for losses in the feces in presenting data on composition of foods.

Physiological calories based on data from the experiment with the two whole-wheat flours were calculated to be the sum of the calories from carbohydrate obtained in the same way as for available calories above, plus the gross calories from fat (9.4×grams of fat in the wheat sample) present in the food, plus the gross calories from protein present with a deduction for urinary loss (4.35×grams of protein content in the wheat).

Data reported by McCance and Walsham from this study for gross, available, and physiological calories for the two samples of whole-wheat flour (15 percent moisture) were as follows:

Type of data	Canadian wheat	English wheat
Gross calories:	*Calories*	*Calories*
Food (bomb)	372	350
Fecal (bomb)	−45	−40
Urinary loss (1.3×net absorbed N)	−17	−8
Available calories (from above)	310	302
Available calories calculated by McCance procedure	299	304
Physiological calories calculated by McCance procedure	320	320

Additional calculations of energy values.—Using data from the same study, McCance and Walsham also made two additional energy calculations—one attributed to the Atwater procedure and one in which energy factors for wheat used by Food and Agriculture Organization were applied. We have not included results for these two calculations for two reasons. The application of the general calorie factors for protein, fat, and carbohydrate of a mixed diet to a specific food is not a procedure used by Atwater. Moreover, McCance and Walsham do not report values for ash content and thus it is not possible to determine the total carbohydrate (by difference), a value needed to use the Atwater procedure correctly. When assumed figures for ash suggested by the authors were used, gross calories calculated from composition were observed to differ from bomb determinations by 15 calories per 100 grams in the case of Canadian wheat and 24 calories per 100 grams in the case of English wheat. In view of the close agreement previously reported (p. 6) between calculated values for gross calories and bomb calorimeter determinations, the discrepancies of 4 percent for the Canadian and 7 percent for the English wheat seem too large to warrant the use of these assumed figures for a comparison between the two methods of calculation.

We have not located any reports in the literature in which adequate data are given for evaluating the two methods of assessing available calories in foods—the McCance procedure outlined above and the Atwater procedure as we use it. For a correct appraisal of the two methods by means of digestion experiments, the following data are essential: (1) Chemical composition of the food samples, which should include moisture content, nitrogen compounds, fat, ash, carbohydrate by difference, and available carbohydrate (starch and sugar); (2) bomb calorimeter determinations of the foods and excreta. Such an evaluation, if made for other types of food as well as wheat, would provide very useful information.

Alimentary pastes; other flour mixtures

Macaroni and other alimentary pastes usually are made with semolina or durum flour as the principal ingredient. This type of wheat has characteristics different from wheats used for preparing wheat flours for bakers and homemakers. Digestion experiments were carried out in 1905 by Snyder (*168*) and at an earlier date by several European scientists to determine the digestibility of macaroni and other kinds of alimentary pastes. Only in the study reported by Snyder was the flour used in making the pastes described in any detail. In this latter study the flour milled from durum wheat represented a somewhat larger portion of the kernel and was more granular in appearance than the patent flour used for bread making purposes. The average coefficients of digestibility found for macaroni, 86 percent for protein and 98 percent for carbohydrate, seemed reasonable in view of other studies indicating that both degree of extraction and coarseness of grind affected the apparent digestibility, particularly of the protein, of flours.

The specific energy factors for protein and carbohydrate calculated by use of these coefficients of digestibility and the heats of combustion of wheat flours were 3.91 and 4.12, respectively. The factors are considered applicable to the various alimentary pastes made from flour and water. Digestibility of those containing eggs or milk might be somewhat different, but as only small amounts of these optional ingredients are present separate factors are not proposed.

The digestibility of some other products in which flour is the main ingredient has been studied also. Deuel published results found for a variety of baked products including yeast breads, baking powder biscuits, cakes, cookies, crackers, and others (*48*). The coefficient of digestibility of protein ranged from 85 to 94 percent and that for carbohydrate from 97 to 99 percent.

For flour mixtures that vary considerably with respect to ingredients, such as cookies, energy factors were calculated for each product, weighting the energy factors of each ingredient in proportion to the amounts present in the product. This procedure is explained in more detail on page 42.

Bran

Differences in apparent digestibility between whole-grain flours and those of short extraction suggested that bran might have a low coefficient of digestibility. Some investigations have been undertaken to determine the digestibility of bran alone, and while the results were variable, the coefficients were in every case very low. The average apparent digestibility found for the protein of bran was 40 percent based on 14 digestion experiments, and for carbohydrate, 56 percent based on 16 experiments. These coefficients were applied to the heats of combustion of protein (nitrogenous matter) and carbohydrate of wheat, and the energy factors obtained for the two nutrients after customary deduction for urinary nitrogen loss were 1.82 and 2.35.

Wheat breakfast foods

Foods in this group have been studied in some detail in digestion experiments, but as the experimental diets were low in protein the apparent digestibility as determined may have been too low. Hence, rather than use these data in estimating digestibility, we used the coefficients of digestibility of whole-wheat flour (table 13) to obtain tentative estimates for whole-wheat meals and other whole-wheat cereals. Likewise for farina and other breakfast foods made from the endosperm we used the coefficients of digestibility of patent flour. These factors would result in some overestimation of energy values for foods subjected to special processing that reduces utilization of any of the organic nutrients and possibly for meals of a coarser grind than that of wheat flour. For breakfast foods that are mixtures, we derived weighted energy factors if we knew the kind and approximate proportions of ingredients.

Products of grain other than wheat

The digestibility and physiological fuel values of corn, oat, rice, and rye products have been studied less than wheat but more than most of the remaining grains.

Although information on the various cereals is not strictly comparable, on the whole it indicates that differences in digestibility may be expected among grains and that neither the fiber content nor the level of protein intake alone appears to be adequate basis to explain differences observed among cereals when fed to human subjects.

Spriggs and Weir (*172*) found the digestibility of the protein in a mixed diet containing bread made with white flour to be 91 percent, but when only a third of the flour was replaced successively by oatmeal, barley flour, fine sifted corn flour or rice flour the digestibility was 87.6, 81.5, 86.7, and 89.7 percent, respectively. Jones and Waterman (*77*) observed significant differences in the extent to which proteins may be digested in vitro by pepsin and trypsin. They found that arachin, casein, and cooked phaseolin were 48, 61, and 58 percent digested and suggested that the order in which the amino acids were united to form the proteins might be responsible for the incomplete digestion; some linkages are more resistant than others to the hydrolytic action of digestive enzymes.

Other workers studying the physiological availability of purified proteins have observed wide differences in the proportions of a given amino acid in the feces of experimental animals, depending on the protein fed. These and other studies indicate that among the various kinds of cereals considerable difference in digestibility and physiological fuel values may be expected. Digestibility data from the literature for the various kinds of cereals have been summarized separately. The average coefficients of digestibility and the number of experiments on which each was based are shown in table 16. As more research becomes available these data will no doubt need revision. Data on wheat have been included in the table for ease in comparison.

TABLE 16.—*Coefficients of apparent digestibility for grain products*

Grain Product	Protein		Carbohydrate	
	Coefficient of digestibility	Experiments	Coefficient of digestibility	Experiments
	Percent	*Number*	*Percent*	*Number*
Cornmeal, whole-ground, bolted	60	3	96	3
Cornmeal, degermed	76	21	99	21
Oatmeal, rolled oats	76	48	98	24
Rice, brown	75	22	98	22
Rice, white or milled	84	119	99	119
Rye flour:				
Dark	65	(1)	90	(1)
Whole-grain	67	(1)	92	(1)
Medium	71	(1)	95	(1)
Light	75	(1)	97	(1)
Wheat flour:				
Essentially whole wheat, 97 – 100 percent extraction	79	72	90	72
Intermediate, 85 – 93 percent extraction	83	53	94	53
Straight or patent, 70 – 74 percent extraction	89	104	98	104

[1] Coefficients of digestibility for rye flours were derived less directly as explained on pages 33 and 34. Therefore, the number of experiments is not indicated.

Cornmeal

The cornmeals studied have been of two general types, whole meal, sifted through a 16-mesh sieve which may have removed a small amount of the bran, and degermed cornmeal which probably had most of the bran, as well as the germ, removed. In addition to the meals, digestibility data for several other corn products have been reported. Although most of these other studies were not used directly they have been included in appendix table 23 and were helpful in that the digestibility coefficients tended to confirm the averages for the two cornmeals shown in table 16. Data for only three digestion trials were found in which sifted whole-ground cornmeal was used. The average coefficient of digestibility of the meal eaten in the form of cornbread by three subjects was close to 60 percent for protein and 96 percent for carbohydrate. These values are in line with digestibility coefficients for field corn (pressure-cooked) and for hulled corn (hominy), which, judging by their fat and fiber content, must have contained the germ and more of the branny portion than degermed corn products. Degermed cornmeal prepared as mush or as cornbread has been used in several studies. Average coefficients based on 21 digestibility trials were found to be 76 percent for protein and 99 percent for carbohydrate. Hence, the energy factors suggested and used here for protein and carbohydrate in whole grain corn products are 2.73 and 4.03 calories per gram, and in degermed corn products, 3.46 and 4.16.

Data on apparent digestibility of frozen raw cornmeal and toasted corn breakfast products also were found in the literature or could be calculated from the information reported by the authors. They have been recorded in appendix, table 23, for reference but for various reasons were not used in assessing the energy value of corn products.

Oatmeal

Several studies have been made of oat products, mainly oatmeal or rolled oats, which were either cooked and used as a porridge or baked as oat cakes. Also recorded in this appendix table but not used in obtaining average digestibility figures were a few experiments on ready-to-eat cereals.

Based on 48 digestibility trials, the average coefficient of digestibility for protein was found to be 76 percent and that for carbohydrate, based on 24 trials, 98 percent. As was the case with most of the cereals there was more variation in the coefficients of digestibility for protein than for carbohydrate. Using the average coefficients of digestibility, the energy factors for protein and carbohydrate are 3.46 and 4.12 calories per gram, respectively.

In most cereals the quantity of fat present is so small that the use of Atwater's assumed digestibility coefficient of 90 percent for fat in plant foods introduces very little error in the total energy value of the food. Oatmeal, which contains 7 to 8 percent fat on an average, has more fat than most cereals and its digestibility is of more significance. In 28 experiments in which the digestibility of fat in oatmeal has been reported or could be calculated from data given, the results have varied from 56 percent to complete digestibility. These values were largely from two studies, a recent report by McCance and Glaser, 1948 (*102*), and a much earlier article by Harcourt and Fulmer, 1907 (*62*). The range in digestibility of fat found by McCance and Glaser was 62.5 to 77.6 percent. In their experiments, six subjects were fed a mixture of two oatmeals, having an average fiber content of 0.9 percent, supplemented with a little bramble jelly or sirup. The daily intake of 34 to 67 grams of fat was supplied entirely by the oatmeal.

A very wide range, 57.6–97.9 percent, in the coefficients of digestibility for fat in oatmeal was calculated from data in 16 experiments published by Harcourt and Fulmer (*62*). These investigators tested four oatmeals with fiber contents of 1.94, 1.15, 1.12, and 1.04 percent. Seven subjects participated but not all subjects ate each of the four meals. The daily intake of 58–120 grams of fat was supplied by oatmeal and either milk or cream, with about one-fifth to one-third of the total contributed by oatmeal. For the purpose of calculating the digestibility of the fat in oatmeal from data supplied we assumed the digestibility of the fat of milk and cream to be 95 percent. To the extent that this average figure may not be applicable for these specific experiments there may be some error in our calculated results for oatmeal.

The data from Harcourt and Fulmer suggest that there may be some relation between digestibility and fiber content of oatmeal. When the oatmeals of both 1.94 percent fiber and lower fiber contents were fed to the same subjects under similar experimental conditions, the fat digestibility of the oatmeal of 1.94 percent fiber was lower than that of samples with the much smaller percentages of fiber. Of interest in this connection are results reported by McCance and Glaser (*102*) who found that the substance or mixture of substances which they estimated as fiber in oatmeal passed through the gut almost without change. The results raise several questions. Is intestinal motility related to the fiber content of oatmeals and if so does this affect the digestibility of fat? To what extent do metabolic products account for fat (ether-extractable matter) in the feces? The experimental evidence is inadequate either to interpret the widely divergent coefficients found or to determine which part of the range would be closer to the true value. The Atwater energy factor, 8.37 calories per gram of fat in cereals and other plant foods in general, therefore has been used without change for fat in oat products.

Rice

The most extensive study on digestibility of rice was carried out in a series of experiments by Sugimoto, Higuchi, Momyeda, Tonaka, Yasuda, and others and was published by Saiki in 1926 (*178*). The subjects, all Japanese men, ate rice as part of a mixed diet. The rice used was of four categories which were described in one of the articles as follows:

(a) Unpolished rice.—Rice from which the husk had been removed, but which still retained the outer layer, or silver skin, and the embryo or germ.

(b) 50% polished rice.—Rice which had been milled and polished but which retained half of the outer layer and germ.

(c) 70% polished rice.—Rice which still retained about 30 percent of the outer layer and germ.

(d) Polished rice (white rice).—Rice which had been polished perfectly, so that the germ was almost entirely rubbed off in the milling.

The actual amounts of the rice kernel removed in the polishing differ somewhat with the variety of rice, but about 4 percent of the unpolished rice kernel was removed in making the half-polished rice, nearly 6 percent in making the 70-percent polished rice, and approximately 7 to 8 percent in making the fully polished white rice. According to one article in the series no polishing powder was used. Judging from other information given, the unpolished rice may have been the same as brown rice; the half-polished rice may be considered as an extraction of about 96 percent of the brown rice; the 70-percent polished, as an extraction of about 94 percent; and the polished rice, about a 92-percent extraction. On the basis of paddy or rough rice, which is a more common basis for expressing milling yields, the extraction rates, assuming the loss in removing the hulls to be 21 percent, would be about 79 percent for brown rice, 76 percent for half-polished, 74 percent for 70-percent polished, and 73 percent for polished white rice.

Rubner (*144*) and also Snyder (*167*) studied the digestibility of rice when eaten by men subjects as part of very simple diets. Probably the rice used was ordinary white rice but it was not described in either study. The number of experiments in which Europeans and Americans were subjects was too small to permit a good comparison but there appeared to be no marked difference in digestibility of the rice for the Japanese men who very likely were accustomed to eating it as a major item in their diet and for the German and American subjects who probably had it only occasionally.

The average coefficients of digestibility for the unpolished (brown) rice, based entirely on the Japanese studies, were 75 percent for protein and 98 percent for carbohydrate; for half-polished rice the coefficients were 82 and 99 percent, respectively, for the two nutrients, and for 70-percent polished rice, 83 and 99 percent. For white rice the average coefficients of digestibility based on data reported by Saiki, Rubner, and Snyder were 84 percent for protein and 99 percent for carbohydrate.

The energy factors we suggest for the protein and carbohydrate of brown rice are 3.41 and 4.12 calories per gram respectively, and for white rice, 3.82 and 4.16.

Rye

Many of the digestion experiments on rye flours were conducted years ago in Germany. In some studies the diet was simple rye bread or rye bread and beer. Some of the subjects who were unaccustomed to eating large quantities of rye bread experienced pain in the digestive tract and in some cases diarrhea, a factor that might vitiate the digestibility figures. But on the basis of the data reported there was no clear-cut means of eliminating this factor. In other experiments there was more variety in the diet but on the whole the diets were simple. Results indicate no appreciable differences in digestibility when subjects had rye bread alone or as part of simple mixed diets.

Rye flours have been described as dark, whole-grain meal, medium, and light, and the following data on their composition have been cited as being representative for these products (*100*, *185*):

Constituent	Dark	Whole-grain meal	Medium	Light
	Percent	*Percent*	*Percent*	*Percent*
Water	11. 0	11. 0	11. 0	11. 0
Protein	16. 3	12. 1	11. 4	9. 4
Fat	2. 6	1. 7	1. 7	1. 0
Ash	2. 0	1. 8	1. 1	. 7
Fiber	2. 4	2. 0	1. 0	. 4
Carbohydrate, total by difference	68. 1	73. 4	74. 8	77. 9

As there are no standards of identity for these products, much variation may be expected in appearance and composition of samples of a given designation or grade. For example, light rye has been described as ranging from white to medium-light flour with a comparatively wide range in proximate composition. In these circumstances, it was difficult to determine the type of flour used in the early digestibility studies. However, there is a marked decrease in fiber and ash content with increasing degree of refinement, and the ash content reported for the rye flours studied in the digestion experiments served as a criterion for deciding in which of the above four categories—dark, whole-grain, medium, or light—to include the data.

Little information is available on digestibility of medium and dark rye flours. However, the relationship of the digestibilities of either protein or carbohydrate observed between the light and whole-grain rye flours was similar to that observed between the straight patent and whole-wheat flours. On the assumption that this similarity in ratios can be extended to include intermediate extractions of rye and wheat flours, digestibility values for other extractions of rye flour were imputed from ratios for wheat flours where data on rye flour were lacking. Ash content was taken as a general index of the degree of extraction of the flour. Thus for rye flours of the composition shown in Agriculture Handbook No. 8 (*185*) and described as dark, whole-grain, medium, and light we estimated the digestibility of protein as 65, 67, 71, and 75 percent and the corresponding digestibility of the carbohydrate as 90, 92, 95, and 97 percent, respectively. Using these coefficients of digestibility and Atwater's heats of combustion for cereals, the energy factors to apply to dark, whole-meal, medium, and light rye flour are, respectively, 2.96, 3.05, 3.23, and 3.41 calories per gram of protein and 3.78, 3.86, 3.99, and 4.07 per gram of carbohydrate.

Other grains

For grains and grain products not included in table 16, very few digestibility data are available. Among the reports on these products is one by Woods and Snyder (*196*) which summarizes the results of the digestion experiments on cereal foods at the Connecticut (Storrs), Maine, and Minnesota Agricultural Experiment Stations.

For pearled and flaked barleys, Woods and Snyder applied their estimated coefficients of digestibility of barley products, 78 percent for protein and 94 percent for carbohydrate. These products had undergone some refinement and in chemical composition were much like modern pearled barley (*185*). The energy factors for pearled barley, calculated from these coefficients by use of the customary heat of combustion of grain products, are 3.55 and 3.95 calories per gram of protein and carbohydrate, respectively.

For buckwheat flour, "farina," and groats, Woods and Snyder estimated digestibility at 78 percent for protein and 94 percent for carbohydrate. Their composition data indicated that the products were refined forms, the fat, fiber, and ash content of 1.2, 0.4, and 0.9 percents for the flour being comparable to composition of modern light buckwheat flour. The above coefficients of digestibility applied to the heats of combustion for protein and carbohydrate in cereal products result in the following energy factors, 3.55 calories per gram of protein and 3.95 calories per gram of carbohydrate.

For dark buckwheat flour, we have found no experimental work on digestibility. The figures in table 13 have been calculated arbitrarily from data for light buckwheat flour, assuming that the ratio of digestibility of dark to light flour would be the same as that between whole-wheat flour and wheat flour of intermediate extraction. Judging by the ash content, the light buckwheat flour may have been comparable in degree of refinement to wheat flour of intermediate extraction and the dark buckwheat flour to whole-wheat flour. The coefficients of digestibility thus assumed for dark buckwheat flour were 74 percent for protein and 90 percent for carbohydrate, and the energy factors were 3.37 and 3.78 calories per gram, respectively

For wild rice, data are also to be found in the summary by Woods and Snyder. They report the coefficients of digestibility to be 78 percent for protein and 94 percent for carbohydrate, which would result in energy factors of 3.55 and 3.95 calories per gram, respectively.

Sorghums and *millets*, while little used in this country for human consumption, are important foods in some parts of the world. In sections of the Far East, both grains are used extensively, frequently prepared as a mush or ground into meal and used in bread.

Langworthy and Holmes (*93*) conducted experiments with the dual purpose of comparing the digestibilities of the different kinds of sorghums—kaoliang, feterita, kafir, and milo—and the digestibility of sorghums in general with that of other cereals, namely, wheat and corn. The grains were ground in the same mill and put through a 16-mesh sieve. By this treatment 5 percent of the bran was removed from kaoliang, 15 percent from feterita, 19 percent from milo, and 21 percent from kafir.

The differences in the structure of the grains probably account for the different amounts of the ground meals that passed through the 16-mesh sieve, being largest for the softer kaoliang which grinds more readily than the corneous types. The portions of the wheat and corn kernels removed was not stated. Each of the sorghums was used as bread or as mush; the corn and wheat as bread only.

In one of the kafir bread series the remainder of the diet consisted of milk, orange, and sugar. Otherwise, the diets in the bread series had in addition to the bread, applesauce, butter, sugar, and in most cases, potato. In the series containing mush, the diet was similar except that potato was omitted so that essentially all of the protein would be supplied by the test food.

Whether a sorghum meal was served as bread or as mush appeared to have had little influence on its digestibility. The carbohydrate was well utilized in all the sorghums; the average digestibility for the kaoliang was 96 percent and the carbohydrate of the other sorghum meals was as well or better utilized. Using 96 percent and 4.20 calories per gram as the heat of combustion, the energy factor for carbohydrate is 4.03.

The digestibility of the protein was extremely variable but considerably lower than that found for the protein in either wheat meal or cornmeal. Feterita and kafir, both hard corneous types of sorghum, showed similar average protein digestibility, approximately 50 percent. Milo is a somewhat softer type with a larger proportion of starchy endosperm; its average protein digestibility was about 40 percent. Kaoliang, which is very soft and has a high proportion of starchy endosperm, had a very low digestibility, slightly less than 20 percent.

In an experiment conducted by Abe and others (*1*) with Japanese subjects, when kaoliang was the main food in a mixed diet, the average digestibility of the protein in the total diet was 77 percent and the carbohydrate, 99 percent. No estimate was made for the sorghum alone. For the total diet the averages in the Langworthy and Holmes experiments were lower, only 24 percent for protein in the diets containing kaoliang, and 42 to 64 percent for protein in the other sorghum diets; for carbohydrate, 96 percent in the diets containing kaoliang and a range of 96 to 97 percent in the diets containing the other sorghums. The digestibility was lower in the experiments of Langworthy and Holmes, particularly for the protein. We question whether the higher coefficients for protein indicated by the experiments on Japanese subjects, possibly accustomed to eating kaoliang, are applicable for measuring digestibility in persons with an entirely different dietary pattern. Furthermore, we need to consider the composition of the other foods used with the sorghums. In many of the experimental diets of Langworthy, fruit, either oranges or applesauce, was a major item.

The data available do not provide a good basis for deriving a satisfactory figure for the apparent digestibility of sorghum protein. The variations observed were extremely wide and the particular extractions used for the Langworthy experiments may not be typical of the sorghum meals ordinarily used for food. A kaoliang meal of 95-percent extraction may not be typical but is not far short of whole meal. If a factor for whole-meal sorghum or nearly whole meal is needed, we suggest as a tentative factor 0.91 caloric per gram of protein. This is based on a digestibility of 20 percent, indicated by the work of Langworthy and Holmes for kaoliang and the usual heat of combustion for protein in cereals. We recognize the possibility that for persons accustomed to eating kaoliang, this factor may be too low. Better digestibility of protein and carbohydrate was indicated for the more refined meals of the other sorghums.

Millet also was studied by Langworthy and Holmes (*94*). The experimental plan was similar to that used for sorghums. Two millets were studied, common millet, *Setaria italica*, from which 40 percent of the bran portion was removed, and proso millet, *Panicum miliaceum*, from which 29 percent bran was removed by sifting the meals through a 16-mesh sieve. Both were fed as bread in a simple mixed diet of potato, orange, butter, and sugar.

The utilization of carbohydrate in millet was about like that for the sorghums. The average digestibility observed for the carbohydrate of each of the millets was high, 96 percent. The digestibility of protein of both millet meals was variable but was low, averaging approximately 40 percent for each kind. For millets as for the sorghums these samples prepared as described may not be at all comparable to the millet meals actually used. We have not attempted to derive calorie factors for millets but have called attention to this work since anyone needing data on millets may be able to adapt the information to their purpose.

Other grain products include various refined cereal foods such as breakfast foods prepared from a mixture of grains and also starches and flour mixtures. For some a few scattered data are available but the experimental conditions were not always such as to make them suitable for use in obtaining representative coefficients of digestibility. In lieu of satisfactory data, Atwater's group factors for cereals were used for these various products. His factors, 3.87 calories per gram for protein, 8.37 for fat, and 4.12 for carbohydrate, were predominantly weighted by refined cereals and therefore should give a fairly close approximation of the energy value of foods that have undergone considerable refinement.

Legumes

The array of data on digestibility of foods in the dry legume group (see appendix table 23) shows that several studies have been made of the more important items. For beans, peas, and soybeans the digestibility of carbohydrate (determined by difference) was high, averaging 96 to 98 percent; for cowpeas it was lower, about 90 percent. These high coefficients suggest possible utilization of some of the fiber and pentosans. Data are inadequate to explain the disappearance from the gut of much of the complex carbohydrate matter. Results of some investigations indicate that some are split by means of bacterial action into their simpler components and ultimately into end products that may be discarded by the body. To what extent intermediate products are absorbed is an unanswered question.

Both the kinds and amounts of carbohydrates present are of particular interest in comparing digestibilities of various legumes. Some legumes are similar in their content of moisture, protein, fat, ash, and total carbohydrate by difference, but several experiments indicate that the similarity does not hold for individual carbohydrates. Differences in digestibility might be more easily understood had more information been obtained on the makeup of the carbohydrate fraction in the legumes samples used. Data in the literature indicate that the proportion of the total carbohydrate (by difference) in the form of the so-called available carbohydrates, mainly starch, sugar, and dextrin, is less than one-half for cowpeas, two-thirds to more than three-fourths for beans (kidney, lima, mung) and chickpeas, 85 to 90 percent for lentils and peas. The total amount of crude fiber plus pentosans varied for the several foods, 12 percent for kidney beans, 10 percent for mung beans, 13 percent for chickpeas, 10 percent for cowpeas, and 7 percent for lentils. The undetermined fraction makes up a relatively large portion of the total carbohydrates in beans and cowpeas but only a small percentage in the other legumes.

For soybeans as much as two-thirds of the total carbohydrate is made up of the carbohydrate fraction usually considered to be of questionable availability. In this fraction a variety of substances has been found in widely varying amounts. These include raffinose, stachyose, pentosans, galactans, arabans, cellulose, lignin, organic acids, phytin, and glycosides. In addition to these some waxes, color principles, tannins, and undetermined hemicelluloses are believed to be present.

Bowers (*29*) studied the composition of the complex carbohydrate fraction of defatted soybean meal and the digestibility of separate constituents with a healthy man engaged in moderately active laboratory work as the subject. The digestion experiment was carried out according to customary procedures. The methods of analyses employed were those used by Street and Bailey (*174*). Analyses were made of both the soybean meal and the feces resulting from a ration of soybean meal porridge, milk, butter, and cane sugar. Bowers reported the coefficients of digestibility for the carbohydrates of cooked soybean meal as follows: Dextrin and starch, 99 percent; sucrose, 100 percent; raffinose, 100 percent; organic acids, 99 percent; pentosans, 93 percent; galactans, 96 percent; cellulose, 79 percent; and the remaining fraction, presumably waxes, color principles, and possibly undetermined hemicelluloses, 94 percent by difference. By calculation from the separate constituents he arrived at a digestibility coefficient of about 94 percent as compared with 96 percent which he found independently for total carbohydrate by difference.

Entirely different results for digestibility of the carbohydrate of uncooked soybeans were obtained by Adolph and Kao (*3*) in a series of in vitro experiments in addition to in vivo digestibility experiments with rats. They estimated the availability of soybean carbohydrate to be about 40 percent. This figure has been widely used in assessing soybean carbohydrate (*36*, *37*, *185*), but its application to soybeans for human use seems questionable.

In the manufacture of soybean curd and milk, much of the carbohydrate fraction is removed and the carbohydrates that are left appear to be almost completely digested. A digestibility coefficient of 98 percent was found for curd in a Japanese experiment (*134*).

Although there may be significant differences in digestibility of carbohydrates in different legumes as indicated in the very few studies available, it does not appear wise at the present time to depart from the group factor, 4.07 calories per gram, originally used by Atwater for carbohydrate in legumes.

A large number of studies has provided data on the apparent digestibility of protein in legumes. Although some variation may be observed (see appendix table 23) the data on the whole support the digestibility and energy factors used by Atwater. They are suggested here for use with soybean curd and milk because the data in the literature are too variable to indicate whether or not the factors for either protein or carbohydrate are applicable to these two products.

Nuts

Nuts present problems regarding digestibility and composition similar to those of the legume group. Little has been reported on their digestibility and it is difficult to evaluate the few results that have been published. The most extensive work on this food group was reported by Jaffa

(*75*), who determined the digestibility of diets composed of fruit and nuts in 28 experiments. The kinds of nuts studied were almonds, Brazil nuts, coconuts, pecans, walnuts, and peanuts, a legume which is used like nuts. In 20 of these experiments, in which most of the protein was supplied by nuts, the average digestibility for the dietary protein was about 75 percent. This value is lower than usually is found for mixed diets in which plant foods predominate. Possibly the low apparent digestibility was the result of the large quantities of fruit consumed. Unfortunately the effect of the amount and kind of carbohydrate from the fruit on the digestibility of the protein and fat in the nuts could not be determined from these studies.

The apparent digestibility of the protein of nuts alone estimated from these 20 experiments by use of Atwater's figure of 85 percent digestibility for fruit protein, ranged from 54 to 87 percent, averaging 70 percent for nuts as a group. From the two experiments on peanuts the calculated coefficient of digestibility for protein would be 81.5 percent. These figures may be too low since the calculation is dependent on the digestibility of the whole diet. Holmes (*70, 72*) found a much higher digestibility, 92 percent, for peanut protein. He used a simple mixed diet which included either pressure-cooked peanuts or baking powder biscuits that had been made with peanut flour. The peanuts Jaffa used were not described; presumably they were ordinary roasted peanuts. In diets in which boiled or roasted chestnuts contributed most of the total protein intake Heupke and others (*67*) found that the digestibility of chestnut protein ranged from 68 to 79 percent.

In view of the variable results for peanuts and for nuts, there is no good basis for estimating digestibility of protein in nuts of different kinds or even as a group. It is preferable to continue to use, as an interim value for nuts, Atwater's group coefficient for protein in legumes, 78 percent. The grouping of nuts with legumes is a common practice and has some basis since there are many points of similarity in the proximate composition of these two food groups.

Very little work on the digestibility of carbohydrate material in nuts has been reported. Only a small fraction of the total carbohydrate intake was furnished by nuts in Jaffa's series of experiments and the digestibility of carbohydrate in nuts has not been estimated. Merrill (*120*) found that more than 98 percent of the carbohydrate in chestnut flour was digested. Heupke and others (*67*) found digestibilities ranging from 96.5 to 99.9 percent in several experiments in which chestnuts were fed as raw flakes or cooked by boiling or roasting.

Data reported in the literature on the composition of various nuts indicate that most nuts contain from one-half to two-thirds of their carbohydrate in the form of sugars or starch or both, up to one-third as crude fiber, pentosans, and similar complex carbohydrate constituents, and a like amount as undetermined matter. Almonds appear to have a lower proportion of sugar and starch, averaging around 40 percent, and have about 25 percent in the form of complex carbohydrates that are of questionable availability. The nature of the remaining portion is undetermined. The limited data for peanuts are too variable to estimate the proportions in which the carbohydrate components are distributed.

As readily can be seen, the information on the composition and the digestibility of the carbohydrate fraction of nuts is far from complete. Therefore, it appears best to continue to use the coefficient, 97 percent, assigned by Atwater to carbohydrate in legumes and nuts, and his energy factor, 4.07 calories per gram.

Vegetables

Very few digestibility studies of vegetables had been made when Atwater proposed for all vegetables as a group the factors 3.11 calories per gram for protein and 3.99 calories per gram for carbohydrate. Data accumulated since are still limited but provide some basis for separate factors that may be applied to smaller groups of vegetables.

Potatoes

Potatoes have been studied more than other vegetables; results from 10 investigations have been noted in the literature. In most cases the composition of the samples used in the digestion experiments was not reported.

The average digestibility coefficients found for protein by the 10 investigators were from 64 to 85, averaging 74 percent. These are surprisingly low values and we consider them tentative estimates. In several of the experiments the total protein intake was low. Potatoes contain very little nitrogen, only about 0.3 percent, but several observers have pointed out that subjects have remained in generally good physical condition for long periods of time on diets in which potatoes are practically the sole source of protein.

One such study was reported by Kon and Klein, 1928 (*83*), who conducted digestion experiments over a period of 167 days. The two subjects, a man aged 25 and a woman aged 28, remained in nitrogen equilibrium and in apparent good health on a very simple diet with the daily intake of nitrogen chiefly from potatoes, averaging only 5.7 grams for the man and 3.8 grams for the woman. The coefficients of digestibility of the potato protein were 66 and 62 percent respectively for the man and woman.

Three subjects in the study by Hindhede, 1913 (*69*), also were on simple diets in which potatoes contributed nearly all the protein over an extended period of time. The diets were planned to provide the minimum protein intake at calorie levels just sufficient to maintain nitrogen equilibrium. The digestibility of the potato protein ranged from 71 to 86 percent. For 9 months one subject, M, had a daily nitrogen intake from 5.8 to 8.4 grams and maintained a schedule of varying activity, including 3 months of hard labor, without any apparent ill effects—his excellent physical condition at the end of the period was confirmed by four physicians. The apparent digestibility of the potato protein in this case averaged 84 percent.

In a 10-day experiment Rose and Cooper (*142*) also observed good utilization of potato protein. The subject, a woman, was able to maintain nitrogen equilibrium, after the third day, on a diet of potato, sugar, and agar-agar, which provided a relatively low nitrogen intake, 4.8 grams per day. The apparent digestibility was 74 percent.

The detailed analyses reported on the nitrogenous fractions of potatoes by Street, Kenyon and Watson, 1946 (*173*), Crook and Watson, 1948 (*44*), Neuberger and Sanger, 1942 (*130*), and Headden, 1927 (*65*), indicated that most of the nitrogenous matter in potatoes would be available. The proportions of the different nitrogenous materials vary greatly from sample to sample, the coagulable fraction (proteins, proteoses, peptones) ranging from 30 to almost 75 percent and averaging around 40 percent, and the amino acid fraction from 30 to 60 percent, averaging about 50 percent. Of the small remaining fraction, 2 to 6 percent has been determined as ammonia and nitrate nitrogen.

Of more practical significance than nitrogenous compounds in estimating energy values for potatoes are data on digestibility and composition of the carbohydrate fractions. Results from six studies reporting digestibility of total carbohydrate ranged from 92 to more than 99 percent, with an average of 96 percent. These values appear reasonable in view of the high proportion of starch, sugar, and dextrin in potatoes. Also present are lignin, cellulose, pentosans, pectins, and other hemicelluloses, but the complex carbohydrate constitutents of doubtful availability appear to make up only about 1 to 3 percent of the potato. Sugars have been found in varying amounts, from less than 1 to as much as 6 percent. The quantities of dextrin present are small. Starch makes up nearly all of the remaining carbohydrate.

In a recent compilation the following average data were obtained: Carbohydrate by difference, 19.1; starch, 17.1; sugar, 0.3; crude fiber, 0.6; and undetermined, 1.1 percent. This last fraction may contain pentosans, pectins, and other carbohydrate constituents not determined as crude fiber by the Weende method. It has been shown by Remy (*139*), Williams and Olmsted (*187*), and Weinstock and Benham (*186*) that this method fails to measure much of the total fiber.

For potatoes it seems to us best to continue the use of the heats of combustion which Atwater assumed for potatoes and other vegetables (see table 7). As a check on the application of these factors to potatoes, we calculated gross heats from the chemical analyses of three samples and compared the results of our calculation with values determined in the bomb calorimeter for the same samples. Data from protein, fat, and carbohydrate analysis and from the bomb calorimeter were taken from a study of Bryant and Milner (*33*). Close agreement between the determined and calculated heats of combustion was found as shown in table 17. The energy factors we derived for potatoes were 2.78 calories per gram for protein and 4.03 calories per gram for carbohydrate. They were derived by applying average coefficients of digestibility found in the literature, 74 percent for protein and 96 percent for carbohydrate, to the heats of combustion, 5.00−1.25 and 4.2 calories per gram, respectively.

TABLE 17.—*Comparison of determined and calculated gross energy values of potatoes*

Sample number	Composition						Heat of combustion per 100 grams	
	Water	Protein	Fat	Carbohydrate by difference	Fiber	Ash	Bomb calorimeter	Calculated [1] from composition
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	*Calories*
1	79. 5	2. 2	0. 1	17. 4	0. 4	0. 8	84. 8	85. 0
2	78. 3	2. 3	. 1	18. 4		. 9	90. 0	89. 7
3	81. 2	1. 9	. 3	15. 5		1. 1	78. 2	77. 4

[1] For heat of combustion factors used see table 13, page 25.

Other vegetables

Because published data are lacking on the digestibility of many vegetables, we have applied group factors—the energy factors for dried legumes to immature shelled beans, peas, and other legumes, those for fruit to rhubarb and tomatoes, and those for potatoes to starchy roots and tubers. For other underground vegetables such as beets, carrots, onions, parsnips, and radishes we have applied the energy factor for protein and the coefficient of digestibility for the carbohydrate in potatoes, but have made an adjustment in the heat of combustion factor generally used for vegetable carbohydrate to correct for the relatively large proportion of sugar. We assumed that from two-thirds to three-fourths of the carbohydrate in most of these underground vegetables is present as sugar, and one-third to one-fourth as starch and fiber. On this basis the weighted heat of combustion would be 4.00 calories per gram and the energy factor calculated for carbohydrate, 3.84 calories per gram.

Coefficients of digestibility for protein and carbohydrate in the few vegetables for which data have been reported vary widely. We rounded the median figure for digestibility of protein, based on 14 experiments, to 65 and have used it rather than Atwater's figure of 83 percent. The carbohydrate fractions are an important source of energy in some vegetables. We have used a coefficient of 85 percent, the median value for 13 experiments on a variety of vegetables, in place of Atwater's figure of 95 percent. For the remaining vegetables except mushrooms we have calculated the energy factors by applying digestibilities of 65 percent for protein and 85 percent of carbohydrate to the heats of combustion used by Atwater for vegetables. The energy factors obtained in this way are 2.44 calories per gram for protein and 3.57 calories per gram for carbohydrate.

Mushrooms

Reports in the literature cover various aspects of the composition of the nitrogenous matter of mushrooms, but as yet there is no complete picture of the quantitative distribution of the various constitutents. From 63 to 72 percent of the total nitrogen has been termed "protein nitrogen" (*53, 123, 175*). Other known constituents are free amino acids, amides, purines, and ammonia. In some instances appreciable amounts of urea have been determined. Iwanoff (*73*) reported that amino acids are formed autolytically during the ripening period before spore formation and are in turn changed into urea. He found that urea was several times as high at the ripened stage as in the young immature mushrooms, and that in some samples the urea nitrogen approximated half of the total nitrogen. Mendel (*116*) suggested that some of the nitrogen in mushrooms is bound with cellulose and that all attempts to separate the nitrogenous constituent from the portion that yields sugar on hydrolysis had failed.

Thus it is apparent that use of the conventional factor 6.25 to convert nitrogen to protein introduces an error in the value for the nitrogenous matter, but at present there are insufficient data to provide a better factor. Hence, we have continued to use the factor 6.25 in calculating total nitrogenous material in mushrooms, although we realize that the error involved may be of some significance.

Urea, as well as some of the other nitrogen-containing substances, has a lower heat of combustion than protein, but since we could make no accurate estimate for these substances we have used the heat of combustion of vegetables, 5.00 calories per gram, for nitrogenous matter in mushrooms.

Very little work has been noted on the digestibility of the nitrogenous matter of mushrooms. Saltet (*152*), in a 2-day study of a 31-year-old man, found that his subject digested 69 percent of the nitrogenous matter when mushrooms combined with a little butter and seasonings were fed. A similar result, 72 percent digestibility, was obtained by Skinner, Peterson, and Steenbock (*161*) when mushrooms were fed to albino rats.

A digestibility coefficient of about 70 percent seems a reasonable estimate and following the usual procedure of applying it to the heat of combustion, 5.00 calories less 1.25, we derive an energy factor of 2.62 calories per gram of nitrogenous matter.

The carbohydrate fraction of mushrooms also includes a variety of components, not all of which have been determined quantitatively.

One of the most complete analyses of carbohydrates in mushrooms reported to date was made by McConnell and Esselen (*109*), but 51.8 percent of the total carbohydrate was still unidentified. The data from this study expressed as percent of fresh mushrooms and as percent of total carbohydrate follow:

Carbohydrates in mushrooms (*Agaricus campestris*)	Content on fresh basis	Proportion of total carbohydrate
	Percent	*Percent*
Total carbohydrate (by difference)	5.75	100.0
Mannitol	.95	16.5
Reducing sugars (as dextrose)	.28	4.9
Pentoses, methyl pentoses, hexuronic acids	.04	.7
Glycogen	.59	10.3
Crude hemicellulose	.91	15.8

Other carbohydrate constituents that have been reported as occurring in mushrooms include cellulose, lignin, trehalose, indican, and amino-hexose. The published data indicate that not only is the total carbohydrate fraction complex but also that some of the components vary in amounts, possibly depending on variety and other factors such as drying and storage.

There is no very reliable information from which an estimate of the digestibility of the carbohydrates in mushrooms can be obtained. Only one digestion experiment, reported by Oshima (*134*), has been noted in the literature. The subject, a Japanese army surgeon, was on an experimental diet consisting of 74 grams of dried mushrooms (*Agaricus sitake*) and 40 grams of soy sauce for 1 day. According to the author a satisfactory separation of the feces was obtained by the use of buckwheat flour. The digestibility found for the carbohydrate was 84 percent

For calculating the energy value of the carbohydrate in mushrooms, Watt and Merrill (*185*) used a factor of 1.35 on the assumption that only mannitol, reducing sugars, and glycogen, which account for approximately 33 percent of the total carbohydrate, were available for absorption. The data from the one digestibility study which has since been located suggests that such a procedure may underestimate appreciably the energy value. Until additional digestibility data on mushrooms are available, it therefore seems preferable to use a digestibility coefficient of 85 percent as for most vegetables and to apply it to a heat of combustion value which corrects for the presence of appreciable amounts of sugars. Using the composition data of McConnell and Esselen and assigning heat of combustion values of 3.75 to mannitol, reducing sugars as dextrose, and pentoses, 4.19 to glycogen, and 4.20 to the remaining fraction, the resulting heat of combustion value for total carbohydrate becomes 4.1 calories per gram. By applying the coefficient of digestibility, 85 percent, to this value the energy factor for carbohydrate in mushrooms is 3.48 calories per gram.

Fruits

The energy from fruits comes largely from carbohydrate. The energy factor, 3.60 calories per gram, was applied by Atwater to carbohydrate, based on the heat of combustion figure of 4.00 calories per gram and digestibility of 90 percent. In arriving at this heat of combustion value he took into consideration that the carbohydrates of fruits are a mixture of sugars, mainly levulose and dextrose, but that starch, cellulose, pentosans, and other complex carbohydrates are also present.

We consider 3.60 a reasonable group factor and have applied it to most individual fruits, but with full recognition of the possible inaccuracies involved. For example, the coefficient of digestibility 90 percent is probably too low for fruit juices and for sweetened canned or cooked fruit.

The group factor for heat of combustion of carbohydrate in fruits will not apply equally well to individual fruits. A compilation of the proximate composition of fresh fruits (*38*) showed considerable variation among fruits in the proportions of sugar, starch, acid, and crude fiber present. There is need for revision and extension of this compilation to include data available since its publication, particularly with respect to the carbohydrate constituents, before further estimates for heats of combustion of carbohydrate in individual fruits are made.

Attention is called to lemons in particular, since they have considerable citric acid with a heat of combustion of only 2.47 calories per gram. As the value 4.00 would be too high for the heat of combustion for total carbohydrate (by difference) in lemons and lemon juice, we have used 2.75 derived by the following calculations:

Constituent	Grams per 100 grams	Calories per gram	Total calories
Invert sugar	1. 5	3. 75	5. 6
Citric acid (anhydrous)	6. 0	2. 47	14. 8
Fiber and unknown constituents	. 2	4. 2	. 8
Total carbohydrate (by difference)	7. 7		21. 2

1 gram carbohydrate = 2.75 calories (21.2 ÷ 7.7).

Since the fiber fraction of lemon juice is very low and since both invert sugar and citric acid may be completely utilized, we took the figure recommended by Atwater for sugar, 98 percent, as a reasonable value for apparent digestibility. The resultant energy factor was 2.70 calories per gram of carbohydrate. Since limes are similar to lemons in carbohydrate constituents we have applied the same energy factor for carbohydrate.

For lack of better data for other fruits we have continued to use the carbohydrate factor, 3.60 calories per gram, derived by Atwater. Likewise, his factors for protein and fat in all fruits have been used.

Miscellaneous foods

Many specific foods have not been studied in human digestion experiments, as can be seen from the compilation on digestibility coefficients (appendix table 23). In many cases when digestibility data on individual foods were lacking, we have used a general value for a group of foods for each food in that group. In other instances when a food has undergone some treatment to change its form, the energy factor of the food in its original form has been applied to the product or products. These procedures no doubt result in some errors.

Where the above procedures were not applicable and when the methods of estimating the energy factors differed in some respects from the general procedure usually followed, these deviations will be explained in turn for the several miscellaneous foods.

Chocolate and cocoa

Chocolate and cocoa present a variety of problems in regard to both chemical composition and digestibility.. Determinations of various nitrogen-containing compounds have been made in a few studies. It appears that from 12 to 23 percent of the total nitrogen present is in the form of alkaloids, mainly theobromine and caffeine, and 1 to 9 percent as ammonia, and that the remainder, although not clearly identified, may be in the form of protein or protein derivatives.

Data reported by Stutzer (*177*) are the most complete of the analyses located and seem to be representative values when compared with several less complete analyses made by other investigators. Stutzer analyzed several kinds of cocoa. For one product which had not been treated with alkaline chemicals (potash, soda, or ammonia) he found that 16.6 percent of the total nitrogen was from alkaloids (mainly theobromine), 1.4 percent from ammonia, 6.3 percent from amides, and 75.8 percent from other nitrogenous matter.

Using these data, we have calculated the gross energy per gram of total nitrogen in cocoa as follows:

Compound	Nitrogen per gram	Conversion factor	Amount of compound	Heat of combustion	Gross energy equivalent
	Gm.		*Gm.*	*Cal./gm.*	*Cal.*
Protein	0.758	6.25	4.74	5.80	27.5
Alkaloids as theobromine	.166	3.22	.53	5.22	2.8
Ammonia	.014	1.22	.02	------	------
Amides as asparagin	.063	5.35	.34	3.45	1.2
Total	1.001	------	5.63	------	31.5

Gross energy equivalent of 1 gm. nitrogenous matter = 5.60 calories.

Digestibility of the nitrogenous portion of cocoa was studied by some of the early German scientists. In these studies there was no attempt to distinguish between the protein and nonprotein fractions of the nitrogenous matter. In some of the studies cocoa supplied all of the nitrogen, and in some the diet included other protein foods in addition to the cocoa. Experiments conducted by Weigmann and by Lebbin, reported through Konig (*84*, pp. 244–245), showed the following results: For three kinds of cocoa fed in amounts of 188–304 grams per day along with sugar and water, Lebbin found protein digestibility coefficients of 41.1, 45.2, and 41.6 percent; for a diet of cocoa and beer or wine, Weigmann found a digestibility of 41.5 percent after correction for metabolic nitrogen. The apparent digestibility was calculated to be 12.7 percent. For two kinds of cocoa, Neumann (*131*) reported that Beddies found digestion coefficients of 55.3 and 54.1 percent. In these latter experiments, 150 grams of cocoa were consumed daily but no information was given on the remainder of the diet.

Several studies have been reported in which cocoa was eaten in combination with other protein-containing foods. There is some indication that digestibility of the cocoa may be affected by the level of cocoa and its proportion of total dietary nitrogen, the combination of foods used with the cocoa and possibly its preparation—whether raw or cooked. Forster (*56*) found for a diet of milk alone that the protein digestibility was 93 percent as compared with 93.2 and 92.4 percent for diets of milk and cocoa, with the latter taken in amounts of 20 grams (2 to 3 cups of beverage) and 60 grams (8 cups), respectively. Schlesinger (*153*) found a digestibility of about 86.5 percent for protein in a mixed diet consisting of milk, meat, refined cereal, and fat, whereas when 60 grams of cocoa were eaten in addition the digestibility of the protein of the total diet was slightly lowered and was about 84 percent. Beddies, as reported by Neumann (*131*), also found the digestibility of protein to be about 84 percent for a mixed diet which included 50 grams of cocoa. Cohn (*41*) observed a lower digestibility coefficient, 75.5 percent. His diet differed from those of Schlesinger and Beddies mainly in that larger amounts of cocoa, 100 to 130 grams, were used and milk was not included.

Neumann has reported two studies on cocoa (*131*, *132*). In one series of investigations he determined digestibility of diets made up of sausage, brie cheese, rye bread, lard, and sugar, in which cocoa replaced equivalent amounts of protein and fat of the diet. The digestibility of the protein of the diet without cocoa averaged 82 percent. When 35 grams of cocoa were included in the diet, the digestibility dropped to 75 percent, decreasing still further to 57 percent when the daily intake of cocoa was increased to 100 grams. In the second series, Neumann found very low digestibility of the cocoa protein, namely, 45 and 25 percent in two experiments in which 35 grams of cocoa were eaten with 350 grams of sugar as the only other food in the diet. Inasmuch as he corrected for the nitrogen in the digestive juices in getting his digestibility of cocoa, the apparent digestibility would be still lower. These results indicate that the digestibility of the nitrogen portion of cocoa is considerably lower than that of the other foods in the mixed diets studied. Unfortunately the digestibility of cocoa cannot be calculated in the several studies on mixed diets and there is no means of determining whether the utilization of cocoa as a flavoring ingredient in the diet as it is normally consumed is better than when it is used alone or with sugar only.

On the basis of studies in which cocoa was the chief source of nitrogen, we have used a digestibility of 42 percent, although this may be too low for ordinary application. When the 42 percent figure is applied to 5.6, the heat of combustion derived as shown above, less 1.25, an energy factor of 1.83 calories per gram of nitrogen-containing material results. Information on the utilization of the nonprotein nitrogen is needed before a more accurate factor can be developed.

The carbohydrates of chocolate and cocoa present problems similar to those for the nitrogenous matter. Some unpublished data [4] for chocolate liquor show the following complex composition: 28.4 percent total carbohydrate by difference; 8.0 percent starch; 2.8 percent fiber; 3.5 percent pentosans; 2 to 3 percent gums and hemicellulose;

[4] Winkler, W. O. Unpublished data. Food and Drug Administration, U. S. Department of Health, Education, and Welfare [n. d.].

9.5 percent products such as tannins and cocoa red; 0.5 percent sugars, mainly glucose; 0.6 percent organic acids; and the remainder, undetermined matter. These data were used in estimating the heat of combustion for the total carbohydrate (by difference). The value obtained was 4.16 calories per gram, using as heats of combustion 3.75 calories per gram for sugar, 2.45 for organic acid, and 4.20 for the remaining constituents and weighting them according to the percentage composition above.

Digestibility data for the carbohydrate of cocoa are even less conclusive than those reported for protein. In the few experiments located in which cocoa was fed in mixed diets, the digestibility of carbohydrate could not be calculated for the total diet or for the cocoa. The experiments of Lebbin on diets of cocoa and sugar reported by Konig (*84*) indicated that probably less than a third of the total carbohydrate of cocoa is available to the body. Here, as in the case of protein, this estimate may be lower than actually found when cocoa is used in a mixed diet. As a tentative coefficient, until satisfactory data can be obtained on the digestibility of cocoa carbohydrate, we are using 32 percent. This was indicated both by the work of Lebbin and by the carbohydrate composition data above for chocolate liquor, assuming the starch, sugar, and organic acids to be almost completely digested and the remaining constituents to be undigested. The energy factor calculated from this coefficient and the heat of combustion factor 4.16 is 1.33 calories per gram.

Yeast

The utilization of yeast "protein" has been a matter of great interest. A number of studies have been reported on the digestibility of the nitrogenous matter in yeast, but in only a few of these were human subjects used. Kuen and Puringer (*87*) compared its digestibility in dried and fresh compressed yeasts, presumably baker's yeast, fed in a mixed diet that furnished 10 to 11 grams of nitrogen and 2,460 to 2,840 calories daily. The estimated digestibility was 90 percent for the nitrogenous matter of dried yeast but only 53 percent for the fresh compressed yeast.

Dirr (*50*) reported experiments in which either dried yeast or animal sources of protein were fed in alternate periods of 7 days each. The daily nitrogen intake in each case was 10.4 grams from the test food with additional 3.4 to 5.6 grams from plant foods. The calorie intake for the four subjects ranged from about 2,000 to 2,800. The digestibility of the nitrogen of the total diet averaged 87.5 percent in the period in which nitrogen was supplied largely from animal sources, and 83.4 percent in the period in which yeast predominated in the diet. These results indicate that the nitrogenous matter of the yeast was almost as completely absorbed as animal protein. Dirr and Soden (*51*) referred to the yeast as wood sugar dried yeast and estimated from analyses that 67 percent of the total N was amino N and 7.5 to 16 percent was ammonia N.

Funk, Lyle, and McCaskey (*59*) reported experiments in which a dried anaerobic yeast preparation was eaten in a diet consisting largely of vegetables and fruits. The daily nitrogen intake, mainly from yeast, was 5.9 grams and the digestibility of the nitrogenous matter was estimated to range from about 60 to 80 percent, averaging about 70 percent. Results of Murlin and others (*125*) indicated that the apparent digestibility of nitrogen in brewer's yeast was about 57 percent. The daily nitrogen intakes were very low, averaging 3.7 grams daily.

The data indicate that the average apparent digestibility of the nitrogenous matter of dried yeast is probably in the range of 70 to 90 percent when the level of intake is fairly adequate. In deriving an energy factor, we have estimated the coefficient of digestibility as 80 percent.

According to an analysis of yeast reported by Frey (*58*) the nitrogenous matter is composed of 60 percent monoamino acids, 20 percent diamino acids, 12 percent purines and pyrimidine bases, and 8 percent ammonia. These data indicate that the heat of combustion is lower than if the nitrogenous matter of yeast were all protein. Therefore, for yeast protein we used the heat of combustion 5.00 calories per gram that we applied to vegetables. The digestibility coefficient, 80 percent, applied to 3.75 (5.00 less 1.25) results in an energy factor of 3.00 calories per gram.

Very little research has been noted on the composition of the different specific carbohydrate constituents in yeast and none at all on their digestibility. Frey (*58*) has reported that 81.5 percent of the total carbohydrate is glycogen and 18.5 percent, such substances as cellulose and gums. On the basis of these data we used 80 percent as a tentative coefficient of digestibility on the assumption that the glycogen is digestible and the other carbohydrates may not be. This coefficient applied to the heat of combustion 4.20 calories per gram, assumed for total carbohydrate (by difference), resulted in the energy factor 3.35 calories per gram.

Food mixtures

To keep pace with marketing practices as well as buying habits, successive editions of food composition tables contain a growing proportion of items that are food mixtures. Included are a wide assortment of baked goods, meat and cereal mixtures, salad dressings, and others that are combinations of ingredients. Because the many food mixtures vary so much in the kinds and proportions of ingredients used, information on their digestibility from experiments can scarcely be expected. If the weights of ingredients are known, calorie factors per unit weight of total protein, fat, and carbohydrate in the finished product may be calculated. For products in which the proportions of ingredients are fairly standard, the calorie factors once worked out may be applied directly to data on the amounts of protein, fat, and carbohydrate in the product.

To calculate the calories for any given weight of an item from its recipe, the weight of the finished product must be known in addition to the weights of the ingredients. Calculations indicating the derivation of energy factors and of calories per 100 grams of baking powder biscuits made with skim milk, item 98 in Agriculture Handbook No. 8 (*185*), are shown in the sample calculation below.

Sample calculation of energy factors for food mixtures (baking powder biscuits)

Kind of data	Weight	Protein			Fat			Carbohydrate (by difference)		
		Weight	Specific energy factor	Energy value	Weight	Specific energy factor	Energy value	Weight	Specific energy factor	Energy value
Ingredients:	*Gm.*	*Gm.*	*Cal./gm.*	*Cal.*	*Gm.*	*Cal./gm.*	*Cal.*	*Gm.*	*Cal./gm.*	*Cal.*
Wheat flour, patent	336	36.3	4.05	147.02	3.0	8.37	25.11	255.0	4.12	1,050.60
Fat	55				55.0	8.84	486.20			
Milk, skim	244	8.5	4.27	36.20	.2	8.79	1.76	12.4	3.87	47.99
Baking powder	16									
Salt	2									
Total	653	44.8		183.32	58.2		513.07	267.4		1,098.59
Weighted factor (per gram)			4.09			8.82			4.11	
Baked yield:										
Total	549	44.8			58.2			267.4		
100-gram portion	100	8.2	4.09	33.54	10.6	8.82	93.49	52.2	4.11	214.54

The factors 4.09, 8.82, and 4.11 calories per gram were applied to the protein, fat, and carbohydrate values of the baked biscuits, with the resultant calorie value 342 calories per 100 grams. Similar calculations were made for the other units of weight given for this item in tables 2 and 3 of Handbook No. 8.

PART IV. APPLICATION OF CALORIE FACTORS

The physiological fuel value of a food resulting from applying the factors summarized in table 13 to the amounts of protein, fat, and carbohydrate present is considered to be a measure of its available energy. Attention is again called to the interpretation of this term to connote that portion available to the body as a source of energy. The difference between total or gross calories of a food and available calories is the caloric value of the organic matter in the urine and feces. Whether this fecal organic matter is entirely of metabolic origin plus bacterial residues and desquamated tissue, or whether it usually or only under some circumstances includes undigested protein, fat, or carbohydrate residues also, is a question of very great importance in dealing with such problems as determining man's use of various foods as sources of specific nutrients. When this question is resolved the information should be helpful also in devising methods for estimating energy values of specific nutrients in food when fed in various combinations and at different levels; present methods are actually not completely satisfactory for estimating available energy from the different nutrients. As a result of changes in method, however, no big changes in actual total available calorie values for the foods are anticipated.

In using data on apparent digestibility for developing the energy factors shown in table 13, the assumption is made that the amount and character of the fecal matter (protein, fat, and carbohydrate) present is dependent on the food; a low apparent digestibility could result from greater excretion of metabolic products caused by that food, from incomplete digestion, or from a combination of several causes. Whatever the contributing factors are, the assumption is that the apparent digestibilities of the energy-yielding components of that food would not vary widely for a subject on a reasonably adequate intake of the nutrient. If the total intake of a nutrient in a diet is very low, the relative proportion in the feces is too high for satisfactory measurement by this procedure. More information is needed on the effect of level of the foods on utilization of nutrients. Most studies in the literature at present are on rather extreme diets, for example, either very high or rather low levels of protein, and moderately high and very high levels of the test food. Data are needed also for intermediate levels, those which are more realistic in terms of common food practices.

Comparison of calculated and determined available calories for diets

The end results obtained by use of the current factors (table 13) for estimating available energy of diets have been compared with results obtained by direct bomb calorimeter determinations. An experiment conducted by Snyder (*164*) with a subject on a very simple diet of whole-wheat bread and milk serves to illustrate the details of calculation (table 18). Snyder's protein figures based on the factor 6.25 for converting nitrogen to protein were recomputed with the factors 5.83 and 6.38 for the bread and milk, respectively; the necessary adjustments were made in the figures for carbohydrate by difference. The gross calorie values for food and feces were from bomb calorimeter determinations and were found to be 4,143 for the food and 418 for the feces. For comparison we also calculated the gross calories of the food. The heats of combustion, 5.80, 9.30 and 4.20 calories, were applied to the protein, fat, and carbohydrate (by difference), respectively, of whole-wheat bread; and 5.65, 9.25, and 3.95 to these nutrients in the milk. The calculated gross calories for bread (2,407) were a little higher than the determined (2,353), and the calculated gross calories for milk (1,737), a little lower than the determined (1,790), but for the total diet the calculated gross calories were in excellent agreement with the determined.

TABLE 18.—*Summary of steps for checking available energy values calculated by factors from table 13*

Type of data	Weight of material	Protein	Fat	Carbohydrate	Gross energy	Available energy: Determined by bomb	Available energy: Calculated by use of factors [1]	Deviation of calculated available energy from determined value
Food consumed in 2-day period:								
Bread made from whole-wheat flour	*Grams* 1,020.8	*Grams* 73.9	*Grams* 12.9	*Grams* 442.4	*Calories* 2,353	*Calories*	*Calories* 2,045.5	*Percent*
Milk	2,500.0	75.2	87.5	127.2	1,790		1,582.5	
Total		149.1	100.4	569.6	4,143	[2] 3,561	3,628	+1.9
Excreta:								
Feces (water-free)	97.0	17.6	10.2	52.1	418			
Urine					[3] 164			
Total					582			

[1] Energy factors from table 13 applied to the protein, fat, and carbohydrate: 3.59, 8.37, and 3.78, respectively, for bread and 4.27, 8.79, and 3.87 for milk.

[2] Gross energy of food minus total energy of excreta (4,143−582).

[3] 7.9 x difference between amount nitrogen in food and in feces.

NOTE.—Data used in this procedure taken from experiment No. 171, Studies of Bread and Breadmaking (*164*)

The urinary calories were 181 when determined by bomb, but 164 when estimated according to Atwater's procedure by multiplying the grams of digested protein 131.5 by 1.25 calories. The wide range in the calorie to nitrogen ratio of the urine (p. 16) indicates that there is less satisfactory agreement between the usual calculation of urinary energy loss and direct determinations. In fact, with the difficulties of drying and burning urine, it may be that much of the discrepancy is in the bomb determination. We have considered it advisable when estimating available energy data to use the calorie-nitrogen factor based on a large number of samples rather than a bomb determination of the particular sample of urine.

The calorie-N ratio for this individual was 6.9, which is lower than the average but within the range found for a large number of studies, table 8, p. 12. This individual was also in negative balance, excreting 26.4 grams of nitrogen in the 2-day period during which he absorbed only 21.8 grams. However, the errors involved are insignificant when considered in terms of total available energy.

The available energy of the diet determined from gross energy values of food, feces, and urine was 3,561 calories. When the average wheat and milk energy factors for protein, fat, and carbohydrate shown in table 13 were applied to the nutrient intake in this experiment, the figure obtained for available calories was 3,628, differing from the determined figure by 1.9 percent. As pointed out earlier, the factor for fat in whole wheat may be too high since it is based on digestibility of 90 percent. If the average digestibility is nearer two-thirds, as indicated in a number of experiments, the energy factor would be approximately 5.95; the figure for available calories, 3,597, would then be in even better agreement with the determined value, differing by only 1.0 percent.

We have checked the results obtained by applying factors from table 13 to data in 108 digestion experiments which provided information on composition of the foods in the diet and data on bomb calorimeter determinations of the food and feces. Although the experimental data needed for using every factor in table 13 were not provided by these experiments, most of the factors could be tested in this way. The available energy calculated by applying the appropriate energy factors to the composition data for the various foods was in excellent agreement with the comparable values for the diets obtained by direct determinations of foods and feces and calculated urinary calories. The differences between the determined and calculated values, not taking direction into account, ranged from 0 to 5 percent and averaged 2 percent. The calculated values were in some cases higher and in some lower than the determined values. These positive and negative deviations were noted even in experiments in which the same type of diet and the same subject were used and suggest that the differences may be in part the result of experimental error.

The digestion experiments that were used to make this comparison include many types of diets: Ordinary mixed diets with foods of animal and plant origin; mixed diets containing large amounts of legumes; diets of fruits and nuts; very simple diets such as combinations of meat and bread, eggs, milk, and bread, whole-wheat bread and milk, bread made of lower extractions of wheat flour and milk, oatmeal and milk, or crackers and milk; other simple diets containing large amounts of rice, dry peas, vegetables, or fruit; and a few diets of single foods. The proportions of protein, fat, and carbohydrate in the food intake as well as the level of protein intake varied widely, the latter ranging from 14 to 184 grams daily. We have grouped some of the diets and summarized the differences we found between determined and calculated values as follows:

In 14 diets of fruits and nuts the absolute deviation (that is, not taking signs into account) ranged from 0 to 5 percent, averaging 2 percent.

In 16 diets containing large quantities of dry beans, peas, or cowpeas the absolute deviation ranged from 1 to 5 percent, averaging 2 percent.

In 7 diets containing a large proportion of rice or oatmeal the absolute values deviated by only 1 percent in all cases.

In 6 diets of whole-wheat bread and milk the absolute deviations ranged from 2 to 4 percent, averaging 2.5 percent.

In 11 diets containing a large proportion of cabbage, potatoes, beets, green corn, or applesauce, the absolute deviations ranged from 0 to 3 percent, averaging 1 percent.

In 6 ordinary mixed diets the absolute deviations ranged from 0 to 3 percent, averaging 1.5 percent.

In 36 simple diets in which lower extractions of wheat flours were fed as bread or crackers the absolute deviations ranged from 0 to 5 percent, averaging 2.5 percent.

Several general observations appear reasonable in view of these data:

1. That the energy factors in table 13 give an accurate estimation of the available energy when applied in various diets containing foods of both animal and plant sources either as mixed diets or simple diets of two or more foods.

2. That the factors are equally suitable when applied to foods in diets in which various plant foods are predominant, as in fruit and nut diets, diets in which large amounts of beans or peas are eaten, and diets in which large proportions of the calories are supplied by rice, wheat, or vegetables.

3. That the factors applied to the several diets of single foods give results in good agreement with the determined values for available energy. This indicates that the factors are applicable to foods used alone in the diet, but further confirmation with additional data is needed.

4. That the level of protein fed apparently does not affect the extent of agreement obtained in estimating available energy by use of the factors. This was indicated particularly in the group of experiments in which fruit and nuts made up a large part of the diet and the daily protein intake ranged from as low as 14 grams to a maximum of 85 grams; there was no evidence of difference in the percentage deviations between calculated and determined values at the different levels of protein intake.

The energy values of the 108 diets were calculated also by applying the general factors, 4, 9, 4. There were larger differences between the direct determinations and calculated values than were observed when the values were calculated by use of the factors from table 13. The largest differences were noted in those diets in which foods of plant origin predominated.

Data have been summarized in table 19 from a few of the experiments selected to represent different types of diets. The data illustrate the extent of agreement between available calories directly determined and those calculated by use of the factors from table 13 and by use of the general factors 4, 9, 4. Although there is good agreement between the determined and the calculated available energy values as illustrated by the data in table 19, examination of the data show that for some kinds of diets similar agreement for the available energy value of specific nutrients does not necessarily follow. For example, in the case of experiment 388 which represents a diet low in protein and fat, the apparent digestibility of the total protein from the diet was 45 percent, with an estimated 25 calories available from protein instead of the 46 which would be calculated by the factors from table 13. Likewise, an estimated 146 calories would be available from fat if the calculation were based on the apparent digestibility for the total fat in the diet, instead of the 201 obtained by use of the factors with the individual foods. For carbohydrate, however, the data from this experiment would indicate approximately 861 available calories instead of the 823 obtained by application of the factors from table 13 to the carbohydrate of the items in the diet.

TABLE 19.—*Comparison of determined and calculated available energy values of various types of diets*

Daily diet	Daily intake[1]					Daily excretion in—								Available energy from daily diet			Deviation from determined value, column a, of—	
						Feces							Urine					
	Protein	Fat	Carbohydrate		Gross energy	Weight water-free	Protein	Fat	Carbohydrate		Gross energy		Gross energy[2]	Determined by bomb	Calculation by use of—		Value in column b	Value in column c
			Total	Fiber					Total	Fiber					Energy factors from table 13	General energy factors 4, 9, 4		
														a	b	c		
	Grams	*Grams*	*Grams*	*Grams*	*Calories*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Calories*		*Calories*	*Calories*	*Calories*	*Calories*	*Percent*	*Percent*
Diets of fruits and nuts																		
2,447 gm. grapes (European type), 13 gm. olive oil, 28 gm. olives, 14 gm. tomatoes (*75*), experiment No. 388	13.8	23.2	228.6	6.0	1,227	31.9	7.6	7.5	12.7	3.4	172		8	1,047	1,070	1,179	+2	+13
595 gm. oranges, 1,120 gm. bananas, 142 gm. pecans (*75*), experiment No. 409	35.7	103.8	206.5	10.8	2,010	40.8	11.4	10.4	13.4	2.6	225		35	1,750	1,741	1,904	−1	+9
1,834 gm. Japanese persimmons, 213 gm. peanuts, 11 gm. tomatoes, 28 gm. granose (a whole wheat product), 7 gm. olive oil, 57 gm. milk (*75*), experiment No. 394	84.8	120.8	298.8	33.8	2,832	58.2	12.4	13.6	25.8	3.3	330		103	2,399	2,406	2,622	0	+9
Diets with large amounts of legumes																		
120 gm. whole wheat bread, 10 gm. butter, 250 gm. bananas, 20 gm. sugar, 15 gm. pork, 438 gm. dry white beans (beans supplied 68 percent of total organic matter) (*184*), experiment No. 335	94.9	31.2	420.4	------	2,555	51.5	19.2	4.5	22.0	------	252		97	2,206	2,268	2,342	+3	+6
420 gm. whole wheat bread, 30 gm. butter, 250 gm. bananas, 40 gm. sugar, 12 gm. pork, 350 gm. beans (beans supplied 42 percent of total organic matter) (*184*), experiment No. 338	118.0	45.5	540.5	------	3,324	53.0	20.8	5.2	19.0	------	262		127	2,936	2,913	3,043	−1	+4
420 gm. whole wheat bread, 30 gm. butter, 250 gm. bananas, 40 gm. sugar, 11 gm. pork, 400 gm. dry cowpeas (peas supplied 46 percent of total organic matter) (*184*), experiment No. 344	138.6	45.2	574.4	------	3,606	77.2	30.5	3.2	36.5	------	380		140	3,085	3,121	3,259	+1	+6
292 gm. whole wheat bread, 650 gm. milk, 32 gm. butter, 20 gm. pork, 228 gm. bananas, 32 gm. sugar, 275 gm. dry cowpeas (peas supplied 35 percent of total organic matter) (*184*), experiment No. 629	105.8	89.8	453.4	------	3,283	61.5	23.5	2.8	28.0	------	303		106	2,874	2,938	3,045	+2	+6

Diets with large amounts of cereals																
433 gm. dry rice, 450 gm. cottage cheese, 30 gm. sugar, 1,607 gm. milk (rice supplied 50 percent of total organic matter) (*167*), experiment No. 5	165. 9	110. 8	474. 3	------	3, 953	41. 6	15. 9	5. 7	11. 1	------	223	189	3, 541	3, 587	3, 559	−2	+1
796 gm. whole wheat bread, 2,400 gm. milk (bread supplied 64 percent of total organic matter) (*193*), experiment No. 131	157. 6	105. 6	597. 2	------	4, 384	76. 6	19. 7	6. 0	37. 6	------	318	179	3, 886	3, 815	3, 770	−2	+2
338 gm. oatmeal, 1,655 gm. milk (oatmeal supplied 62 percent of total organic matter) (*164*), experiment No. 181	92. 2	85. 0	309. 0	------	2, 651	31. 5	8. 8	8. 1	8. 0	------	163	108	2, 380	2, 348	2, 370	−1	0
Diets with large amounts of vegetables																
Basal ration of meat, bread, butter, milk, sugar; 662 gm. beets supplying 24 percent of total organic matter (*33*), experiment No. 5	68. 2	76. 6	288. 1	9. 3	2, 225	25. 3	9. 3	3. 4	7. 3	1. 2	127	75	2, 023	2, 019	2, 115	0	+5
Basal ration of meat, bread, butter, milk, sugar; 600 gm. potatoes supplying 23 percent of total organic matter (*33*), experiment No. 11	88. 4	69. 1	296. 0	4. 6	2, 363	26. 1	11. 6	5. 6	3. 9	. 6	144	97	2, 122	2, 149	2, 159	+1	+2
Basal ration of meat, bread, butter, milk, sugar; 772 gm. cabbage supplying 7 percent of total organic matter, (*33*), experiment No. 8	85. 0	103. 5	306. 8	11. 2	2, 679	19. 1	6. 4	3. 3	5. 3	1. 3	101	99	2, 479	2, 481	2, 498	0	+1
Mixed diets																
170 gm. beef, 120 gm. butter, 750 gm. skimmed milk, 300 gm. bread, 110 gm. maize breakfast food, 75 gm. wheat breakfast food, 75 gm. ginger snaps, 110 gm. sugar, (*14*), experiment No. 11	121. 8	129. 1	488. 1	------	3, 862	41. 5	14. 1	9. 0	12. 4	------	219	139	2, 504	3, 578	3, 602	+2	+3
121 gm. beef, 25 gm. dried beef, 107 gm. eggs, 34 gm. butter, 775 gm. milk, 316 gm. rye bread, 6 gm. wheat breakfast food, 38 gm. sugar, 125 gm. baked beans, 150 gm. canned pears (*7*), experiment No. 37	118. 4	95. 8	280. 9	------	2, 683	25. 0	8. 8	5. 8	5. 5	------	132	140	2, 411	2, 408	2, 459	0	+2
Diets of a single food																
2,173 gm. bananas (*75*), experiment No. 391	22. 0	3. 3	276. 9	7. 2	1, 280	19. 1	5. 3	2. 6	8. 8	. 8	99	21	1, 160	1, 098	1, 224	−5	+6
816 gm. bread made of wheat patent (*193*), experiment No. 123	65. 4	14. 2	436. 8	------	2, 320	19. 5	6. 6	2. 5	7. 2	------	89	83	2, 148	2, 183	2, 136	+2	−1

[1] The reported values for protein based on the factor 6.25 for converting nitrogen to protein have been corrected wherever the conversion factor for a food is different from 6.25 and the necessary adjustment made in the values for carbohydrate by difference.

[2] 7.9× difference between amount of nitrogen in food and in feces.

In this experiment these discrepancies in the values for available calories from the different nutrients are large, as is to be expected in view of the items in the diet and the very low level of protein and fat. This example is useful, therefore, to point out that although the calorie factors in table 13 are satisfactory for calculating total available calories in a diet of widely different composition and character from the ordinary mixed diet, under some conditions there may be considerable error in calculating available calories from specific nutrients. Caution should be used also in applying general digestibility coefficients to such diets with a view to obtaining data on available nutrients.

General factors and more specific factors for calculating calories in individual foods

When the factors shown in table 13 are applied to individual foods and the resulting calories compared with calories obtained by use of the general factors 4, 9, 4, very large differences are observed for some foods. A list of foods representative of different groups has been assembled below in tabular form to illustrate this difference:

Food	Energy value per 100 grams edible portion derived by use of—		Ratio col. b / col. a
	Specific factors (a)	General factors 4, 9, 4 (b)	
	Calories	*Calories*	*Percent*
Animal foods:			
Beef	273	268	98
Salmon, canned	143	138	97
Eggs	162	158	98
Milk	68	69	101
Fats:			
Butter	716	733	102
Vegetable fats and oils	884	900	102
Cereals:			
Cornmeal, whole ground (unbolted)	355	367	103
Cornmeal, degermed	363	356	98
Oatmeal	390	396	102
Rice, brown	360	356	99
Rice, white or milled	362	351	97
Wheat flour, whole wheat	333	355	107
Wheat flour, patent	364	355	98
Legumes:			
Beans, dry seeds	338	346	102
Peas, dry seeds	339	349	103
Vegetables:			
Beans, snap	35	42	120
Cabbage	24	29	120
Carrots	42	45	107
Potatoes	83	85	102
Turnips	32	35	109
Fruits:			
Apples, raw	58	64	110
Lemons, raw	32	44	138
Peaches, canned	68	75	110
Sugar:			
Cane or beet	385	398	103

The significance of some of the differences illustrated above becomes more apparent when related to emergency feeding problems. For example, the general factors overestimate the energy value of whole wheat by 22 calories per 100 grams, and a ton therefore would supply some 200,000 fewer calories than calculated. To supply the higher number of calories, estimated, however, 2,132 pounds instead of 2,000 would be needed.

Application of general factors to national food supplies

Although general factors 4, 9, 4 may not be suitable for estimating available energy values for individual foods, the question arises as to whether they may be suitable for calculating calories of present-day food supplies. Food consumption patterns have changed over the years (*182*). There have been major shifts in consumption of foods within groups and between groups. As a result there has been some shift in the proportions of protein, fat, and carbohydrate supplied by the different foods within a group, and also a shift in the proportions of these nutrients from the various food groups in the national food supply.

We have grouped the foods into a few large categories and have calculated average coefficients of digestibility and calorie factors for the protein, fat, and carbohydrate of each of these groups. For this we weighted data selected from table 13 by the amount of the nutrient each food in the group supplied. These food group averages are shown in table 20. The average or general calorie factors for the total food supply also weighted by current distribution data on nutrients were found to be 4.00, 8.92, and 3.97 calories per gram as shown in table 20. These factors if rounded to simple whole numbers are the same as the general factors that have been used nearly 50 years. No large error is introduced in the calculation of national per capita figures per day if general factors rounded to whole numbers are used instead of the unrounded 4.00, 8.92, and 3.97. The net result of applying these rounded factors to the amounts of protein, fat, and carbohydrate of the food supply would be to overestimate the total available calories from about one-half to less than 1 percent. On a 3,000-calorie diet this would be less than 30 calories.

General factors such as these provide a quick means of calculating the physiological fuel value from composition data of the total food supply in this country. They may be used with family or institutional diets also if the pattern is comparable in the types and proportions of food to those used in this country. However, for limited or unusual diets such as are found in some areas or for food supplies of totally different composition, these general factors might not be suitable. Data in table 21 illustrate the differences that may result from applying the rounded general factors

TABLE 20.—*Factors for digestibility, heats of combustion, and physiological fuel values of nutrients in food groups as used in present-day mixed diets* [1]

Classes of food materials	Protein				Fat				Carbohydrate			
	Proportion of total in mixed diet	Apparent digestibility	Heat of combustion less 1.25 [2]	Physiological fuel value	Proportion of total in mixed diet	Apparent digestibility	Heat of combustion	Physiological fuel value	Proportion of total in mixed diet	Apparent digestibility	Heat of combustion	Physiological fuel value
	Percent	*Percent*	*Cal./gm.*	*Cal./gm.*	*Percent*	*Percent*	*Cal./gm.*	*Cal./gm.*	*Percent*	*Percent*	*Cal./gm.*	*Cal./gm.*
Meats, fish, poultry	31	97	4. 40	4. 27	36	95	9. 50	9. 02	------	------	------	------
Eggs	7	97	4. 50	4. 36	4	95	9. 50	9. 02	------	------	------	------
Dairy products	25	97	4. 40	4. 27	18	95	9. 25	8. 79	8	98	3. 95	3. 87
Separated fats	------	------	------	------	19	95	9. 40	8. 93	------	------	------	------
Total food of animal origin	63	97	4. 41	4. 28	77	95	9. 42	8. 95	8	98	3. 95	3. 87
Cereals	23	86	4. 55	3. 91	2	90	9. 30	8. 37	40	98	4. 20	4. 12
Legumes and nuts	6	78	4. 45	3. 47	3	90	9. 30	8. 37	3	97	4. 20	4. 07
Vegetables	6	70	3. 75	2. 62	1	90	9. 30	8. 37	9	93	4. 19	3. 90
Fruits	2	85	3. 95	3. 36	1	90	9. 30	8. 37	8	90	4. 00	3. 60
Sugars and sirups	------	------	------	------	------	------	------	------	32	98	3. 95	3. 87
Separated fats and oils	------	------	------	------	16	95	9. 30	8. 84	------	------	------	------
Total food of plant origin	37	82	4. 37	3. 58	23	94	9. 30	8. 74	92	97	4. 10	3. 98
Total food	100	91	4. 40	4. 00	100	95	9. 39	8. 92	100	97	4. 09	3. 97

[1] Based on United States of America food consumption data, 1949 (*182*).

[2] Heat of combustion corrected for incompletely oxidized products in the urine.

4, 9, 4 and the specific factors for individual foods or food groups to different kinds of diets. Diet A may be considered comparable to that used currently in this country. It has fairly large quantities of meat, milk, fats, and sugar, and relatively small quantities of cereals; the greater proportion of the cereals are refined products. Diet B, on the other hand, follows the dietary pattern of some of the Eastern European countries and has very high proportions of unrefined cereals and potatoes and relatively small amounts of meat, fat, eggs, and sugar.

Results of applying the general and specific factors in this example show that for Diet A either set of factors would be satisfactory. No significant error is to be expected from applying general factors in this case because the proportions of the different types of food are the same as those used in developing the general factors. In the case of Diet B, which is also a mixed diet but one in which the proportions of different types of food are very different, calories calculated by the use of the general and specific factors are not in as good agreement.

General factors may therefore be used for estimating the energy value of average family diets or of the national food supply of this country from the total quantity of protein, fat, and carbohydrate. The more specific factors should be used for most other calculations, such as those for experimental and therapeutic diets, individual foods, food supplies of a totally different character from that of this country, and particularly for areas of the world where the food supplies consist largely of unrefined cereals and vegetables.

TABLE 21.—*Comparison of energy values for different dietary patterns, calculated with specific and with general calorie factors*

Food	Nutrients per kilogram as purchased [1]			Diet A						Diet B					
				Quantity of food	Total nutrient intake			Energy value by use of—		Quantity of food	Total nutrient intake			Energy value by use of—	
	Protein	Fat	Carbohydrate		Protein	Fat	Carbohydrate	Specific factors [2]	General factors 4, 9, 4		Protein	Fat	Carbohydrate	Specific factors [2]	General factors 4, 9, 4
	Gm.	*Gm.*	*Gm.*	*Kg./yr.*	*Gm./day*	*Gm./day*	*Gm./day*	*Cal./day*	*Cal./day*	*Kg./yr.*	*Gm./day*	*Gm/day*	*Gm./day*	*Cal./day*	*Cal./day*
Whole wheat	133	20	710	3.5	1.3	0.2	6.8	32		198.0	72.1	10.8	385.2	1,805	
Wheat patent flour	105	10	761	88.6	25.5	2.4	184.7	884		0	0	0	0	0	
Dry beans	214	16	616	9.2	5.4	.4	15.5	85		11.0	6.4	.5	18.6	102	
Potatoes; refuse, 16 pct	16.8	.8	160.4	54.1	2.5	.1	23.8	104		174.0	8.0	.4	76.5	334	
Cabbage; refuse, 27 pct	10.2	1.5	38.7	45.0	1.3	.2	4.8	22		25.0	.7	.1	2.7	12	
Carrots; refuse, 12 pct	10.6	2.6	81.8	26.4	.8	.2	5.9	27		10.0	.3	.1	2.2	10	
Turnips; refuse, 13 pct	9.6	1.7	61.8	20.0	.5	.1	3.4	15		18.0	.5	.1	3.0	14	
Apples; refuse, 12 pct	2.6	3.5	131.1	101.8	.7	1.0	36.6	142		7.0	.1	.1	2.5	10	
Beef; refuse, 16 pct	147	184.8	0.0	59.8	24.1	30.3	0.0	376		21.0	8.5	10.6	0.0	132	
Milk	35	39	49	251.1	24.1	26.8	33.7	469		91.0	8.7	9.7	12.2	170	
Eggs; refuse, 11 pct	113.9	102.4	6.2	19.0	5.9	5.3	.3	75		7.0	2.2	2.0	.1	28	
Lard	0.0	1,000	0.0	27.2	0.0	74.5	0.0	672		5.0	0.0	13.7	0.0	124	
Sugar	0.0	0.0	995	41.3	0.0	0.0	112.6	436		11.0	0.0	0.0	30.0	116	
Total					92.1	141.5	428.1	3,339	3,354		107.5	48.1	533.0	2,857	2,995
Percentage relationship								100	100.4					100	104.8

[1] Data on food composition adapted from U. S. Department of Agriculture Handbook No. 8 (*185*).
[2] Calorie factors given in table 13.

CONCLUSIONS

It is recognized that some of the physiological fuel factors for food groups and individual foods developed as shown in this publication and summarized in table 13 are based on a limited amount of data and that factors for food groups may not always be equally suitable for individual foods within the group. Also revisions are anticipated as more complete information becomes available on the various constituents in the nitrogenous matter, fat and carbohydrate of food, and on their heats of combustion and digestibilities. Moreover it is realized that there are problems with direct bearing on the digestibility of protein, fat, and carbohydrate that have not been resolved satisfactorily at this time. Although all of the calorie factors may not be entirely suitable as a result of the various limitations existent in the basic data, nevertheless when they were applied to the nutrients in foods fed alone or in various combinations, the estimated total available energy of the food was always in excellent agreement with the value determined by use of the bomb calorimeter.

In view of the agreement noted and until more basic information becomes available, the modification of the method of Atwater and Bryant as proposed in the present publication for estimating the available (or physiological) energy value of foods seems the most satisfactory procedure to use; the calorie factors presented in table 13 are recommended for calculating the total available energy value of foods until there is basis for further revision or refinement of the factors.

LITERATURE CITED

(1) Abe, A., Takei, U., Ueno, O., and others.
1934. coefficient of digestibility of kaoliang. Jour. Oriental Med. 21(1): 1001–1012. [In Japanese. Esperanto summary, p. 115.]

(2) Adams, G., and Chatfield, C.
1935. classification of fruits and vegetables according to their carbohydrate content. Amer. Dietet. Assoc. Jour. 10: 383–390.

(3) Adolph, W. H., and Kao, H. C.
1934. the biological availability of soybean carbohydrate. Jour. Nutr. 7: 395–406.

(4) Arkansas Agricultural Experiment Station.
1896. concerning wheat and its mill products. parts i and ii. (Appendix by G. L. Teller.) Ark. Agr. Expt. Sta. Bul. 42, pp. [61]–104.

(5) Association of Official Agricultural Chemists, Committee.
1890. editorial notes. U. S. Off. Expt. Stas., Expt. Sta. Rec. 2: 185–190.

(6) Atwater, W. O.
1902. principles of nutrition and nutritive value of food. U. S. Dept. Agr. Farmers' Bul. 142, 48 pp., illus.

(7) ———
1902. on the digestibility and availability of food materials. Conn. (Storrs) Agr. Expt. Sta. 14th Ann. Rpt. 1901, pp. 179–245.

(8) ———
1903. the demands of the body for nourishment and dietary standards. Conn. (Storrs) Agr. Expt. Sta. 15th Ann. Rpt. (1902–1903), pp. 123–146.

(9) ———
1904. experiments on the digestibility of cereal breakfast foods. Conn. (Storrs) Agr. Expt. Sta. 16th Ann. Rpt. for the year ending June 30, 1904, pp. 180–209.

(10) ———
1906. principles of nutrition and nutritive value of food. U. S. Dept. Agr. Farmers' Bul. 142 (First rev.), 48 pp., illus.

(11) Atwater, W. O.
1910. principles of nutrition and nutritive value of food. U. S. Dept. Agr. Farmers' Bul. 142 (Second rev.), 48 pp., illus.

(12) ——— and Benedict, F. G.
1897. experiments on the digestion of food by man. Conn. (Storrs) Agr. Expt. Sta. Bul. 18, pp. 154–167.

(13) ——— and Benedict, F. G.
1899. experiments on the metabolism of matter and energy in the human body. U. S. Dept. Agr. Off. Expt. Stas. Bul. 69 (rev. ed.), 112 pp.

(14) ——— and Benedict, F. G.
1902. experiments on the metabolism of matter and energy in the human body, 1898–1900. U. S. Dept. Agr. Off. Expt. Stas. Bul. 109, 147 pp.

(15) ——— and Benedict, F. G.
1902. an experimental inquiry regarding the nutritive value of alcohol. Natl. Acad. Sci. Sixth Mem., vol. 8, pp. 231–397.

(16) ——— and Benedict, F. G.
1903. experiments on the metabolsim of matter and energy in the human body, 1900–1902. U. S. Dept. Agr. Off. Expt. Stas. Bul. 136, 357 pp., illus.

(17) ——— and Bryant, A. P.
1900. the availability and fuel value of food materials. Conn. (Storrs) Agr. Expt. Sta. 12th Ann. Rpt. (1899). pp. 73–110.

(18) ——— and Bryant, A. P.
1900. composition of common food materials—available nutrients and fuel value. Conn. (Storrs) Agr. Expt. Sta. 12th Ann. Rpt. (1899), pp. 111–123.

(19) ——— and Bryant, A. P.
1902. dietary studies in new york city in 1896 and 1897. U. S. Dept. Agr. Off. Expt. Stas. Bul. 116, 83 pp.

(20) ——— and Bryant, A. P.
1906. the chemical composition of american food materials. U. S. Dept. Agr. Off. Expt. Stas. Bul. 28 (rev. ed.), 87 pp., illus.

(21) Atwater, W. O., and Rosa, E. B.
1899. Description of a new respiration calorimeter and experiments on the conservation of energy in the human body. U. S. Dept. Agr. Off. Expt. Stas. Bul. 63, 94 pp., illus.

(22) ——— and Snell, J. F.
1903. Description of a bomb-calorimeter and method of its use. Amer. Chem. Soc. Jour. 25: 659–699, illus.

(23) ——— Woods, C. D., and Benedict, F. G.
1897. Report of preliminary investigations on the metabolism of nitrogen and carbon in the human organism, with a respiration calorimeter of special construction. U. S. Dept. Agr. Off. Expt. Stas. Bul. 44, 64 pp., illus.

(24) Beazell, J. M., Schmidt, C. R., and Ivy, A. C.
1939. On the digestibility of raw potato starch in man. Jour. Nutr. 17: 77–83.

(25) Benedict, F. G.
1907. Influence of inanition on metabolism. Carnegie Inst. Wash., Pub. 77, 542 pp. Washington.

(26) ———
1915. A study of prolonged fasting. Carnegie Inst. Wash., Pub. 203, 416 pp., illus. Washington.

(27) ——— and Milner, R. D.
1907. Experiments on the metabolism of matter and energy in the human body, 1903–1904. U. S. Dept. Agr. Off. Expt. Stas. Bul. 175, 335 pp., illus.

(28) Blyth, A. W.
1889. Experiments on the nutritive value of wheat meal. Proc. Royal Soc. London 45: 549–553.

(29) Bowers, W. G.
1919. Some studies on the nutritive value of the soy bean in the human diet. N. Dak. Agr. Expt. Sta. Spec. Bul., vol. 5, pp. [278]–327, illus.

(30) Breirem, K., and Nicolaysen, R.
1942. Investigations on the digestibility of rye and wheat bran in domestic animals and humans. *In* Avhandlinger utgitt av Det Norske Videnskaps-Akademi I Oslo 1. Mat.-Naturv. Klasse. No. 2, pp. 3–16. Oslo.

(31) Bricker, M., Mitchell, H. H., and Kinsman, G. M.
1945. The protein requirements of adult human subjects in terms of the protein contained in individual foods and food combinations. Jour. Nutr. 30: 269–283, illus.

(32) Bryant, A. P.
1897. Two digestion experiments with an infant. Conn. (Storrs) Agr. Expt. Sta. 9th Ann. Rpt., 1896, Second pt., pp. 181–185.

(33) ——— and Milner, R. D.
1903. Experiments on the digestibility of vegetables. Amer. Jour. Physiol. 10: 81–99.

(34) Cahill, W. M., Schroeder, L. J., and Smith, A. H.
1944. Digestibility and biological value of soybean protein in whole soybeans, soybean flour, and soybean milk. Jour. Nutr. 28: 209–218.

(35) Carpenter, T. M.
1940. The metabolism of alcohol: a review. Quart. Jour. of Studies on Alcohol 1: [201]–226.

(36) Chatfield, C.
1949. Food composition tables for international use. Food and Agr. Organ. Nutr. Studies 3, 56 pp.

(37) Chatfield, C., and Adams, G.
1940. Proximate composition of American food materials. U. S. Dept. Agr. Cir. 549, 91 pp.

(38) ——— and McLaughlin, L. I.
1928. Proximate composition of fresh fruits. U. S. Dept. Agr. Cir. 50, 20 pp.

(39) Cheng, L. T., Li, H. C., and Lan, T. H.
1941. Biological values of soybean protein and mixed soybean-pork and soybean-egg proteins in human subjects. Chinese Jour. Physiol. 16: 83–89.

(40) Clark, L. C., Ryer, H., and Murlin, J. R.
1949. Relative to egg biological values and replacement values of some cereal proteins in human subjects. Jour. Nutr. 38: 405–420.

(41) Cohn, H.
1895. Ueber cacao als nahrungsmittel. Ztschr. f. Physiol. Chem. 20: 1–27.

(42) Constantinidi, A.
1887. Ueber die ausnützung des weizenklebers im darmkanale und über die verwendung desselben zur ernährung des menschen. Ztschr. f. Biol. 23: [433]–455.

(43) Crampton, E. W., Irwin, M. I., Lloyd, L. E., and Neilson, H. R.
1951. The apparent digestibility of essentially similar diets by rats, guinea pigs, sheep, swine and by human subjects. Jour. Nutr. 43: 541–550.

(44) Crook, E. M., and Watson, D. J.
1948. Studies on the storage of potatoes. I. Changes in composition during storage in clamps. Jour. Agr. Sci. [London] 38: 440–457, illus.

(45) Daniel, L. J.
1951. The nutritive value of alcohol. N. Y. State Jour. Med. 51: 1283–1284.

(46) Desikachar, H. S. R., De, S. S., and Subrahmanyan, V.
1948. Protein value of soya-bean milk: human feeding experiments. Indian Jour. Med. Res. 36: 145–148.

(47) ——— and Subrahmanyan, V.
1949. Infant feeding experiments with soya-bean milk. Indian Jour. Med. Res. 37: 77–83.

(48) Deuel, H. J.
1923. Digestibility of baked goods made from patent flour. Jour. Home Econ. 15: [699]–701.

(49) ———
1924. The digestibility of tepary beans. Jour. Agr. Res. 29: 205–208.

(50) Dirr, K.
1942. Über den wert der wuchshefen für die menschliche ernährung. II. Mitteilung: über die biologische brauchbarkeit der bergin-holzzuckertrockenhefe. Biochem. Ztschr. 312: [233]–251.

(51) ——— and Soden, O.
1941. Über den wert der wuchshefen für die menschliche ernährung. I. Mitteilung: aminosäuregehalt von bergin-holzzuckertrockenhefe. Biochem. Ztschr. 309: [329]–336.

(52) Erismann, F.
1901. Die brotsurrogate in hungerszeiten und ihre ausnutzung im menschlichen verdauungskanal. Ztschr. f. Biol. 42: [672]–709.

(53) FITZPATRICK, W. H., ESSELEN, W. B., JR., and WEIR, E.
1946. COMPOSITION AND NUTRITIVE VALUE OF MUSHROOM PROTEIN. Amer. Dietet. Assoc. Jour. 22: 318–323.

(54) FOLIN, O.
1905. A THEORY OF PROTEIN METABOLISM. Amer. Jour. Physiol. 13: 117–138.

(55) FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.
1947. ENERGY-YIELDING COMPONENTS OF FOOD AND COMPUTATION OF CALORIE VALUES. 23 pp. Washington.

(56) FORSTER, J.
1900. UEBER "HOLLÄNDISCHEN" KAKAO. Hyg. Rundschau 10: [305]–317.

(57) FRAPS, G. S.
1946. COMPOSITION, DIGESTIBILITY AND ENERGY VALUES OF SOME HUMAN FOODS. Texas Agr. Expt. Sta. Bul. 680, 41 pp.

(58) FREY, C. N.
1930. HISTORY AND DEVELOPMENT OF THE MODERN YEAST INDUSTRY. Indus. and Engin. Chem. 22: 1154–1162.

(59) FUNK, C., LYLE, W. G., MCCASKEY, D., and others.
1916. THE NUTRITIVE VALUE OF YEAST, POLISHED RICE, AND WHITE BREAD, AS DETERMINED BY EXPERIMENTS ON MAN. Jour. Biol. Chem. 27: 173–191.

(60) FUNNELL, E. H., VAHLTEICH, E. MCC., MORRIS, S. O., and others.
1936. PROTEIN UTILIZATION AS AFFECTED BY THE PRESENCE OF SMALL AMOUNTS OF BRAN OR ITS FIBER. Jour. Nutr. 11: 37–45.

(61) GROSZFELD, J.
1917. ZUR FETTBESTIMMUNG IN BACKWAREN. Ztschr. f. Untersuch. der Nahr. u. Genussmtl. 34: 490–491.

(62) HARCOURT, R., and FULMER, H. L.
1907. BREAKFAST FOODS. THEIR CHEMICAL COMPOSITION, DIGESTIBILITY, AND COST. Ontario Agr. Col. Bul. 162, 56 pp.

(63) HARTMANN, B. G., and HILLIG, F.
1934. ACID CONSTITUENTS OF FOOD PRODUCTS. SPECIAL REFERENCE TO CITRIC, MALIC, AND TARTARIC ACIDS. Assoc. Off. Agr. Chem. Jour. 27: 522–531.

(64) HAWLEY, E. E., MURLIN, J. R., NASSET, E. S., and others.
1948. BIOLOGICAL VALUES OF SIX PARTIALLY-PURIFIED PROTEINS. Jour. Nutr. 36: 153–169, illus.

(65) HEADDEN, W. P.
1927. EFFECTS OF NITRATES ON COMPOSITION OF THE POTATO. Colo. Expt. Sta. Bul. 325, 96 pp., illus.

(66) HERTWIG, R.
1923. DETERMINATION OF FAT IN ALIMENTARY PASTE, FLOUR AND DRIED EGG. Assoc. Off. Agr. Chem. Jour. 6: 508–510.

(67) HEUPKE, W., MIESEN, G., and PREISER, A.
1939. DIE AUSNUTZUNG DER EDELKASTANIE. Ernahr. [Leipzig] 4: 238–242.

(68) HILLS, J. L., WAIT, C. E., and WHITE, H. C.
1909. DIETARY STUDIES IN RURAL REGIONS IN VERMONT, TENNESSEE, AND GEORGIA. U. S. Dept. Agr. Off. Expt. Stas. Bul. 221, 142 pp., illus.

(69) HINDHEDE, M.
1913. STUDIEN ÜBER EIWEISS MINIMUM. Skand. Arch. f. Physiol. 30: [97]–182.

(70) HOLMES, A. D.
1918. DIGESTIBILITY OF PROTEIN SUPPLIED BY SOYBEAN AND PEANUT PRESS-CAKE FLOURS. U. S. Dept. Agr. Bul. 717, 28 pp.

(71) HOLMES, A. D.
1919. EXPERIMENTS ON THE DIGESTIBILITY OF WHEAT BRAN IN A DIET WITHOUT WHEAT FLOUR. U. S. Dept. Agr. Bul. 751, 20 pp.

(72) ———
1920. DIGESTIBILITY OF STEAM-COOKED SOY BEANS AND PEANUTS. Amer. Med. Assoc. Jour. 74: 798–801.

(73) IWANOFF, N. N.
1923. ÜBER DIE ANHAUFUNG UND BILDUNG DES HARNSTOFFS IN CHAMPIGNONS. Biochem. Ztschr. 143: 62–74.

(74) JACOANGELI, T., and BONANNI, A.
1897. L'ALIMENTAZIONE CON LE PASTE ALIMENTARI, DI GRANTURCO E MISTE. Bol. di Not. Agr. 19 (Secondo Semes.): 434–448.

(75) JAFFA, M. E.
1903. FURTHER INVESTIGATIONS AMONG FRUITARIANS AT THE CALIFORNIA AGRICULTURAL EXPERIMENT STATION, 1901–1902. U. S. Dept. Agr. Off. Expt. Stas. Bul. 132, 81 pp.

(76) JONES, D. B.
1941. FACTORS FOR CONVERTING PERCENTAGES OF NITROGEN IN FOODS AND FEEDS INTO PERCENTAGES OF PROTEIN. U. S. Dept. Agr. Cir. 183, 22 pp. (Slightly rev. ed.)

(77) ——— and WATERMAN, H. C.
1922. STUDIES ON THE DIGESTIBILITY OF PROTEINS IN VITRO. III. ON THE CHEMICAL NATURE OF THE NUTRITIONAL DEFICIENCIES OF ARACHIN. Jour. Biol. Chem. 52: 357–366.

(78) JOSLYN, M. A.
1950. METHODS IN FOOD ANALYSIS APPLIED TO PLANT PRODUCTS. 525 pp., illus. New York.

(79) KELSEY, H. P., and DAYTON, W. A., eds.
1942. STANDARDIZED PLANT NAMES. Ed. 2, 675 pp. Harrisburg, Pa.

(80) KEYS, A.
1943. PHYSICAL PERFORMANCE IN RELATION TO DIET. Fed. Proc. 2: 164–187.

(81) ———
1945. THE REFINEMENT OF METABOLIC CALCULATIONS FOR NUTRITIONAL PURPOSES AND THE PROBLEM OF "AVAILABILITY." Jour. Nutr. 29: 81–84.

(82) KLATSKIN, G., GEWIN, H. M., and KREHL, W. A.
1951. EFFECTS OF PROLONGED ALCOHOL INGESTION ON THE LIVER OF THE RAT UNDER CONDITIONS OF CONTROLLED ADEQUATE DIETARY INTAKE. Yale Jour. Biol. and Med. 23: [317]–331, illus.

(83) KON, S. K., and KLEIN, A.
1928. XXXV. THE VALUE OF WHOLE POTATO IN HUMAN NUTRITION. Biochem. Jour. 22: 258–260.

(84) KONIG, J.
1904. CHEMIE DER MENSCHLICHEN NAHRUNGS- UND GENUSSMITTEL. vol. 2, 1,557 pp. Berlin.

(85) KRAMER, M. M., and HALSTEAD, M. J.
1925. THE INFLUENCE OF THE METHOD OF PREPARATION ON THE DIGESTIBILITY OF CORN MEAL. Jour. Home Econ. 17: 75–78.

(86) KREBS, H. A., and MELLANBY, K.
1942. DIGESTIBILITY OF NATIONAL WHEATMEAL. Lancet [London] 242: 319–321.

(87) KUEN, F. M., and PÜRINGER, K.
1934. ÜBER DIE AUSNUTZUNG VON FRISCHER HEFE UND TROCKENHEFE. Biochem. Ztschr. 271: [152]–167.

(88) Kuether, C. A., and Myers, V. C.
1948. THE NUTRITIVE VALUE OF CEREAL PROTEINS IN HUMAN SUBJECTS. Jour. Nutr. 35: 651–667.
(89) Langworthy, C. F.
1904. THE FUNCTIONS AND USES OF FOOD. U. S. Dept. Agr. Off. Expt. Stas. Cir. 46 (rev.), 10 pp.
(90) ——— and Deuel, H. J., Jr.
1919. THE EFFECT OF MILLING ON THE DIGESTIBILITY OF GRAHAM FLOUR. Natl. Acad. Sci. Proc. 5: 514–517.
(91) ——— and Deuel, H. J., Jr.
1920. DIGESTIBILITY OF RAW CORN, POTATO, AND WHEAT STARCHES. Jour. Biol. Chem. 42: 27–40.
(92) ——— and Deuel, H. J., Jr.
1922. DIGESTIBILITY OF RAW RICE, ARROWROOT, CANNA, CASSAVA, TARO, TREE-FERN, AND POTATO STARCHES. Jour. Biol. Chem. 52: 251–261.
(93) ——— and Holmes, A. D.
1916. STUDIES ON THE DIGESTIBILITY OF THE GRAIN SORGHUMS. U. S. Dept. Agr. Bul. 470, 30 pp.
(94) ——— and Holmes, A. D.
1917. EXPERIMENTS IN THE DETERMINATION OF THE DIGESTIBILITY OF MILLETS. U. S. Dept. Agr. Bul. 525, 11 pp.
(95) ——— and Holmes, A. D.
1917. THE DIGESTIBILITY OF THE DASHEEN. U. S. Dept. Agr. Bul. 612, 12 pp.
(96) ——— and Holmes, A. D.
1921. THE EFFECT OF A VARIATION IN MILLING ON THE DIGESTIBILITY OF WHEAT FLOURS. Natl. Acad. Sci. Proc. 7: 119–123.
(97) ——— and Merrill, A. T.
1924. DIGESTIBILITY OF RAW STARCHES AND CARBOHYDRATES. U. S. Dept. Agr. Bul. 1213, 16 pp.
(98) ——— and Milner, R. D.
1904. INVESTIGATIONS ON THE NUTRITION OF MAN IN THE UNITED STATES. U. S. Off. Expt. Stas. Doc. 713, 20 pp., illus.
(99) Lehmann, K. B.
1902. HYGIENISCHE UNTERSUCHUNGEN ÜBER MEHL UND BROT. XI. ÜBER DIE BEDEUTUNG DER SCHÄLUNG UND ZERMAHLUNG DES GETREIDES FÜR DIE AUSNUTZUNG (AVEDYK- UND STEINMETZVERFAHREN). Arch. f. Hyg. 45: 177–211.
(100) Leung, W. W., Pecot, R. K., and Watt, B. K.
1952. COMPOSITION OF FOODS USED IN FAR EASTERN COUNTRIES. U. S. Dept. Agr. Handb. 34, 62 pp.
(101) Lusk, G.
1928. THE ELEMENTS OF THE SCIENCE OF NUTRITION. Ed. 4, 844 pp., illus. Philadelphia and London.
(102) McCance, R. A., and Glaser, E. M.
1948. THE ENERGY VALUE OF OATMEAL AND THE DIGESTIBILITY AND ABSORPTION OF ITS PROTEINS, FATS AND CALCIUM. Brit. Jour. Nutr. 2: 221–228.
(103) ——— and Lawrence, R. D.
1929. THE CARBOHYDRATE CONTENT OF FOODS. Brit. Med. Res. Council Spec. Rpt. Ser., No. 135, 73 pp. London.
(104) ——— and Walsham, C. M.
1948. THE DIGESTIBILITY AND ABSORPTION OF THE CALORIES, PROTEINS, PURINES, FAT AND CALCIUM IN WHOLEMEAL WHEATEN BREAD. Brit. Jour. Nutr. 2: 26–41, illus.
(105) ——— and Widdowson, E. M.
1940. THE CHEMICAL COMPOSITION OF FOODS. Brit. Med. Res. Council Spec. Rpt. Ser., No. 235, 150 pp. London.
(106) McCance, R. A., and Widdowson, E. M.
1947. THE DIGESTIBILITY OF ENGLISH AND CANADIAN WHEATS WITH SPECIAL REFERENCE TO THE DIGESTIBILITY OF WHEAT PROTEIN BY MAN. Jour. Hyg. 45: 59–64.
(107) ——— and Widdowson, E. M.
1947. THE CHEMICAL COMPOSITION OF FOODS. Ed. 2, rev. [Reprint of British ed. 2, 1946. No basic text changes.] 156 pp. Brooklyn, N. Y.
(108) ——— Widdowson, E. M., Moran, T., and others.
1945. THE CHEMICAL COMPOSITION OF WHEAT AND RYE AND OF FLOURS DERIVED THEREFROM. Biochem. Jour. 39: 213–222, illus.
(109) McConnell, J. E. W., and Esselen, W. B., Jr.
1947. CARBOHYDRATES IN CULTIVATED MUSHROOMS (AGARICUS CAMPESTRIS). Food Res. 12: 118–121.
(110) Macrae, T. F., Hutchinson, J. C. D., Irwin, J. O., and others.
1942. COMPARATIVE DIGESTIBILITY OF WHOLEMEAL AND WHITE BREADS AND THE EFFECT OF THE DEGREE OF FINENESS OF GRINDING ON THE FORMER. Jour. Hyg. 42: 423–435.
(111) Macy, I. G.
1942. NUTRITION AND CHEMICAL GROWTH IN CHILDHOOD. VOL. I. EVALUATION. Springfield, Ill. and Baltimore, Md.
(112) ———
[1946.] NUTRITION AND CHEMICAL GROWTH IN CHILDHOOD. VOL. II. ORIGINAL DATA. Springfield, Ill.
(113) Malfatti, H.
1884. ÜBER DIE AUSNUTZÜNG EINIGER NAHRUNGSMITTEL IM DARMCANAL DES MENSCHEN. K. Akad. der Wiss. Sitzber. [Vienna] 90: 323–350.
(114) Maynard, L. A.
1944. THE ATWATER SYSTEM OF CALCULATING THE CALORIC VALUE OF DIETS. Jour. Nutr. 28: 443–452.
(115) ———
1946. INTERNATIONAL FOOD-EVALUATION ACTIVITIES AND PROBLEMS. Fed. Proc. 5: 270–273
(116) Mendel, L. B.
1898. THE CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF SOME EDIBLE AMERICAN FUNGI. Amer. Jour. Physiol. 1: [225]–238.
(117) ——— and Fine, M. S.
1912. STUDIES IN NUTRITION. IV. THE UTILIZATION OF THE PROTEINS OF THE LEGUMES. Jour. Biol. Chem. 10: 433–458.
(118) Merrill, A. L., and Watt, B. K.
1948. PHYSIOLOGIC ENERGY VALUES OF WHEAT. Amer. Dietet. Assoc. Jour. 24: 953–956.
(119) Merrill, L. H.
1905. CEREAL FOODS. Maine Agr. Expt. Sta. Bul. 118, pp. [117]–135.
(120) ———
1906. INDIAN CORN AS FOOD FOR MAN. DIGESTION EXPERIMENTS WITH CHESTNUTS. Maine Agr. Expt. Sta. Bul. 131: [133]–148.
(121) ———
1908. FOOD OF MAN STUDIES. Maine Agr. Expt. Sta. Bul. 158, pp. [219]–238.
(122) Mitchell, H. H., and Curzon, E. G.
1940. THE FOOD VALUE OF ETHYL ALCOHOL. Quart. Jour. of Studies on Alcohol 1: [227]–245.
(123) Mörner, C. T.
1886. BEITRÄGE ZUR KENNTNISS DES NÄHRWERTHES EINIGER ESSBAREN PILZE. Ztschr. f. Physiol. Chem. 10: [503]–516

(124) Murlin, J. R., Edwards, L. E., Hawley, E. E., and Clark, L. C.
1946. biological value of proteins in relation to the essential amino acids which they contain. i. the endogenous nitrogen of man. Jour. Nutr. 31: 533–554, illus.

(125) ——— Edwards, L. E., Fried, S., and others.
1946. biological value of proteins in relation to the essential amino acids which they contain. iii. comparison of proteins with mixtures of the amino acids. Jour. Nutr. 31: 715–736.

(126) ——— Line, W. R., Piper, H. A., and Pierce, H.B.
1929. the nutritive value of cereal breakfast foods. i. composition and heat value. Jour. Nutr. 2: 83–90.

(127) ——— Marshall, M. E., and Kochakian, C. D.
1941. digestibility and biological value of whole wheat breads as compared with white bread. Jour. Nutr. 22: 573–588, illus.

(128) ——— and Mattill, H. A.
1938. digestibility and nutritional value of cereal proteins in the human subject. Jour. Nutr. 16: 15–35.

(129) ——— Nasset, E. S., and Marsh, M. E.
1938. the egg-replacement value of the proteins of cereal breakfast foods, with a consideration of heat injury. Jour. Nutr. 16: 249–269.

(130) Neuberger, A., and Sanger, F.
1942. the nitrogen of the potato. Biochem. Jour. 36: 662–671.

(131) Neumann, R. O.
1906. die bewertung des kakaos als nahrungs- und genufsmittel. i. teil. versuche über den einflufs der menge, des fettgehaltes, des schalengehaltes, des kakaos und der mit demselben eingeführten nahrung auf die resorption und assimilation desselben. Arch. f. Hyg. 58: 1–62. (Data from Beddies, A., pp. 16–17.)

(132) ———
1906. die bewertung des kakaos als nahrungs-und genufsmittel. ii. teil. versuche mit verschiedenen kakaohandelssorten. Arch. f. Hyg. 58: 63–124.

(133) Newman, L. F., Robinson, G. W., Halnan, E. T., and Neville, H. A. D.
1912. some experiments on the relative digestibility of white and whole meal breads. Jour. Hyg. 12: [119]–143.

(134) Oshima, K.
1905. a digest of japanese investigations on the nutrition of man. U.S. Dept. Agr. Off. Expt. Stas. Bul. 159, 224 pp.

(135) Pittman, M. S.
1932. the utilization by human subjects of the nitrogen, calcium, and phosphorus of the navy bean (phaseolus vulgaris) with and without a supplement of cystine. Jour. Nutr. 5: 277–294.

(136) Plagge and Lebbin.
1897. untersuchungen über das soldatenbrot. 234 pp., illus. Berlin. (Veröffentlichungen aus dem Gebiete des Militär-Sanitätswesens, Heft 12.)

(137) Prausnitz, W.
1890. die ausnutzüng der bohnen im darmkanale des menschen. Ztschr. f. Biol. 26: 227–232.

(138) Pugliese, A.
1915. la valeur alimentaire des divers types de pain. Rev. Gén. des Sci. Pures et Appl. 26: 612–617. illus.

(139) Remy, E.
1931. experimentelle studien zur biochemie und biologie der rohfaser. Biochem. Ztschr. 236: 1–18.

(140) Richter, A. P. F.
1903. über die ausnützung von erbsen im darmkanal des menschen bei weichem und hartem kochwasser. Arch. f. Hyg. 46: 264–273.

(141) Romberg, E.
1897. der nährwerth der verschiedenen mehlsorten einer modernen roggenkunstmühle. Arch. f. Hyg. 28: [244]–290.

(142) Rose, M. S., and Cooper, L. F.
1917. the biological efficiency of potato nitrogen. Jour. Biol. Chem. 30: 201–204.

(143) ——— and MacLeod, G.
1925 maintenance values for the proteins of milk, meat, bread and milk, and soy bean curd. Jour. Biol. Chem. 66: 847–867.

(144) Rubner, M.
1879. ueber die ausnützung einiger nahrungsmittel im darmcanale des menschen. Ztschr. f. Biol. 15: [115]–202.

(145) ———
1880. ueber die ausnützung der erbsen im darmkanale des menschen. Ztschr. f. Biol. 16: 119–128.

(146) ———
1883. ueber den werth der weizenkleie für die ernährung des menschen. Ztschr. f. Biol. 19: 45–100.

(147) ———
1885. calorimetrische untersuchungen. i and ii. Ztschr. f. Biol. 21: [250]–334; [337]–410.

(148) ———
1901. der energiewert der kost des menschen. Ztschr. f. Biol. 42: [261]–308.

(149) ———
1930. über die elementarzusammensetzung des harnes bei verschiedener ernährung nach versuchen von Elmer Berry M. P. E. Ztschr. f. die Gesam. Expt. Med. 72: [144]–177.

(150) ——— and Heubner, O.
1898. die natürliche ernährung eines säuglings. Ztschr. f. Biol. 36: 1–55.

(151) ——— and Thomas, K.
1918. die ernährung mit kartoffeln. Arch. f. Anat. u. Physiol. (Physiol. Abt.) pp. 1–15.

(152) Saltet, R. H.
1885. ueber die bedeutung der essbaren schwamme als nahrungsmittel für den menschen. Arch. f. Hyg. 3: [443]–463.

(153) Schlesinger, H.
1895. beiträge zur beurtheilung des cacaos bei der ernährung des menschen. Deut. Med. Wchnschr. 21: 80–82.

(154) Schoch, T. J.
1938. absence of combined fatty acid in cereal starches. (Communications to the Editor.) Amer. Chem. Soc. Jour. 60: 2824–2825.

(155) Sealock, R. R., Basinski, D. H., and Murlin, J. R
1941. apparent digestibility of carbohydrates, fats, and "indigestible residue" in whole wheat and white breads. Jour. Nutr. 22: 589–596, illus.

(156) SHERMAN, H. C.
1902. THE METABOLISM OF NITROGEN, SULPHUR, AND PHOSPHORUS IN THE HUMAN ORGANISM. U. S. Dept. Agr. Off. Expt. Stas. Bul. 121, 47 pp., illus.

(157) ———
1911. CHEMISTRY OF FOOD AND NUTRITION. 355 pp., illus. New York.

(158) ———
1937. CHEMISTRY OF FOOD AND NUTRITION. Ed. 5 640 pp., illus. New York.

(159) ———
1952. CHEMISTRY OF FOOD AND NUTRITION. Ed. 8. 721 pp., illus. New York.

(160) SHERWOOD, R. C., NORDGREN, R., and ANDREWS, J. S.
1941. THIAMIN IN THE PRODUCTS OF WHEAT MILLING AND IN BREAD. Cereal Chem. 18: 811–819, illus.

(161) SKINNER, J. T., PETERSON, W. H., and STEENBOCK, H.
1933. NÄHRWERT VON SCHIMMELPILZMYCEL. Biochem. Ztschr. 267: [169]–178.

(162) SNYDER, H.
1897. THE DIGESTIBILITY OF POTATOES AND EGGS. *In* U. S. Dept. Agr. Off. Expt. Stas. Bul. 43, Losses in Boiling Vegetables and the Composition and Digestibility of Potatoes and Eggs, pp. 20–24.

(163) ———
1899. MISCELLANEOUS ANALYSES: COMPOSITION OF TOMATOES. PROTEIDS OF WHEAT FLOUR. Minn. Agr. Expt. Sta. Bul. 63, pp. [495]–533.

(164) ———
1901. STUDIES ON BREAD AND BREAD MAKING AT THE UNIVERSITY OF MINNESOTA IN 1899 AND 1900. U. S. Dept. Agr. Off. Expt. Stas. Bul. 101, 65 pp., illus.

(165) ———
1902. HUMAN FOOD INVESTIGATIONS. Univ. Minn. Agr. Expt. Sta. Bul. 74, pp. [109]–174, illus.

(166) ———
1903. STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD AT THE UNIVERSITY OF MINNESOTA IN 1900–1902. U. S. Dept. Agr. Off. Expt. Stas. Bul. 126, 52 pp., illus.

(167) ———
1905. THE DIGESTIBILITY AND NUTRITIVE VALUE OF COTTAGE CHEESE, RICE, PEAS AND BACON. Univ. Minn. Agr. Expt. Sta. Bul. 92, pp. [259]–275.

(168) ———
1905. STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD AND OF MACARONI AT THE UNIVERSITY OF MINNESOTA, 1903–1905. U. S. Dept. Agr. Off. Expt. Stas. Bul. 156, 80 pp., illus.

(169) ———
1908. HUMAN FOODS AND THEIR NUTRITIVE VALUE. 362 pp., illus. New York.

(170) ——— and VOORHEES, L. A.
1899. STUDIES ON BREAD AND BREAD MAKING. U. S. Dept. Agr. Off. Expt. Stas. Bul. 67, 51 pp., illus. (Reprinted, 1903.)

(171) SOUTHARD, L., RICHARDS, E. H., USHER, S., TERRILL, B. M., and SHAPLEIGH, A.
1903. DIETARY STUDIES IN BOSTON AND SPRINGFIELD, MASS., PHILADELPHIA, PA., AND CHICAGO, ILL. U. S. Dept. Agr. Off. Expt. Stas. Bul. 129, 103 pp.

(172) SPRIGGS, E. I., and WEIR, A. B.
1917. THE DIGESTIBILITY OF BREAD MADE FROM TWO PARTS OF WHEAT AND ONE PART OF OATS, BARLEY, MAIZE, OR RICE. Lancet [London] 193: 724–726.

(173) STREET, H. E., KENYON, A. E., and WATSON, G. M.
1946. THE NATURE AND DISTRIBUTION OF VARIOUS FORMS OF NITROGEN IN THE POTATO. Ann. Appl. Biol. 33: 1–12, illus.

(174) STREET, J. P., and BAILEY, E. M.
1915. THE CARBOHYDRATES AND THE ENZYMES OF THE SOY BEAN. Indus. and Engin. Chem. Jour. 7: 853–858.

(175) STROHMER, F.
1886. EIN BEITRAG ZUR KENNTNIS DER ESSBAREN SCHWÄMME. Arch. f. Hyg. 5: [322]–332.

(176) STRÜMPELL, A.
1875. UEBER DEN NÄHRWERTH DER LEGUMINOSEN UND IHRE BEDEUTUNG ALS KRANKENSPEISE. Deut. Arch. f. Klin. Med. 17: [108]–119.

(177) STUTZER, A.
1891. NEUES AUS DER RÖST-, DARR- UND TROCKNUNGS-INDUSTRIE. Ztschr. f. Angew. Chem. Jahrg. 1891, Heft. 12: 368–375.

(178) SUGIMOTO, K.
1926. STUDIES ON THE DIGESTIBILITY AND UTILISATION OF RICE OF DIFFERENT GRADES OF POLISHING. *In* Saiki, T., [ed.] Progress of the Science of Nutrition in Japan. League of Nations Health Organ. III. Health III. 25. C. H. 523, pp. [87]–154.

(179) ——— HIGUCHI, M., MOMOYEDA, S., and others.
1926. THE DIGESTIBILITY AND UTILISATION OF RICE COOKED BY DIFFERENT METHODS. *In* Saiki, T., [ed.] Progress of the Science of Nutrition in Japan. League of Nations Health Organ. III. Health III. 25. C. H. 523, pp. [155]–233.

(180) TANGL, F.
1899. BEITRAG ZUR KENNTNISS DES ENERGIEGEHALTES DES MENSCHLICHEN HARNES. *In* Arch. f. Anat. u. Physiol. (Physiol. Abt.), pp. 251–266. Leipzig.

(181) TSO, E., and CHU, F. T.
1931. NITROGEN METABOLISM IN INFANTS ON GRADED INTAKE OF SOYBEAN "MILK" PROTEINS. Chinese Jour. Physiol. 5: 287–294, illus.

(182) UNITED STATES BUREAU OF AGRICULTURAL ECONOMICS.
1953. CONSUMPTION OF FOOD IN THE UNITED STATES, 1909–52. U. S. Dept. Agr. Handb. 62, 249 pp., illus.

(183) UNITED STATES DEPARTMENT OF AGRICULTURE, DIVISION OF CHEMISTRY.
1898. FOODS AND FOOD ADULTERANTS. (Investigation under direction of H. W. Wiley.) U. S. Dept. Agr. Bul. 13, pp. 1169–1374, illus.

(184) WAIT, C. E.
1907. STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF LEGUMES AT THE UNIVERSITY OF TENNESSEE, 1901–1905. U. S. Dept. Agr. Off. Expt. Stas. Bul. 187, 55 pp.

(185) WATT, B. K., and MERRILL, A. L.
1950. COMPOSITION OF FOODS—RAW, PROCESSED, PREPARED. U. S. Dept. Agr. Handb. 8, 147 pp.

(186) WEINSTOCK, A., and BENHAM, G. H.
1951. THE USE OF ENZYME PREPARATIONS IN THE CRUDE FIBER DETERMINATION. Cereal Chem. 28: 490–497, illus.

(187) WILLIAMS, R. D., and OLMSTED, W. H.
1935. A BIOCHEMICAL METHOD FOR DETERMINING INDIGESTIBLE RESIDUE (CRUDE FIBER) IN FECES: LIGNIN, CELLULOSE, AND NON-WATERSOLUBLE HEMICELLULOSES. Jour. Biol. Chem. 108: 653–666.

(188) WILLIAMS, R. T., ed.
1952. LIPID METABOLISM. Biochem. Soc. Symposia 9, 101 pp. [London.]

(189) WINTGEN, M.
1905. UEBER DIE AUSNUTZBARKEIT VON LEGUMINOSENMEHLEN. Veröffentl. aus. dem Gebiete des Milit.—Sanitatsw. 29: [37]–55.

(190) WOLLAEGER, E. E., COMFORT, M. W., and OSTERBERG, A. E.
1947. TOTAL SOLIDS, FAT AND NITROGEN IN THE FECES: III. A STUDY OF NORMAL PERSONS TAKING A TEST DIET CONTAINING A MODERATE AMOUNT OF FAT; COMPARISON WITH RESULTS OBTAINED WITH NORMAL PERSONS TAKING A TEST DIET CONTAINING A LARGE AMOUNT OF FAT. Gastroenterol. 9: 272–283.

(191) ——— LUNDBERG, W. O., CHIPAULT, J. R., and MASON, H. L.
1953. FECAL AND PLASMA LIPIDS. A STUDY OF 2 NORMAL HUMAN SUBJECTS TAKING (1) A DIET FREE OF LIPID AND (2) A DIET CONTAINING TRIOLEIN AS THE ONLY LIPID. Gastroenterol. 24: 422–436.

(192) WOOD, T. B.
1911. THE COMPOSITION AND FOOD VALUE OF BREAD. Royal Agr. Soc. England Jour. 72: 1–24.

(193) WOODS, C. D., and MERRILL, L. H.
1900. A REPORT OF INVESTIGATIONS ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD. U. S. Dept. Agr. Off. Expt. Stas. Bul. 85, 51 pp.

(194) ——— and MERRILL, L. H.
1904. ENTIRE WHEAT FLOUR. Maine Agr. Expt. Sta. Bul. 103, pp. [61]–76, illus.

(195) ——— and MERRILL, L. H.
1904. STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD AT THE MAINE AGRICULTURAL EXPERIMENT STATION 1899–1903. U. S. Dept. Agr. Off. Expt. Stas. Bul. 143, 77 pp.

(196) ——— and SNYDER, H.
1906. CEREAL BREAKFAST FOODS. U. S. Dept. Agr. Farmers' Bul. 249, 36 pp.

APPENDIX. TABULAR SUMMARY OF EXPERIMENTS ON DIGESTIBILITY OF FOODS OF PLANT ORIGIN BY HUMAN SUBJECTS

Apparent Digestibility and Available Energy

Scope of compilation.—The compilation of human digestion experiments given in table 23 presents data on the apparent digestibility of protein, fat, carbohydrate, and energy, and in some cases the availability of the total energy of various foods of plant origin. It covers research in this field since 1875. Data published in languages other than English may not have been covered completely but the greater portion is believed to have been reviewed. The reports included in the compilation may be identified by the numbers in the last column of the table, which refer to Literature Cited, page 51.

Coefficients of apparent digestibility of fat are shown in the table, but in many cases are not considered to be reliable. With the exception of a few kinds of plant foods, such as nuts, the fat content is too low to contribute more than a small part of the total fat intake. Thus, in calculating the digestibility of the fat of the test food even a small error in the assumptions made for digestibility of fat of the remainder of the diet may result in a relatively large error in the estimated digestibility of the test food.

Too much importance should not be given to the reported figures for gain or loss of body nitrogen in studies in which the experimental periods were short and in studies in which no preliminary period on the experimental diet was indicated. If the period on the experimental diet had been sufficiently long the subjects might have reached nitrogen equilibrium.

This compilation includes studies in which the apparent digestibility of the test food was reported or could be calculated from data given by the author. A wide variety of experimental conditions are represented, some of which were too extreme for derivation of coefficients of digestibility for general use as represented in table 13. However, they are useful in considering the effects that various conditions of dietary intake and experimental procedures may have upon the digestibility of foods and for this reason are included in the compilation.

Order of foods.—The order in which the food groups appear in the table follows that used by Atwater and Bryant in their report of 1899 (*17*) and by the Food and Agriculture Organization ad hoc Committee in its report of May 1947 (*55*). This order seemed desirable in that the first two groups, "Grain, Grain Products" and "Legumes and Nuts," are both important sources of calories, and it is on foods in these two groups the greater portion of the research on digestibility of foods of plant origin has been done.

The food items within each group have been arranged alphabetically except where some other arrangement is believed to be more useful to the reader. For example, the wheat items are in the order of their relation to the original grain, starting with the items most similar to the whole grain in composition and form. Thus, the whole-grain flours appear first, followed by intermediate extractions, 80-percent extraction and lower extractions.

The common plant names in table 23 are followed by their scientific names to aid the user in identification of items. Occasionally the scientific names were given by the authors (items 23, 24, 88–91, 316–320). Otherwise we have used the ones preferred in Standardized Plant Names (*79*) with a few exceptions where other names were recommended by the Horticultural Crops Research Branch of the Agricultural Research Service, U. S. Department of Agriculture.

Apparent digestibility.—The coefficients of digestibility reported in the table represent apparent digestibility. In calculating the apparent digestibility no attempt has been made to distinguish between metabolic products and undigested food in the feces. Using protein as an example, these coefficients are calculated as follows:

$$\frac{\text{Protein intake from test food} - \text{Protein (from test food) in feces}}{\text{Protein intake from test food}} \times 100 = \text{Coefficient of apparent digestibility of protein of test food as percent.}$$

Where there were no data on the basal diet and the diets used were relatively simple, the fecal protein for the diet exclusive of the test food was calculated from the coefficient of digestibility of the various items in the diet. For example, in a very simple diet of bread and milk in which bread was the test food, it was commonly assumed that milk protein would have a digestibility of 97 percent. Then the fecal protein from milk would be 3 percent of the milk protein intake (100−97) and that from bread would be the difference between the total fecal protein and the milk fecal protein.

When the authors determined the digestibility of a mixed diet during a preliminary period and then substituted the test food for a specified proportion of the mixed diet, it was assumed that reducing the intake of the basal diet did not change its digestibility. If the test food replaced 15 percent of the basal diet, the fecal protein in the test period due to the basal diet was considered to be 85 percent of the fecal protein found experimentally for the basal period. The resulting value was subtracted from the total fecal protein in the test period to obtain the protein from the test food in the feces.

The coefficients of digestibility of fat, carbohydrate, and of energy have been calculated in the same way.

The proportion of gross energy available to the body was reported in a limited number of studies. To obtain this value the energy lost in the urine, as well as the energy value of the feces, was deducted from the gross energy of the food intake. The absorbed fat and carbohydrate were considered to be completely oxidized, and the unoxidized organic matter of the urine was assumed to be mainly nitrogenous products. The energy loss in the urine was assumed to average 1.25 calories per gram of absorbed protein. On these assumptions the available energy of the test food was calculated as follows:

Gross energy of test food−fecal energy from test food−energy lost in urine (digestible protein from test food×1.25) = available energy from test food.

$$\frac{\text{Available energy} \times 100}{\text{Gross energy}} = \text{Percent of gross energy available to the body.}$$

Table 22 shows in detail the results of calculations for estimating the coefficients of digestibility of protein, fat, carbohydrate, and energy, and the proportion of energy actually available to the body. This experiment was taken from one of the early reports of Snyder (*164*).

Adaptations of published data.—All the studies in which original basic data were reported by the authors have been recalculated prior to inclusion in table 23. Differences, when found, between the results as originally reported and the recalculated figures were of three types:

1. Whereas in most studies investigators assumed digestibility coefficients for the basal foods close to or the same as those shown in table 13, in occasional studies they applied other coefficients of digestibility. As a result, the original figures for digestibility and proportion of energy available from the test food were in some cases considerably different from results we obtained by applying the usual coefficients to the basal diets. If our recalculated figures differed from the reported results by more than 1 percent, they were entered in table 23, and attention called to this change by a footnote.

2. In some studies the authors did not report apparent digestibility or available energy but reported the basic data needed for making such calculations. For these cases we have calculated the values entered in table 23 as noted in a footnote.

3. In still other experiments when we used the basic data and assumptions reported by the authors in calculation, we obtained a different result. Our recalculated values have been entered in brackets in table 23.

TABLE 22.—*Use of digestibility data to determine coefficients of apparent digestibility and available energy*

Sample No.		Weight of material	Protein (Nx6.25)	Fat	Carbohydrate	Ash	Heat of combustion
	Food consumed:	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Calories*
70	Bread (made from graham flour)	908. 3	70. 5	11. 5	389. 0	8. 6	2, 093
69	Milk	3, 250. 0	95. 9	113. 8	167. 4	25. 7	2, 327
	Total		166. 4	125. 3	556. 4	34. 3	4, 420
71	Feces (water free)	90. 0	16. 3	9. 4	49. 6	14. 7	392
	Estimated feces from food other than bread		2. 9	5. 7	3. 3		83
	Estimated feces from bread		13. 4	3. 7	46. 3		309
	Total amount digested		150. 1	115. 9	506. 8	19. 6	4, 028
	Estimated digestible nutrients in bread		57. 1	7. 8	342. 7		1, 784
			Percent	*Percent*	*Percent*	*Percent*	*Percent*
	Coefficients of digestibility of total food		90. 2	92. 5	91. 1	57. 1	91. 1
	Estimated coefficients of digestibility of bread		81. 0	67. 8	88. 1		85. 2
	Proportion of energy actually available to body:						
	In total food						86. 9
	In bread alone						81. 8

NOTE.—This table appears as table 18 in U. S. Department of Agriculture Bul. 101 (*164*).

Terms and symbols used.—References to "authors" in either the footnotes or descriptive columns in table 23 apply to the authors of the specific digestibility reports and not to the compilers of table 23.

The proportion of protein, fat, carbohydrate, and energy supplied by the test food in the diet has been shown in the table wherever suitable information on composition and amounts of food were reported. In some cases composition data given were not complete and we have used figures from Agriculture Handbook No. 8 (*185*) to supply missing composition data and have entered the results in parentheses in table 23.

Parentheses were used also in the descriptive columns for added explanatory phrases as interpreted from the authors' description. To illustrate, for item 9 the term "hominy" was not used in the text of the article but since there was little doubt as to the identity of the product this interpretation of the test food was noted in parenthesis in addition to the author's description of the product.

Quotation marks have been used with certain food items to indicate that they were quoted directly from the article. This was done whenever a term might have different connotations. For example, entire-wheat flour, as used in studies reported in the early part of the 20th century, was a flour of intermediate extraction having part of the bran removed. Today this term applies to a whole-grain product.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS															
	Barley Products (*Hordeum vulgare*):		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
1	Barley,* flaked	Barley porridge, cooked 20 min.; cream, sugar. Average daily intake: 26 gm. protein, 1,780 calories.	CBT			63	4	64	43	57.6		96.3	[1] 87.3	[2] 85.9	Subjects, young men. Experimental period, 4 days. No preliminary experimental period. Fecal marker, lampblack.	62
			FAC			75	5	72	53	74.0		97.2	[1] 90.6	[2] 88.5		
			Av.			69	4	68	48	65.8		96.8	89.0	87.2		
2	Barley,* germinated, flaked.	Barley porridge, cooked 20 min.; cream, sugar. Average daily intake: 28 gm. protein, 2,170 calories.	FAC			81	3	66	40	67.8		97.0	[1] 92.7	[2] [90.4]		
			WJH			80	3	68	40	76.9		98.4	[1] 96.8	[2] 94.3		
			CBT			78	2	65	36	69.3		97.3	[1] 93.1	[2] 90.7		
			Av.			80	3	67	39	71.3		97.6	94.2	91.8		
3	Barley products (pearled; flaked).[3]									77.8		93.8	86.4		Subjects, healthy men. Coefficients of digestibility estimated by authors from unpublished data available at Conn., Maine, and Minn. Agr. Expt. Stas.	196
	Buckwheat Products (*Fagopyrum esculentum*):															
4	(Farina, flour, groats)[3]									77.8		93.8	86.4			
5	Flour*	Buckwheat flour, boiled with water, salt, and small amount meat extract. 600 gm. uncooked weight of flour eaten daily.	KY 46	1.1		100	100	100		74.3		96.8			Subject, 47-yr. old man. Experimental period, 3 days. Marker, red mungo bean. Study by Y. Washitsu and K. Uki in *(134, p. 166)*.	134
6	Flour (presumably similar to item 5).	Buckwheat flour, prepared like macaroni; beef extract, shoyu.	KY 47	1.0		(89)	100	100		76.3	76.4	97.2			Subject, 49-yr. old man. Experimental period, 3 days. Marker, raw red mungo bean. Study by K. Kawanishi in *(134, p. 167)*.	
	Corn, Corn Products (*Zea mays*):															
7	Field corn, yellow hybrid, dried several days.	Corn, ground and cooked with water and salt. Also unground, cooked 1 hr. at 15 lb. pressure. Sucrose added in diets of AF and GS; butter, in diet of CK.	AF 86	.7		100				[1] 62.9					Subjects, 3 men. Collection period, 9 days, began on 3rd day. Marker, charcoal or barium sulfate at beginning and end collection period. N-balance average, −1.6 gm. per day.	88
			CK 78	.7		100				[1] 58.4						
			GS 75	.7		100				[1] 71.2						
			Av.	.7	37.5	100				64.2						
8	Hominy*	Hominy, cooked. Eaten in simple and mixed diets.[4]								74.5		98.2	94.4		Subjects (see remarks, item 14). Experimental period, 6 days.	120
9	(Hominy),* hulled using alkali, steamed.	Hulled steamed corn, milk								61.2		96.4		86.7	4 subjects, C, D, M, S. 8 experiments. Authors' usual method followed.	121
10	Meal, coarsely ground, sifted through 16-mesh sieve.	Cornbread (recipe: 15 c. cornmeal, 1⅝ c. molasses, 1 c. lard, 1⅓ qt. water, 3¾ tsp. salt, 3¾ tsp. soda, 5 tsp. ginger), potatoes, applesauce, butter, sugar. Average daily intake: 38 gm. protein, 115 gm. fat, 451 gm. carbohydrate.	DGG			78		(55)		[1] 53.5		95.1			Subjects, young men. Experimental period, 3 days. Marker, charcoal. See also remarks for sorghum, items 88–91.	93
			RLS			81		(60)		[1] 68.1		97.2				
			OES			79		(50)		[1] 51.6		96.2				
			Av.			79		55		57.7		96.2				
11	Meal* (presumably degermed, fiber and ash low).	Cornmeal porridge, cooked 20 min.; cream, sugar. Average daily intake: 27.6 gm. protein, 1,930 calories.	KGMc			66	3	73	50	75.0		99.2	[1] 97.4	[2] 95.6	Subjects, young men. Experimental period, 4 days. Marker, lampblack.	62
			JEB			65	3	73	51	74.3		99.1	[1] 96.1	[2] 94.5		
			CRK			66	3	72	52	71.9		98.3	[1] 95.6	[2] 94.0		
			Av.			66	3	73	51	73.7		98.9	96.4	94.7		

12	Meal, reported as maize meal.	Polenta (629 gm. cornmeal cooked with water to form a mush). Daily intake: 43 gm. protein, 10 gm. fat, 481 gm. carbohydrate.					100	100	100	100	81.7	57.9	96.6			Subject, young man. Experimental period, 2 days for 1st, and 3 days for 2d and 3d experiments. Marker, lampblack.	113
		Polenta (776 gm. cornmeal) with butter, 95 gm. Daily intake: 54 gm. protein, 92 gm. fat, 590 gm. carbohydrate.					98	13	100		68.5		96.3				
		Polenta (794 gm. cornmeal) with Swiss cheese, 130 gm. Daily intake: 90 gm. protein, 37 gm. fat, 612 gm. carbohydrate.					61	27	100		[1] 89.9		[1] 97.7				
13	Meal	Cornmeal wafers (240 gm. cornmeal) in simple diet of 255 gm. apple, 31 gm. dried whole milk, 28 gm. sugar, 93 gm. butter.	RC				72		74		78.0		99.3			Subjects, young women. Experimental period, 3 days.	85
			EG				72		74		71.4		99.7				
			MH				72		74		76.3		99.4				
			Av.				72		74		75.2		99.5				
		Cornmeal mush, cooked 30 min. at 20 lb. pressure in simple diet described above.	RC				72		74		81.9		99.5				
			EG				72		74		73.8		98.9				
			MH				72		74		82.4		99.5				
			HR				72		74		73.7		99.3				
			Av.				72		74		78.0		99.3				
		Cornmeal muffins in simple diet described above.	MK				72		74		70.3		99.0				
			EG				72		74		75.0		98.8				
			MH				72		74		78.4		98.7				
			HR				72		74		70.1		98.8				
			Av.				72		74		73.5		98.8				
		Raw cornmeal in frozen pudding eaten in simple diet described above.	RC				72		74		82.8		99.5				
			MH				72		74		82.7		99.0				
			Av.				72		74		82.8		99.3				
		Cornmeal mush, cooked 10 min., eaten in simple diet described above.	RC				72		74		79.9		98.9				
			EG				72		74		80.1		99.1				
			MH				72		74		79.7		98.9				
			HR				72		74		76.7		99.2				
			Av.				72		74		79.1		99.0				
14	Meal,* granulated	Hasty pudding (cornmeal, salt, water) eaten in simple and mixed diets.[4]									73.2		98.3	93.1		Several experiments made with 2 subjects, most of them with 4. Experimental period, 6 days.	120
		Johnnycake (equal parts cornmeal and wheat flour) eaten in simple and mixed diets.[4]									86.3		98.9	93.5			
		Brown bread (equal parts cornmeal and wheat flour) eaten in simple and mixed diets.[4]									83.0		98.6	93.4			
		Hoe cake (cornmeal, sugar, salt, water) eaten in simple and mixed diets.[4]									77.1		98.6	93.8			
		Hoe cake with sirup, eaten in simple and mixed diets.									78.8		98.7	94.0			
15	Meal,* waxy variety of maize imported from China.	Frozen pudding (raw cornmeal, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 39 gm. protein, 1,970 calories.	ATM				(45)	(12)	46		[1] 79.3		97.7			Subjects, women. Experimental period, 3 days, 9 meals. Marker, carmine, with lampblack for following period of 3 or 4 days on regular diet.	97
			CM				(45)	(12)	50		[1] 80.1		98.0				
			ER				(45)	(12)	46		[1] 69.4		96.2				
16	Meal,* white	Diet same as for item 15. Average daily intake: 34 gm. protein, 1,750 calories.	ATM				(40)	(8)	51		[1] 73.7		98.3				
			RJ				(40)	(8)	48		[1] 76.4		98.6				
			CM				(40)	(8)	49		[1] 69.3		98.8				
17	Meal, yellow	Polenta, a hasty pudding of cornmeal, water, and salt.		58	1.2		100	100	100	100	75.6	84.9	96.9			Subject, 45-yr.-old farmer. Experimental period, 3 days, 2 meals per day.	74
				58	1.1		100	100	100	100	74.1	85.9	94.7				
				58	1.3		100	100	100	100	76.9	83.8	92.6				
			Av.		1.2		100	100	100	100	75.5	84.9	94.7				
18	Starch	Frozen pudding (raw cornstarch, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 22 gm. protein, 1,920 calories.	GB				(4)	(.4)	57				100.0			Subjects, women. Experimental period, 3 days, 9 meals. Marker, carmine, with lampblack for following period of 3 to 4 days on regular diet.	97
			ATM				(4)	(.4)	44				100.0				
			CM				(4)	(.4)	57				100.0				
			RLP				(4)	(.4)	49				100.0				
19	Starch	Frozen pudding (raw cornstarch, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 31 gm. protein, 2,760 calories.	WVD				(4)	(.4)	54				100.0			Subjects, men students. Experimental period, 3 days. Authors' usual laboratory procedure followed.	91
			HLO				(4)	(.4)	57				100.0				
			ELM				(4)	(.4)	59				100.0				

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Calculated from authors' data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[3] Coefficients of digestibility estimated for "products" were considered by authors of article to be applicable to these items.

[4] Simple diet, milk, sugar and/or butter; mixed diet, meat and canned peaches in addition.

*Indicates that composition, and in some cases also heat of combustion, was reported by the author. See table 24.

493-781 O - 73 - 5

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Corn, Corn Products (*Zea mays*)—Con. Ready-to-eat breakfast food:		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
20	Corn endosperm,[6] toasted, added sugar, salt.	Toasted corn endosperm, sugar, cream, and coffee.[4]				80						97.1			Details of experiment not given. Authors reported "coefficient of utilization" of protein, 84 percent; not included in this table since not clear if value is true or apparent digestibility.	126
21	Corn flakes	Corn flakes. Sucrose added in diets of AF and GS; butter added in diet of CK.	AF 86	0.7		100				[1]65.4					Subjects, 3 men. Collection period, 9 days, began on 3d day. Marker, charcoal or barium sulfate at beginning and end of collection period. N-balance average, −1.7 gm. for corn flakes period, −1.6 gm. for oven-expanded corn cereal period.	88
			CK 78	.7		100				[1]67.9						
			GS 75	.7		100				[1]67.0						
			Av. 80	.7	37.5	100				66.8						
22	Oven-expanded corn cereal.	Corn cereal. Sucrose added in diet of AF; butter added in diets of CK and GS.	AF 86	.7		100				[1]66.2						
			CK 78	.7		100				[1]70.2						
			GS 75	.7		100				[1]66.5						
			Av. 80	.7	37.5	100				67.6						
	Millet:															
23	Meal (*Panicum miliaceum*), proso, 29 percent of the millet (chiefly bran) removed by sifting through a 16-mesh sieve.	Millet bread (recipe: 15 c. millet meal, 1⅞ c. molasses, 1 c. lard, 2 qt. water, 3¾ tsp. salt, 3¾ tsp. soda, 5 tsp. ginger), potato, orange, tea or coffee as desired. Daily intake: 45 gm. protein, 2,140 to 3,080 gross calories.	DGG			80	(3)	(49)		[1]34.2		96.2			Subjects, young men (medical and dental students). Experimental period, 3 days. Marker, charcoal, taken with 1st meal of experimental period and with 1st meal following.	94
			HRG			80	(4)	(56)		[1]32.0		93.9				
			AJH			77	(2)	(45)		[1]39.0		98.2				
			PK			85	(4)	(61)		[1]64.9		96.6				
24	Meal (*Setaria italica*), common millet,[6] 40 percent of the millet (chiefly bran) removed by sifting through a 16-mesh sieve.	Millet bread (see recipe, item 23), potato, orange, tea or coffee as desired. Daily average intake: 49 gm. protein, 2,140 to 3,080 gross calories.	DGG			85	(5)	(55)		[1]23.8		94.0				
			AJH			85	(5)	(55)		[1]31.3		95.6				
			RLS			92	(7)	(58)		[1]30.3		95.3				
			DGG			88	(6)	(54)		[1]36.2		94.3				
			AJH			87	(6)	(52)		[1]28.7		96.7				
			RLS			90	(7)	(60)		[1]61.3		96.9				
			OES			83	(6)	(47)		[1]46.2		97.2				
	Oats, Oat Products (*Avena sativa*):															
25	Rolled oats[6]	Rolled oats, cooked 4 hrs.; milk. "Full ration"	4 93	1.4	40.7	54	28	77	59	[1]72.3	[1]56.4	94.4	[1]85.1	[2]82.2	Two subjects, young men. Experimental period, 2 days with 6 meals. Preliminary experimental period of 1 meal. Marker, charcoal. N-balance per day; subject No. 4, full ration, −0.5 gm.; half ration, +3.6 gm. Subject No. 5, full ration, +1.3 gm.; half ration, −0.6 gm.	164
			5 72	1.8	50.7	54	29	78	59	[1]69.2	[1]57.6	95.7	[1]85.9	[2]83.1		
		"One-half ration"	4 93	1.0	28.5	52	28	75	58	[1]85.1	[1]78.7	97.2	[1]92.2	[2]88.8		
			5 72	1.1	28.9	45	23	72	52	[1]79.9	[1]77.9	95.6	[1]90.1	[2]86.9		
26	Rolled oats	Rolled oats, cooked; cream, sugar								78.4			89.8		Average of 16 experiments.	119
27	Rolled oats[6]	Rolled oats, cooked; sugar, cream, coffee.[4]				80						96.6			Details of experiment not given. Authors reported "coefficient of utilization" of protein, 84 percent; not included in this table since not clear if value is true or apparent digestibility.	126

28	Rolled oats	Rolled oats, cooked; milk-cream mixture, sucrose. Proportions of oats and milk-cream mixture differed for the two experimental periods.	GG	57	.7		57				[1] 68.8					Subjects, 3 women (GG, LG, RL) and 5 men (CK, WP, MP, GS, AF). Collection period of 9 days began on 3d day of experimental period. Marker, charcoal or barium sulfate. Average N-balance for the 6 subjects were −0.3 gm. per day for 1st period; −0.8 gm. per day for 2d period. For 3d period, subjects, 3 men, average N-balance was −1.2 gm. per day.	88
			LG	52	.7		57				[1] 78.9						
			RL	61	.7		58				[1] 72.1						
			CK	78	.7		58				[1] 82.4						
			WP	68	.7		58				[1] 64.6						
			MP	73	.7		57				[1] 69.4						
			Av.	63	.7	37.5	58				72.7						
			GG	57	.7		80				[1] 73.6						
			LG	52	.7		80				[1] 84.8						
			RL	61	.7		80				[1] 73.7						
			CK	78	.7		80				[1] 79.7						
			WP	58	.7		80				[1] 64.5						
			GS	73	.7		80				[1] 77.1						
			Av.	63	.7	37.5	80				75.6						
		Rolled oats, cooked; sucrose, butter.	AF	86	.7		100				[1] 72.6						
			CK	78	.7		100				[1] 80.2						
			GS	75	.7		100				[1] 70.2						
			Av.	80	.7	37.5	100				74.3						
29	Rolled oats	Rolled oats, cooked; cream, butter, lettuce, raw tomatoes with seeds removed, applesauce, orange marmalade or jam, coffee, tea, carbonated beverage. Vitamin and mineral supplements.	*Av.*	71	.5	45	80				[1] 71.5					Subjects, 11 men, ages 17–31 yr. Egg replacement method as used previously in authors' laboratory. 80 pct. of protein from egg or cereal, 10 pct. from cream and butter, 10 pct. from remaining diet. These amounts have been used here to calculate apparent digestibility of test food.[7] Subjects in negative N-balance during test periods.	40
30	Rolled oats	See diet, item 29	*Av.*	71	.5	45	80				[1] 72.7						
31	Rolled oats, quick cooking.	Oats, cooked; butter, cream, prunes, bananas. N-intake, 5.6 gm.; gross calories, 2,680.	JM	92	.4		80				[8] 57					Experimental period, 4 days, preceded by 3-day period in which milk protein replaced cereal protein. Markers, charcoal and carmine, used alternately.	128
			JC	70	.4		80				[8] 50						
			RA	80	.4		80				[8] 76						
			GS	66	.4		80				[8] 57						
			Av.	77	.4		80				60						
32	Rolled oats,* quick cooking.	Oats, cooked; fruits, cream, lettuce, coffee or beer, vitamin B complex. Average daily intake: 37 gm. protein, 2,930 calories.	*Av.*	71	.5	41.3	78				[1] 73.2					Subjects, 10 young men. Marker, charcoal. Experimental period, 5 days, preceded by 5-day period in which egg protein replaced cereal protein. 78 pct. of protein from egg or cereal, 11 pct. from cream and butter, 11 pct. from remaining foods. These amounts have been used here to calculate apparent digestibility of test food.[7] N-balance, −0.1 gm. per day.	129

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[3] Calculated from author's data allowing a urinary loss of 1.25 calories per gm. of digested protein as shown in table 13, p. 25.

[4] Diet as described by Clough, Carmen, and Austin, in Jour. Nutr. 3: 1–15, 1930.

[6] Author identified common millet as *Setaria italica*, but according to classification in Standardized Plant Names (*79*) *Setaria italica* applies to foxtail millet.

[7] Apparently authors made no correction for N of foods other than test food in total N intake or fecal N.

[8] Authors gave two reasons for low digestibility: (1) low level at which protein was fed; (2) the rather liberal fruit intake.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Oats, Oat Products (*Avena sativa*)—Con.		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
33	Meal,[9] granulated or pinhead, fine-cut with low-grade materials removed.	Oatmeal, cooked 20 min.; cream, sugar. Average daily intake: 44 gm. protein, 2,200 gross calories.	FAC			86	25	76	60	65.7		96.3	[1] 85.6	[2] 83.2	Subjects, healthy young men. Experimental period, 4 days. Marker, lampblack.	62
			WJH			83	21	71	54	71.9		97.2	[1] 88.9	[2] 86.3		
			CBT			81	19	68	51	83.0		99.1	[1] 94.7	[2] 91.6		
			Av.			83	22	72	55	73.5		97.5	89.7	87.0		
34	Meal,[9] midcut or standard; had more of the germ left than pinhead.	Oatmeal, cooked 20 min.; cream, sugar. Average daily intake: 39 gm. protein, 1,860 gross calories.	WJH			87	30	70	60	88.1		98.8	[1] 95.7	[2] 92.3		
			FAC			85	29	73	61	87.9		98.9	[1] 96.1	[2] 92.8		
			CBT			79	21	62	49	88.4		97.8	[1] 96.0	[2] 92.6		
			Av.			84	27	68	57	88.0		98.5	95.9	92.6		
35	Meal,[9] rolled (authors reported product as oatmeal).	Rolled oatmeal, cooked 20 min.; cream, sugar. Average daily intake: 50 gm. protein, 2,480 gross calories.	CBT			86	27	75	60	75.0		98.1	[1] 91.6	[2] 88.9		
			KGM			86	27	76	60	82.3		98.5	[1] 94.1	[2] 91.2		
			FAC			86	27	75	64	75.7		98.2	[1] 92.0	[2] 89.3		
			Av.			86	27	75	61	77.7		98.3	92.6	89.8		
		Rolled oatmeal, cooked 8 hrs.; cream, sugar. Average daily intake; 50 gm. protein, 2,530 gross calories.	FAC			81	23	73	55	80.0		98.6	[1] 94.4	[2] 91.5		
			CBT			81	23	74	56	83.3		98.7	[1] 94.4	[2] 91.5		
			KGM			82	25	75	57	84.4		98.7	[1] 95.7	[2] 92.7		
			Av.			81	24	74	56	82.6		98.7	94.8	91.9		
36	Meal[9] (reported as oatmeal but possibly was rolled oats).	Oatmeal, cooked 20 min.; cream, sugar. Average daily intake: 76 gm. protein, 3,420 gross calories.	JB			90	31	81	66	80.9		97.6	[1] 92.5	[2] 89.4		
		Oatmeal, cooked 8 hrs.; cream, sugar. Average daily intake: 56 gm. protein, 2,680 gross calories.	CLK			80	20	71	52	86.8		98.7	[1] 96.5	[2] 93.1		
			JB			83	24	75	57	78.5		97.4	[1] 92.4	[2] 89.4		
			WJC			76	17	66	46	79.0		98.8	[1] 95.8	[2] 92.7		
			Av.			80	20	71	52	81.4		98.3	94.9	91.7		
37	Meal (no further description).	Oatmeal, cooked; bread, butter, milk.								75	64	[3] 99.1			Subjects, 2. 3-day preliminary period and 2-day collection period.	57
										94	100	[3] 97.9				
			Av.							84.5	82	98.5				
38	Meal,[9] mixture of 2 kinds, coarsely ground "pinhead" and medium-ground.	Oatmeal [10] eaten as porridge or oat cakes made without fat; bramble jelly or sirup. Oatmeal provided 92.8 to 100 percent of the diet.	EG 85	1.0	42.4				95	65.7	71.7		88.0		Subjects, 6 men, ages 20–48 yrs. Followed general plan of conducting experiment used by McCance and Walsham (1948). See remarks, item 106. Total period 11-12 days of which 7 days was experimental period. Marker, carmine.	102
			RM 58	1.4	53.2				100	67.9	64.8		85.2			
			MW 75	1.1	43.3				99	64.9	65.2		86.0			
			JH 68	1.4	54.6				96	72.8	67.2		87.1			
			LH 62	.8	32.5				93	65.2	62.5		84.1			
			SH 64	1.1	42.8				97	81.0	77.6		89.1			
			Av. 69	1.1	44.8				97	69.6	68.2		86.6			
39	Oat products (oatmeal, rolled oats, flaked and malted oats).[3]	Oat cereal, cream, sugar. In some of experiments the cereal was eaten in simple mixed diet.								77.9		97.0	87.8		Subjects, men.	196
40	Ready-to-eat cereal, exploded; mixture included 70 pct. oat flour, 20 pct. corn and rye flours.	Oat, corn, and rye cereal; milk-cream mixture, sucrose. Proportions of cereal and milk-cream mixture differed for the two experimental periods.	GG 57	.7		53				[1] 57.8					Subjects, 3 women (GG, LG, RL) and 5 men (CK, WP, MP, GS, AF). Collection period began on 3d day and continued 9 days. Marker, charcoal or barium sulfate. Average N-balances for the 6 subjects were, −1.1 gm. per day for 1st period, −0.8 gm. for 2d period; for the 3 men in 3d period, −1.2 gm.	88
			LG 52	.7		53				[1] 73.2						
			RL 61	.7		53				[1] 64.8						
			CK 78	.7		53				[1] 84.0						
			WP 58	.7		53				[1] 59.5						
			MP 73	.7		53				[1] 68.0						
			Av. 63	.7	37.5	53				67.9						
			GG 57	.7		80				[1] 71.4						
			LG 52	.7		80				[1] 60.0						
			RL 61	.7		80				[1] 65.1						
			CK 78	.7		80				[1] 90.8						
			WP 58	.7		80				[1] 66.0						
			GS 73	.7		80				[1] 77.0						
			Av. 63	.7	37.5	80				71.7						
		Oat, corn, and rye cereal; sucrose, butter.	AF 86	.7		100				[1] 77.6						
			CK 78	.7		100				[1] 82.3						
			GS 75	.7		100				[1] 75.9						
			Av. 80	.7	37.5	100				78.6						

41	Ready-to-eat cereal, exploded. Mixture of 75 pct. ground oats, 20 pct. corn and rye flours, 5 pct. salt, sugar, oil, mineral salts, and vitamins.	Oat, corn, and rye cereal; cream, butter, lettuce, raw tomatoes with seeds removed, applesauce, orange marmalade or jam, coffee, tea, carbonated beverage. Vitamin and mineral supplements.	*Av.*	---	---	---	80	---	---	---	[1] 66.0	---	---	---	---	Subjects, 11 men, ages 17-31 yrs. See remarks, item 29.	40
	Rice, Rice Products (*Oryza sativa*):															*General:* Test food taken ad lib., other foods kept constant. Marker, carmine or carbo sanguinis. Data given in 2 reports.	178
42	Unpolished, 3d grade Shonai. Husk removed, but outer layer and germ retained.	Boiled rice eaten in mixed diet.[11] Average daily intake: 63 gm. protein, 1,570 calories.	H	---	---	---	---	---	---	---	68.3	77.9	96.8	---	---	Plan of 1st report [11] followed. Average N-balance of 3 subjects, −3.7 gm. per day.	
			M	---	---	---	---	---	---	---	74.1	70.3	97.1	---	---		
			S	---	---	---	---	---	---	---	65.2	75.3	97.4	---	---		
			Av.	---	---	---	33	22	75	57	69.2	74.5	97.1	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 77 gm. protein, 1,630 calories.	H	---	---	---	---	---	---	---	76.0	64.1	98.4	---	---	See general remarks. Plan of 2d report [14] followed. N-balances for 14 subjects used in these 3 experiments were: 7 positive, averaging +0.9 gm. per day; 7 negative, averaging −1.0 gm. per day. Some subjects not consistently in negative or positive N-balance during the series of experiments.	
			M	---	---	---	---	---	---	---	76.5	60.1	98.7	---	---		
			S	---	---	---	---	---	---	---	80.6	70.6	99.1	---	---		
			T	---	---	---	---	---	---	---	78.0	58.8	98.8	---	---		
			Av.	---	---	---	39	35	70	60	77.8	63.4	98.8	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 83 gm. protein, 1,970 calories.	S	---	---	---	---	---	---	---	74.5	51.5	98.4	---	---		
			H	---	---	---	---	---	---	---	73.6	54.5	98.9	---	---		
			I	---	---	---	---	---	---	---	67.7	62.6	98.7	---	---		
			K	---	---	---	---	---	---	---	71.9	56.4	98.6	---	---		
			Y	---	---	---	---	---	---	---	68.4	47.6	98.0	---	---		
			Av.	---	---	---	43	36	77	67	71.2	54.3	98.5	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 80 gm. protein, 1,850 calories.	N	---	---	---	---	---	---	---	78.4	61.2	98.9	---	---		
			H	---	---	---	---	---	---	---	77.6	56.6	98.8	---	---		
			I	---	---	---	---	---	---	---	73.6	52.8	98.4	---	---		
			K	---	---	---	---	---	---	---	75.6	65.7	98.6	---	---		
			Y	---	---	---	---	---	---	---	73.0	59.4	98.3	---	---		
			Av.	---	---	---	41	34	75	64	75.6	57.1	98.6	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 85 gm. protein, 1,790 calories.	Y	---	---	---	---	---	---	---	77.7	60.3	98.7	---	---	See general remarks and plan of 2d report.[14] The 10 subjects used in these 2 experiments were all in positive N-balance, averaging +0.7 gm. per day.	179
			M	---	---	---	---	---	---	---	80.6	66.3	98.8	---	---		
			T	---	---	---	---	---	---	---	80.4	63.6	98.7	---	---		
			I	---	---	---	---	---	---	---	75.8	60.3	97.8	---	---		
			K	---	---	---	---	---	---	---	78.5	58.7	98.6	---	---		
			Av.	---	---	---	45	43	73	63	78.6	61.8	98.5	---	---		
43	Unpolished, powdered, Shonai quality No. 3.	Dango (rice and water formed into balls, 50-60 gm. weight, and cooked in water) eaten in a mixed diet.[13] Average daily intake: 93 gm. protein, 2,050 calories.	Y	---	---	---	---	---	---	---	80.2	89.8	98.9	---	---		
			M	---	---	---	---	---	---	---	85.1	89.7	99.2	---	---		
			T	---	---	---	---	---	---	---	84.5	89.8	99.1	---	---		
			I	---	---	---	---	---	---	---	82.0	87.3	99.0	---	---		
			K	---	---	---	---	---	---	---	83.0	86.1	99.0	---	---		
			Av.	---	---	---	49	47	77	68	83.0	88.5	99.0	---	---		
44	Half-polished, 3d grade Shonai. Partially milled, half of outer layer and germ retained.	Boiled rice eaten in mixed diet.[12] Average daily intake: 81 gm. protein, 2,270 calories.	H	---	---	---	---	---	---	---	73.3	81.7	99.4	---	---	See general remarks, item 42, and plan of 1st report.[11] Subjects H and S showed negative N-balance, −1.5 and −1.2: subject M, N-balance was +0.3 gm. per day.	178
			M	---	---	---	---	---	---	---	80.6	80.1	99.4	---	---		
			S	---	---	---	---	---	---	---	80.7	81.2	98.9	---	---		
			Av.	---	---	---	47	20	84	71	78.2	81.0	99.2	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 87 gm. protein, 2,250 calories.	Ha	---	---	---	---	---	---	---	83.8	76.7	99.4	---	---	See general remarks, item 42, and plan of 2d report.[14] 13 of the 15 subjects used in these 3 experiments were in positive N-balance, averaging +1.5 gm. per day. 2 subjects were in slightly negative N-balance: S in 1st experiment, −0.2 gm., and I in 3d experiment, −0.1 gm. per day.	
			Hi	---	---	---	---	---	---	---	80.1	78.9	99.1	---	---		
			M	---	---	---	---	---	---	---	82.4	77.7	99.4	---	---		
			S	---	---	---	---	---	---	---	82.8	78.5	99.4	---	---		
			T	---	---	---	---	---	---	---	81.3	77.2	99.4	---	---		
			Av.	---	---	---	46	33	81	71	82.1	77.8	99.3	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 84 gm. protein, 2,150 calories.	S	---	---	---	---	---	---	---	81.5	73.8	99.4	---	---		
			In	---	---	---	---	---	---	---	77.5	69.9	99.1	---	---		
			Is	---	---	---	---	---	---	---	81.8	77.7	99.4	---	---		
			Ka	---	---	---	---	---	---	---	81.1	76.0	99.3	---	---		
			Ko	---	---	---	---	---	---	---	83.0	72.4	99.4	---	---		
			Av.	---	---	---	44	25	80	70	81.0	74.0	99.3	---	---		
		Boiled rice eaten in mixed diet.[13] Average daily intake: 79 gm. protein, 2,070 calories.	N	---	---	---	---	---	---	---	80.6	72.9	99.3	---	---		
			H	---	---	---	---	---	---	---	82.6	71.9	99.4	---	---		
			I	---	---	---	---	---	---	---	84.0	77.4	99.4	---	---		
			K	---	---	---	---	---	---	---	82.6	72.7	99.3	---	---		
			Y	---	---	---	---	---	---	---	82.8	74.2	99.0	---	---		
			Av.	---	---	---	43	24	78	68	82.5	73.8	99.3	---	---		

[1] Calculated from authors' data, using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Calculated from authors' data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[3] Coefficients of digestibility estimated for "products" were considered by authors of article to be applicable to these items.

[9] Calculated from author's data for N-free-extract and crude fiber.

[10] Each subject chose a different mixture of the oatmeals but the total for the 6 men amounted to equal parts of coarse and medium ground meals.

[11] Included bean paste, taro, daikon (raw and pickled), potatoes, onions, soybean curd, sardines, dried fish powder, soysauce, sugar, and vinegar, supplying daily 656 calories, 43 gm. protein, 63 gm. carbohydrate (expressed as glucose), and 24 gm. fat.

[11] Plan of 1st report: The total period of 13 days included 3 days preliminary period, 2 days post period, and 8-day experimental period. The experimental period was divided into 2-day periods in which polished, half-polished, 70-percent polished, and unpolished rice were fed successively in a mixed diet.

[13] Included bean paste, wakame, fish powder, mackerel, pork, potatoes, burdock, cabbage, onions, daikon (raw and pickled), bean curd, fuki (boiled), sugar, soysauce, and vinegar, supplying daily 656 calories, 47 gm. protein, 81 gm. carbohydrate (expressed as glucose), and 14 gm. fat.

[14] Plan of 2d report: Total period was 6 days. On 1st, 2d, 5th, and 6th days polished rice was fed while on 3d and 4th days rice of a different grade of polishing was fed so that in each experiment half-polished, 70-percent polished, or unpolished rice was compared with polished grade.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Rice, Rice Products (*Oryza sativa*)—Con.		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
45	70-percent polished, 3d grade Shonai. 30 pct. of outer layer and germ retained.	Boiled rice eaten in mixed diet.[11] Average daily intake: 84 gm. protein, 2,610 calories.	H							76.9	83.5	99.1			See general remarks, item 42, and plan of 1st report.[12] Daily N-balance for H was −1.3 gm.; for M, +1.1 gm.; for S, −0.3 gm.	
			M							81.6	84.4	99.2				
			S							83.1	86.5	99.4				
			Av.			49	21	87	75	80.5	84.8	99.2				
		Boiled rice eaten in mixed diet.[13] Average daily intake: 88 gm. protein, 2,510 calories.	Ha							83.4	79.7	99.6			See general remarks, item 42, and plan of 2nd report.[14]. 13 of the 15 subjects were in positive N-balance, averaging +1.4 gm. S and H in 2nd experiment showed negative N-balances of −0.4 and −1.5 gm. per day, respectively.	
			Hi							84.5	84.7	99.6				
			M							76.7	76.2	99.5				
			S							83.4	83.4	99.6				
			T							83.2	76.2	99.6				
			Av.			46	27	83	74	82.2	80.0	99.6				
		Boiled rice eaten in mixed diet.[13] Average daily intake: 79 gm. protein, 2,230 calories.	S							84.6	82.5	99.7				
			In							82.3	82.8	99.6				
			Is							84.7	81.9	99.7				
			Ka							84.2	82.1	99.7				
			Ko							84.0	82.2	99.6				
			Av.			40	20	81	71	84.0	82.3	99.6				
		Boiled rice eaten in mixed diet.[12] Average daily intake: 81 gm. protein, 2,310 calories.	S							83.1	81.5	99.6				
			H							78.3	76.1	99.6				
			I							83.4	83.4	99.6				
			K							81.9	80.1	99.5				
			Y							80.2	84.0	99.4				
			Av.			41	21	82	72	81.4	81.0	99.5				
46	Polished, 3d grade Shonai. Germ almost entirely rubbed off in milling.	Boiled rice eaten in mixed diet.[11] Average daily intake: 76 gm. protein, 2,500 calories.	H							89.7	91.8	99.7			See general remarks, item 42, and plan of 1st report.[12] Daily N-balance for H was −0.2; for M, +1.3; for S, −0.7 gm.	
			M							90.2	91.9	99.7				
			S							88.1	91.1	99.6				
			Av.			44	12	87	74	88.7	91.6	99.7				
		Boiled rice eaten in mixed diet.[13] Average daily intake: 81 gm. protein, 2,550 calories.	Ha							85.5	85.3	99.7			See general remarks, item 42, and plan of 2d report.[14] The 5 subjects in this experiment were in positive N-balance, averaging +1.1 gm. per day.	
			Hi							85.8	85.5	99.7				
			M							84.7	87.1	99.7				
			S							84.6	87.7	99.7				
			T							85.6	88.1	99.7				
			Av.			42	15	84	74	85.2	86.7	99.7				
		Boiled rice eaten in mixed diet.[13] Average daily intake: 82 gm. protein, 2,560 calories.	Ha							86.7	89.8	99.7			See general remarks, item 42, and plan of 2d report.[14] The 5 subjects in this experiment were in positive N-balance, averaging +1.4 gm. per day.	
			HI							83.1	87.2	99.6				
			M							87.9	88.3	99.8				
			S							87.2	90.2	99.7				
			T							87.3	90.6	99.7				
			Av.			42	15	84	74	86.4	89.2	99.7				
		Boiled rice eaten in mixed diet.[13] Average daily intake: 78 gm. protein, 2,360 calories.	H							82.9	88.5	99.6			See general remarks, item 42, and plan of 2d report.[14] The 4 subjects in this experiment were in positive N-balance, averaging +0.4 gm. per day.	
			M							83.9	84.4	99.6				
			S							85.6	87.3	99.7				
			T							84.2	89.1	99.7				
			Av.			39	14	82	72	84.2	87.3	99.6				

Boiled rice eaten in mixed diet.[13] Average daily intake: 83 gm. protein, 2,350 calories.	S								82.1	87.5	99.6			See general remarks, item 42, and plan of 2d report.[14] Boiled polished rice was used in 8 experiments of the series reported, and 37 subjects were used. 24 were in positive N-balance, averaging +1.3 gm. per day. 13 subjects were in negative balance, averaging −0.7 gm. per day. 3 subjects on rice gruel diet showed negative balance, averaging −3.5 gm. per day. 5 subjects on "ojiya" diet were in negative N-balance, averaging −1.6 gm. per day. 4 subjects on "sushi" diet were in positive N-balance, averaging +1.3 gm. per day. Subject N in slightly negative N-balance, −0.03 gm. per day. 4 subjects on "akanogohan" diet in negative N-balance, averaging −1.5 gm. per day. Subject H in positive N-balance, +0.3 gm. per day.	179
	H								80.0	86.5	99.5				
	M								84.2	84.3	99.6				
	T								82.0	87.5	99.6				
	Y								80.4	85.6	99.4				
	Av.				43	29	82	72	81.7	86.3	99.5				
Boiled rice eaten in mixed diet.[13] Average daily intake: 79 gm. protein, 2,120 calories.	Y								83.8	87.3	99.4				
	M								87.1	88.3	99.6				
	T								85.3	87.8	99.5				
	I								87.4	89.8	99.7				
	K								89.3	90.2	99.6				
	Av.				40	28	79	69	86.6	88.7	99.6				
Boiled rice eaten in mixed diet.[13] Average daily intake: 88 gm. protein, 2,600 calories.	H								86.9	91.2	99.8				
	M								85.1	90.5	99.7				
	T								81.6	88.5	99.7				
	Av.				46	30	84	74	84.5	90.1	99.7				
Rice gruel eaten in mixed diet.[13] Average daily intake: 60 gm. protein, 1,050 calories.	H								84.2	91.4	99.4				
	M								81.6	92.1	99.2				
	T								76.1	89.2	99.1				
	Av.				22	19	48	38	80.6	90.9	99.2				
Boiled rice eaten in mixed diet.[13] Average daily intake: 94 gm. protein, 2,910 calories.	Kay								86.9	91.2	99.8				
	I								86.3	90.9	99.7				
	S								86.1	91.1	99.7				
	T								85.4	89.0	99.7				
	Kat								85.8	90.1	99.8				
	Av.				50	34	86	77	86.1	90.5	99.7				
Ojiya (963 gm. rice, 80 gm. bean paste, boiled in 400 cc. water to obtain 3,860 gm. ojiya) eaten in mixed diet.[13] Average daily intake: 73 gm. protein, 1,460 calories.	Kay								86.2	94.9	99.7				
	I								84.4	92.8	99.5				
	S								83.3	91.8	99.4				
	T								82.6	91.7	99.5				
	Kat								81.9	91.0	99.4				
	Av.				35	29	66	55	83.7	92.4	99.5				
Boiled rice eaten in mixed diet.[13] Average daily intake: 91 gm. protein, 2,900 calories.	N								83.0	90.4	99.7				
	T								79.9	90.1	99.7				
	I								83.1	91.6	99.7				
	S								83.3	90.8	99.8				
	TT								80.7	89.0	99.8				
	Av.				48	35	86	77	82.0	90.4	99.7				
Sushi (rice cooked in usual way with salt, sugar, and vinegar added) eaten in mixed diet.[13] Average daily intake: 93 gm. protein, 2,990 calories.	N								84.6	92.9	99.8				
	T								83.0	92.6	99.8				
	I								85.5	92.7	99.8				
	S								85.7	92.1	99.8				
	TT								82.4	90.0	99.8				
	Av.				49	28	86	78	84.2	92.1	99.8				
Boiled rice eaten in mixed diet.[13] Average daily intake: 87 gm. protein, 2,580 calories.	H								81.4	91.1	99.8				
	T								79.7	90.9	99.6				
	I								82.8	89.8	99.7				
	S								84.7	90.0	99.7				
	TT								81.7	90.8	99.6				
	Av.				45	31	84	75	82.1	90.5	99.7				
Akanogohan (1,171 gm. rice cooked with 1,600 cc. water and 400 cc. juice prepared from boiled red beans by squeezing through cloth) eaten in mixed diet.[13] Average daily intake: 87 gm. protein, 2,300 calories.	H								90.6	96.0	99.8				
	T								81.3	91.0	99.7				
	I								83.6	91.0	99.7				
	S								85.2	91.3	99.7				
	TT								82.8	91.6	99.6				
	Av.				46	29	81	72	84.7	92.2	99.7				
Boiled rice eaten in mixed diet.[13] Average daily intake: 89 gm. protein, 2,600 calories.	S								86.1	93.5	99.7				
	I								83.8	90.2	99.6				
	N								82.8	90.0	99.7				
	H								85.3	87.7	99.7				
	Av.				47	19	84	75	84.5	90.4	99.7				
Boiled rice eaten in mixed diet.[13] Average daily intake: 85 gm. protein, 2,380 calories.	K								86.2	91.5	99.6				
	Sa								84.6	91.8	99.6				
	I								83.7	91.3	99.5				
	Sh								83.6	90.6	99.6				
	T								81.9	91.1	99.4				
	Av.				44	30	83	74	84.0	91.3	99.6				

[11] Included bean paste, taro, daikon (raw and pickled), potatoes, onions, soybean curd, sardines, dried fish powder, soy sauce, sugar, and vinegar, supplying daily 656 calories, 43 gm. protein, 63 gm. carbohydrate (expressed as glucose), and 24 gm. fat.

[12] Plan of 1st report: The total period of 13 days included 3 days preliminary period, 2 days post-period, and 8-day experimental period. The experimental period was divided into 2-day periods in which polished, half-polished, 70-percent polished, and unpolished rice were fed successively in a mixed diet.

[13] Included bean paste, wakame, fish powder, mackerel, pork, potatoes, burdock, cabbage, onions, daikon (raw and pickled), bean curd, fuki (boiled), sugar, soy sauce, and vinegar, supplying daily 656 calories, 47 gm. protein, 81 gm. carbohydrate (expressed as glucose), and 14 gm. fat.

[14] Plan of 2d report: Total period was 6 days. On 1st, 2d, 5th, and 6th days polished rice was fed while on 3d and 4th days rice of a different grade of polishing was fed so that in each experiment half-polished, 70-percent polished, or unpolished rice was compared with polished grade.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Rice, Rice Products (*Oryza sativa*)—Con.															
			Kg.	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
47	Polished, powdered, Shonai, quality No. 3.	Dango (mixture rice and water formed into balls, 50–60 gm. weight, and cooked in water) eaten in mixed diet.[13] Average daily intake: 83 gm. protein, 2,350 calories.	S							84.0	90.8	99.7			See general remarks, item 42 and plan of 2d report.[14] For diet containing "dango," subjects H and T in positive N-balance, +0.4 and +0.9; subjects S, M, and Y in negative N-balance, −0.2, −0.3, and −0.7 gm. per day, respectively.	
			H							83.1	89.3	99.7				
			M							90.1	92.7	99.7				
			T							85.9	92.4	99.8				
			Y							82.4	89.4	99.5				
			Av.			44	29	82	72	85.1	90.9	99.7				
48	Polished, glutinous, Shonai, quality No. 3.	Okowa (glutinous rice soaked 24 hr., then steamed 45 min.) eaten in mixed diet.[13] Average daily intake: 74 gm. protein, 1,660 calories.	N							78.4	90.8	99.6			See general remarks, item 42, and plan of 2d report.[14] All 4 subjects on "okowa" diet were in negative N-balance, averaging −1.2 gm. per day.	
			A							81.3	88.4	99.6				
			K							82.1	88.9	99.6				
			T							81.7	88.4	99.5				
			Av.			38	22	73	60	80.9	89.1	99.6				
		Mochi (prepared like okowa, then pounded and rolled to 2 cm. in thickness) eaten in mixed diet.[13] Average daily intake: 82 gm. protein, 2,120 calories.	N							83.1	94.5	99.6			See general remarks, item 42, and plan of 2d report.[14] For diet containing "mochi" subjects A and T were in positive N-balance, +0.6 and +0.3; subjects N and K in negative N-balance, −0.1 and −0.3 gm. per day, respectively.	
			A							85.7	91.8	99.7				
			K							87.6	92.1	99.8				
			T							84.4	90.8	99.6				
			Av.			43	25	79	69	85.2	92.3	99.7				
40	Polished* or white	Rice, cottage cheese, sugar, milk	*Av.*			20	1	66	38	83		98		90	Subjects, 3 men. Experimental period, 3 days. All subjects in positive N-balance, averaging +0.5 gm. per day.	167
50	Undescribed*	Boiled rice, a little fat and meat extract added. Average daily intake: 62 gm. protein, 74 gm. fat, 493 gm. carbohydrate.	A 72	0.9		85		100		79.6		99.1			Subject, medical student, 22 yr. old. Experimental period, 3 days. Marker, meat diet at beginning and milk at end of experiment. N-balance, −3.3 gm. per day.	144
51	Starch	Frozen pudding (raw rice starch, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 25 gm. protein, 1,830 calories.	PHC									100.0			Subjects, young men. Experimental period, 3 days. Marker, carmine for experimental period, lampblack for subsequent regular diet of 3 to 4 days.	92
			WVD									100.0				
			HLG									100.0				
			ELM									99.8				
			JFS									100.0				
52	Starch	Same diet as described for item 51. Average daily intake: 22 gm. protein, 1,675 calories.	ATM			4		59				100.0			Subjects, women. Experimental procedure as described for item 51.	97
			RJ			4		58				100.0				

	Rye, Rye Products (*Secale cereale*):																
53	Flour, whole-grain, ground.	Pumpernickel bread	B								48.0		90.3			Details of experiment not given. Data from Pannwitz in (*136, pp. 216–217*).	136
54	Flour* No. 18, 13th grinding of middlings. Ash, 2.18 pct. 2d poorest in quality.	Rye bread made from equal amounts of flours No. 18 and No. 6 (good dark bread). Daily intake: 607 gm. fresh bread (399 gm. dry weight).	R	68	.7						[15] 56.8		[15] 88.1				
			H	72	.7						[15] 61.2		[15] 88.9				
		Rye bread made from flour No. 18 (very wet after 3 hr. baking, unpalatable). Daily intake: 304 gm. fresh bread (192 gm. dry weight).	R	68	.7						49.0		79.2			Subjects, young men. Marker, milk. 2 liters milk and cheese—cottage, Swiss, or Dutch—eaten 1st and 5th days. Bread alone eaten on 2d, 3d, and 4th days. Clear differentiation of feces in most cases. Subject R while on bread diet (flour No. 18 usually used in blends) had severe stomach ache and colic, also diarrhea. Subject F had severe stomach ache on 1st day of bread diet (flour No. 17). Some diarrhea but good differentiation of feces. Subject H had severe stomach ache and mild diarrhea on 2d day of bread diet (flour No. 15). Bread diet (flour II) lasted only 2 days. Subject R had severe stomach ache on 2d day; very thin feces.	141
55	Flour III,* a commercial flour of poorer quality than Flour II, item 60. Ash, 1.97 pct.	Rye bread, made from equal amounts of flours III and 0, Item 53 (very dark bread). Daily intake: 522 gm. fresh bread (311 gm. dry weight). 2 liters beer.	R	68	.5						[15] 52.8		[15] 82.5				
			H	72	.4						[15] 61.1		[15] 88.7				
56	Flour No. 17*, 12th grinding of middlings. Ash, 1.90 pct.	Rye bread (very moist, although baked long time). Daily intake: 447 gm. fresh bread (272 gm. dry weight). 2 liters beer.	F	72	.9						68.6		89.0				
57	Flour No. 4,* 3d grinding of whole grain. Ash, 1.87 pct.	Rye bread (dark). Daily intake: subject R, 667 gm. fresh bread (408 gm. dry weight); subject B, 567 gm. fresh bread (366 gm. dry weight). 2 liters beer.	R	68	1.1						69.7		89.4				
			B	80	.7						70.4		93.0				
58	Flour No. 16,* 11th grinding of middlings. Ash, 1.74 pct.	Rye bread (very dark but edible). Daily intake: 667 gm. fresh bread (401 gm. dry weight). 2 liters beer.	H	72	1.0						79.1		92.0				
			F	72	1.0						74.0		92 4				
59	Flour No. 15,* 10th grinding of middlings. Ash, 1.69 pct.	Rye bread (sour, soggy, and unpalatable). Daily intake of 2 subjects similar, averaging 499 gm. fresh bread (322 gm. dry weight).	H	72	1.1						74.1		92.6				
			B	80	1.1						77.5		93.5				
60	Flour II,* a commercial flour of poor quality. Ash, 1.68 pct.	Rye bread (a very dark but well-baked bread). Daily intake: 618 gm. fresh bread (409 gm. dry weight). 2 liters beer.	R	68	.9						69.5		91.9				
61	Flour* made by Steinmetz process from Swiss rye. 94 pct. yield (3 pct. grinding loss). Most external ligneous layer of bran removed. 46 pct. of flour coarser than 0.2 mm. mesh sieve. Ash, 1.52 pct.	Rye bread, meat, butter, beer. Daily intake: 500 gm. bread (crustless), 450 gm. meat, 45 gm. butter, ½ liter beer, water ad lib.	L				23				[16] 51.1					Subjects, men, ages 26–33 yr. Experimental period of 2 days preceded and followed by 1 day on milk and cottage cheese diet used as marker. Good separation of feces obtained. Author verified by experiment that meat and butter in amounts consumed had no marked effect on quantity of feces.	99
			N				23				[14] 39.3						
			N				26				[16] 45.5						

[13] Included bean paste, wakame, fish powder, mackerel, pork, potatoes, burdock, cabbage, onions, daikon (raw and pickled), bean curd, fuki (boiled), sugar, soysauce, and vinegar, supplying daily 656 calories, 47 gm. protein, 81 gm. carbohydrate (expressed as glucose), and 14 gm. fat.

[14] Plan of 2d report: Total period was 6 days. On 1st, 2d, 5th, and 6th days polished rice was fed while on 3d and 4th days rice of a different grade of polishing was fed so that in each experiment half-polished, 70-percent polished, or unpolished rice was compared with polished grade.

[15] Coefficient of digestibility of test flour, indirectly estimated by author from the known digestibility of the flour with which the test flour was combined.

[16] In author's opinion the low figure for digestibility may be due to the low N content of the rye flours used in this study. The percent fecal loss becomes proportionately large in relation to lower N intake.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Rye, Rye Products (*Secale cereale*)—Con.		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
62	Flour, from peeled kernel, 8.4 pct. bran removed (4.9 pct. milling bran and 3.5 pct. peeling bran). Coarsely ground.	Bread made from the rye flour	P							38.5		89.3			Details of experiment not given. Data from Pannwitz in (*136, pp. 216–217*).	136
			L							48.2		92.6				
63	Flour, from peeled Magdeburg rye, 10.84 pct. bran removed (7.76 pct. milling bran and 3.08 pct. peeling bran). Finely ground.	Bread made from the rye flour, baked with yeast.	P							66.8		92.1			See remarks, item 62.	
			P [17]							55.0		89.3				
			Sch.							70.2		93.2				
			R							68.6		92.2				
			Sch.							72.5		94.1				
64	Flour,* flours No. 6 and No. 18 blended in equal amounts. Ash, 1.40 pct.	Rye bread (a good dark bread). Daily intake: 609 gm. fresh bread (399 gm. dry weight). 2 liters beer.	R 68	0.7						68.9		93.2			See remarks, item 54 for details of experiment.	141
			H 72	.7						71.1		93.6				
65	Flour,* commonly used in Wurzburg; like item 75, except 4.5 pct. of flour coarser than 0.2-mm. mesh sieve. Ash, 1.24 pct.	Same diet as described in item 61	L			24				[14] 55.6					See remarks, item 61	99
66	Flour,* flours O and III blended in equal amounts. Ash, 1.20 pct.	Rye bread (very dark). Daily intake: 522 gm. fresh bread (311 gm. dry weight).	R 68	.5						65.4		90.4			See remarks, item 54 for details of experiment.	141
			H 72	.4						69.5		93.5				
67	Flour, from unpeeled kernel, 15 pct. bran removed. Coarsely ground.	Ordinary soldier bread made from the rye flour.	P							50.1		88.5			Experimental method not given. Data from Pannwitz in (*136, pp. 216–217*).	136
			L							60.8		92.4				
			P							53.0		90.6				
			P							55.0		90.8				
			vB							61.2		94.1				
			F							59.3		91.7				
			Sch.							56.3		92.5				
			vB							57.5		92.8				
68	Flour, from peeled kernel, 15 pct. bran removed (11.85 pct. milling bran and 3.15 pct. peeling bran). Coarsely ground.	Bread made from the rye flour	P							55.0		90.2				
			vB							62.2		94.6				
			G							62.0		93.7				
69	Flour, from unpeeled kernel, 84 pct. yield, 12.68 pct. bran removed (10.94 pct. milling bran and 1.74 pct. from point end of kernel). Finely ground.	Bread made from the rye flour	P							61.7		92.2				
			G							60.1		91.2				
70	Flour of 4th to 6th millings of item 69 and comparable to last 10 pct. of yield (from 73.5 to 84 pct. of item No. 69 yield).	Bread made from the rye flour	P							49.2		80.0				
			L							58.3		82.0				

71	Flour* made by Steinmetz process from rye of Silesia. 82 pct. yield, i. e., 12 pct. bran removed in milling, 3 pct. husk bran, 3 pct. loss in grinding. Rather coarsely ground; 23 pct. of flour coarser than 0.2-mm. mesh sieve. Ash, 1.18 pct.	Rye bread, meat, butter, beer. Daily intake: 500 gm. crustless bread, 450 gm. meat, 45 gm. butter, and ¾ liter beer.	L				27				[16] 52.6					Subjects, men, ages 26–33 yr. Experimental period, 2 days, preceded and followed by 1 day on a milk and cottage cheese diet used as a marker. Good separation of feces obtained. Author verified by experiment that meat and butter in amounts consumed had no marked effect on quantity of feces.	99
			N				33				[16] 55.6						
72	Flour,* made by "old process" of milling from Swiss rye. 72 pct. yield, i. e., 25 pct. removal of bran and 3 pct. loss in grinding. Finely ground; 2.8 pct. of flour coarser than 0.2-mm. mesh sieve. Ash, 1.10 pct.	Rye bread, meat, butter, beer. Daily intake: 500 gm. crustless bread, 450 gm. meat, 45 gm. butter, and ½ liter beer.	L				21				[16] 45.1						
			N				21				[16] 43.4						
73	Flour No. 13,* 8th grinding of middlings. Ash, 1.04 pct.	Rye bread (dark). Daily intake: 667 gm. fresh bread (423 gm. dry weight). 2 liters beer.	B	90	.7						69.0		94.7			See remarks, item 54. Subject B had diarrhea on 2d day of bread diet (flour No. 13).	141
74	Flour No. 12,* 7th grinding of middlings. Ash, 0.96 pct.	Rye bread (quite dark). Daily intake: 667 gm. fresh bread (364 gm. dry weight). 2 liters beer.	W	85	.5						71.5		96.9				
75	Flour,* commonly used in Wurzburg, about 75 pct. yield. 2.5 pct. of flour coarser than 0.2-mm. mesh sieve. Ash, 0.86 pct.	Rye bread, meat, butter, beer. Daily intake: 500 gm. crustless bread, 450 gm. meat, 45 gm. butter, ¼ liter beer.	L				25				[17] 49.2					See remarks, item 71	99
			L				25				[16] 55.3						
76	Flour, 25 pct. bran removed. Finely ground.	Bread made from the rye flour	P								68.1		93.8			Experimental method not given. Data from Pannwitz in (*136, pp. 216–217*).	136
			M								63.3		95.2				
			M								67.3		94.2				
77	Flour I*, commercial flour. Ash, 0.81 pct.	Rye bread. Daily intake: 667 gm. fresh bread (406 gm. dry weight). 2 liters beer.	R	68	.6						68.0		95.3			See remarks, item 54. Subject S had diarrhea but differentiation of feces was good. Subject R in experiment on flour No. 10 had severe stomach ache and diarrhea on 2d day.	141
			H	72	.5						72.8		95.4				
			S	87	.4						73.3		96.9				
78	Flour No. 10,* 5th grinding of middlings. Ash, 0.77 pct.	Rye bread. Daily intake: 667 gm. fresh bread (404 gm. dry weight). 2 liters beer.	R	68	.7						68.3		95.1				
			T	72	.7						[74.7]		97.0				
79	Flour No. 2,* 1st flour of the bran grinding. Ash, 0.73 pct.	Rye bread (good white color). Daily intake: 667 gm. fresh bread (435 gm. dry weight). 2 liters beer.	R	68	.7						73.4		96.4				
			O	67	.7						81.5		98.0				
80	Flour No. 7,* 2d grinding of middlings. Ash, 0.62 pct.	Rye bread (good white color). Daily intake: 667 gm. fresh bread (414 gm. dry weight). 2 liters beer.	B	80	.6						70.5		97.1				
			O	67	.6						78.2		97.8				
81	Flour No. 6,* 1st grinding of middlings. Ash, 0.62 pct.	Rye bread (very white and palatable). Intake: 667 gm. fresh bread (416 gm. dry weight). 2 liters beer.	H	72	.6						82.7		98.2				
			F	72	.6						79.0		98.3				
82	Flour,* made by "old process" of milling from rye of Silesia. 62 pct. yield, i. e., 35 pct. removal of bran and 3 pct. loss in grinding. Finely ground; 0.32 pct. of flour coarser than 0.2-mm. mesh sieve. Ash, 0.55 pct.	Rye bread (quite sour but well leavened). Daily intake: 500 gm. bread, 450 gm. meat, 45 gm. butter, ¾ liter beer, water ad lib.	L				24				[16] 46.8					See remarks, item 71.	99
			M				24				[16] 56.5						

[16] In author's opinion the low figure for digestibility may be due to the low N content of the rye flours used in this study. The percent fecal loss becomes proportionately larger in relation to lower N intake.

[17] Bread used in this experiment was baked with leaven (sour dough).

*Indicates that composition, and in some cases also heat of combustion, was reported by the author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Rye, Rye Products (*Secale cereale*)—Con.		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
83	Flour O,* a commercial flour. Ash, 0.43 pct.	Rye bread (a very white bread). Daily intake: 667 gm. fresh bread (425 gm. dry weight). 2 liters beer.	R 68	0.5						75.2		98.0			See remarks, item 54 for details of experiment.	141
			B 75	.5						80.7		98.6				
84	Flour No. 1,* 1st flour from whole-grain groats. Ash, 0.39 pct.	Rye bread (white color). Daily intake: 667 gm. fresh bread (427 gm. dry weight). 2 liters beer.	R 68	.5						69.2		97.4				
			T 72	.4						69.7		97.8				
85	Branny portion,* fraction of 67–85 pct.[18]	Rye bran fed with diet of fruit, canned meat and fish, potatoes, bread, butter, cheese, turnips.	1							67					Subjects, 4 students, preliminary period, 1 wk. Experimental period 3 or 4 wk. Quantities of foods eaten kept constant. Marker, charcoal given weekly.	30
			2							60						
			3							83						
			4							96						
			Av.							77						
86	Branny portion,* fraction of 67–95 pct.[18]	Diet same as for item 85.	1							91						
			2							70						
			3							75						
			4							82						
			Av.							80						
87	Branny portion,* fraction of 85–95 pct.[18]	Diet same as for item 85.	1							95						
			2							60						
			3							73						
			4							77						
			Av.							76						
	Sorghum meals (*Sorghum vulgare*): Hard, corneous type:															
88	Feterita, 15 pct. bran removed with a 16-mesh sieve, size commonly used in the home.	Feterita bread (recipe: 15 c. sorghum meal, 1⅓ c. molasses, 1 c. lard, 1⅞ qt. water, 3¾ tsp. salt, 3¾ tsp. soda, 5 tsp. ginger), potatoes, applesauce, butter, sugar. Average daily intake: 40 gm. protein, 81 gm. fat, 320 gm. carbohydrate.	DGG			78		(50)		[1] 52.1		98.0				
			RLS			79		(50)		[1] 54.4		98.5				
			OES			75		(40)		[1] 41.0		97.4				
			RFT			80		(40)		[1] 62.2		98.6				
			DGG			75		(45)		[1] 30.5		95.2				
			RLS			78		(50)		[1] 65.8		98.6				
			OES			72		(40)		[1] 45.3		97.6				
			RFT			83		(45)		[1] 39.4		95.1				
			Av.			78		45		48.8		97.4				
		Feterita mush cooked 3–4 hr. in double boiler, applesauce, butter, sirup, sugar. Average daily intake: 44 gm. protein, 59 gm. fat, 661 gm. carbohydrate.	HFB			96		38		77.5		99.3				
			DGG			98		44		43.6		97.3				
			RLS			96		42		42.1		98.3				
			OES			97		34		30.4		99.6				
			Av.			97		40		48.4		98.6				
89	Kafir, 21 pct. bran removed with a 16-mesh sieve, size commonly used in the home.	Kafir bread (recipe: 3 c. sorghum meal, 3 c. water, 3 tbsp. lard, salt; cooked ½ hr.; baking powder added, baked in thin layer until hard and crusty), milk, oranges, sugar. Average daily intake: 91 gm. protein, 117 gm. fat, 363 gm. carbohydrate.	RLS			50		74		76.0		97.9			Subjects, young men. Experimental period, 3 days. Preliminary and final periods omitted since ration was made up to resemble closely an ordinary mixed diet. Marker, charcoal in gelatin capsules. Samples of bread analyzed, but composition of potato, applesauce and butter estimated by comparison with average values of large number of earlier analyses.	93
			IDB			44		55		43.5		96.7				
			WD			38		58		65.4		98.6				
			EEM			43		53		55.7		98.7				
			IDB			50		52		43.0		97.2				
			WD			38		50		67.5		97.9				
			EEM			44		48		59.7		97.5				
			Av.			44		56		58.7		97.8				
		Kafir bread (see recipe, item 88, a softer bread than that used in the preceding experiment on Kafir), potatoes, applesauce, butter, sugar. Average daily intake: 46 gm. protein, 104 gm. fat, 385 gm. carbohydrate.	DGG			75		(45)		[1] 88.8		98.7				
			RLS			74		(45)		[1] 35.5		94.6				
			OES			75		(45)		[1] 36.1		93.6				
			RFT			77		(45)		[1] 32.6		95.1				
			DGG			80		(50)		[1] 58.8		98.7				
			RLS			80		(45)		[1] 48.4		97.2				
			OES			79		(45)		[1] 42.9		95.0				
			Av.			77		46		49.0		96.1				
		Kafir mush cooked 3–4 hr. in double boiler, applesauce, butter, sirup, sugar. Average daily intake: 44 gm. protein, 66 gm. fat, 558 gm. carbohydrate.	DGG			98		39		59.4		96.8				
			RLS			97		45		61.5		97.4				
			OES			97		38		23.5		94.2				
			Av.			97		41		48.1		96.1				

90	Soft starch type: Kaoliang, 5 pct. bran removed with a 16-mesh sieve, size commonly used in the home.	Kaoliang bread (see recipe, item 88), potatoes, applesauce, butter, sugar. Average daily intake: 49 gm. protein, 128 gm. fat, 414 gm. carbohydrate.	DGG				84		(55)		[1] 28.2		96.4				
			AJH				84		(60)		[1] 17.6		96.5				
			RLS				85		(55)		[1] 16.3		95.4				
			OES				84		(50)		[1] 35.3		97.5				
			DGG				85		(55)		[1] 13.2		94.8				
			AJH				82		(55)		[1] 17.0		96.7				
			RLS				85		(55)		[1] 17.3		96.2				
			OES				83		(45)		[1] 25.0		96.5				
			Av.				84		54		21.2		96.2				
		Kaoliang mush cooked 3 to 4 hr. in double boiler, applesauce, butter, sirup, sugar. Average daily intake: 29 gm. protein, 71 gm. fat, 399 gm. carbohydrate.	DGG				94		31				96.9				
			AJH				94		47				96.0				
			RLS				94		57				95.6				
			OES				94		32				96.1				
			DGG				97		40				95.7				
			AJH				96		63		7.3		95.3				
			RLS				96		54		21.4		96.7				
			OES				96		35		6.5		97.4				
			Av.				95		45		11.7		96.2				
91	Milo, 19 pct. bran removed with a 16-mesh sieve, size commonly used in the home.	Milo bread (see recipe, item 88), potatoes, applesauce, butter, sugar. Average daily intake: 45 gm. protein, 95 gm. fat, 405 gm. carbohydrate.	DGG				78		(45)		[1] 30.1		95.5				
			RLS				78		(50)		[1] 43.5		97.9				
			OES				79		(45)		[1] 47.5		97.3				
			RFT				81		(40)		[1] 38.1		95.8				
			DGG				81		(50)		[1] 43.2		96.8				
			RLS				82		(55)		[1] 49.0		98.0				
			OES				83		(45)		[1] 29.6		95.2				
			RFT				82		(45)		[1] 21.7		93.9				
			Av.				80		47		37.8		96.3				
		Milo mush cooked 3 to 4 hr. in double boiler, applesauce, butter, sirup, sugar. Average daily intake: 40 gm. protein, 72 gm. fat, 583 gm. carbohydrate.	HFB				96		36		21.2		96.0				
			DGG				98		42		39.5		96.6				
			RLS				96		40		47.2		99.2				
			OES				97		36		29.6		98.9				
			Av.				97		38		34.4		97.7				
	Wheat, Wheat Products (*Triticum aestivum*):[19] Flour, whole-grain and nearly whole grain:																
92	Graham,* 100-pct. extraction, milled from hard spring wheat, Scotch Fife.	Bread (made with yeast), milk	1	72	1.2	30.7	42	9	70	47	81.0	67.8	88.1	85.2	81.8	Subjects, 3 men, 24–27 yr. Experimental period, 2 days; preliminary meal of bread and milk. Marker, charcoal. Average N-balance of 3 subjects, −2.0 gm. per day.	164
			2	64	1.2	32.4	52	13	77	57	80.6	55.1	88.7	85.0	81.6		
			3	76	1.5	40.8	42	9	70	47	71.1	51.2	88.5	81.6	78.6		
			Av.	71	1.3	34.6	45	10	72	50	77.6	58.0	88.4	83.9	80.7		
93	Graham,* 100-pct. extraction. Unbolted, contained coarse particles of bran. Milled from hard spring wheat, Scotch Fife.	Bread (made of flour, yeast, salt, water), milk.	1	76	2.1	52.5	50	2	76	52	81.1	41.2	90.9	87.7	83.9	Subjects, 3 young men. Experimental period, 4 days; preliminary meal of bread and milk. Marker, charcoal. Average N-balance of 3 subjects, +1.2 gm. per day.	166
			2	70	2.2	53.6	45	2	73	47	81.5		91.4	88.9	85.1		
			3	73	2.5	61.3	46	2	73	48	85.9		92.2	90.3	86.2		
			Av.	73	2.3	55.8	47	2	74	49	82.8		91.5	89.0	85.1		
94	Graham,* 100-pct. extraction. Unbolted, contained coarse particles of bran. Milled from hard spring wheat, Scotch Fife.[20]	Bread (made with yeast), milk, butter, sugar.	PHM	81	1.4	54.5	66	14	81	55	81.0	72.1	91.5	86.6	83.4	Subjects, young men. Experimental period, 2 days. Marker, charcoal, taken with meal of milk preceding and following experimental period. Average N-balance of 3 subjects, −0.6 gm. per day.	195
			JCT	54	1.2	61.0	74	9	80	45	81.2	75.1	90.2	84.5	81.3		
			WBW	65	1.0	45.5	76	12	85	55	81.6	73.7	91.5	86.6	83.3		
			Av.	67	1.2	53.7	72	12	82	52	81.3	73.6	91.1	85.9	82.7		
95	Graham, 100-pct. extraction, milled from hard spring wheat by 5 methods.[21]	Basal ration of oranges, butter, sugar, tea or coffee if desired, eaten with bread made from:															
	(a) Lab. roller mill flour.	Flour (a). Daily intake: 36 gm. protein, 391 gm. carbohydrate.					91	35	57		70.7		95.3			Subjects, young men. Experimental period, 3 days. Authors' customary experimental procedure followed. 3–5 experiments made with each flour.	90
	(b) Commercial roller mill flour.	Flour (b). Daily intake: 41 gm. protein, 413 gm. carbohydrate.					91	32	63		70.4		93.8				
	(c) Steel burr mill flour.	Flour (c). Daily intake: 48 gm. protein, 428 gm. carbohydrate.					93	30	64		78.5		95.3				
	(d) Attrition mill flour.	Flour (d). Daily intake: 39 gm. protein, 371 gm. carbohydrate.					92	34	64		74.5		95.4				
	(e) Stone burr mill flour.	Flour (e). Daily intake: 43 gm. protein, 429 gm. carbohydrate.					92	28	64		78.2		96.8				

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[18] The rye was milled to 67 percent and the branny fraction was obtained from the remaining portion of the grain. (Refers to original grain with 5 percent loss from cleaning.)

[19] Applies to all wheat items except Semolina flours, item 164, 165, and presumably items 166–171 which are *Triticum durum*.

[20] Ground from same lots of wheat and in same mill as those used by Snyder in experiments reported in references (*164*) and (*166*).

[21] Flours (a) to (e) named in order of coarseness of grind.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.															
	Wheat, Wheat Products (*Triticum aestivum*)—Continued															
	Flours, whole-grain and nearly whole grain—Continued															
96	Graham,* practically wheat meal. Unbolted, contained coarse, unpulverized particles. Milled from Oregon white winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	Subjects, 3 young men. Experimental period, 4 days. Marker, lampblack. Author's customary experimental procedure followed. Average N-balance of 3 subjects on Oregon wheat, −4.3 gm. per day. Subject 3 lost 3 lb. during experiment. Average N-balance of 3 subjects on Oklahoma wheat, −1.2 gm. per day.	168
			1 79	1.1	45.5	59	10	81	61	60.6	....	90.1	82.5	80.7		
			2 70	1.1	44.2	54	8	77	57	65.3	....	90.9	85.5	83.5		
			3 70	.7	29.9	46	6	71	48	[22] 40.5	....	92.6	83.8	82.6		
			Av. 73	1.0	39.9	53	8	76	55	63.0	....	91.2	83.9	82.3		
97	Graham,* practically wheat meal. Unbolted, contained coarse, unpulverized particles. Milled from hard winter Weissenburg wheat from Oklahoma.	Bread (made of flour, yeast, salt, and water), milk.	1 80	2.3	55.0	52	5	79	52	74.1	....	85.6	80.0	76.1		
			2 70	1.8	41.8	57	7	83	57	82.2	....	89.1	90.5	86.1		
			3 70	1.4	32.4	46	4	75	46	75.6	....	87.4	83.6	79.6		
			Av. 73	1.8	43.1	52	5	79	52	77.3	....	87.4	84.7	80.6		
98	Graham,* milled from Michigan soft winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1 77	2.3	61.3	45	6	76	51	79.2	....	88.9	85.8	82.7	For experimental details see remarks, item 93. Average N-balance of 3 subjects on Michigan wheat, +7.6 gm. per day.	166
			2 76	2.2	59.8	43	5	75	50	80.1	7.0	89.5	84.9	81.7		
			3 69	2.4	64.9	46	6	77	52	79.0	76.8	89.6	86.6	83.5		
			Av. 74	2.3	62.0	45	6	76	51	79.4	....	89.3	85.8	82.6		
99	Graham, 100-pct. extraction, milled in commercial mill from mixture of wheats.[23]	663 gm. bread (made of flour, yeast, salt, and water), oranges, butter, sugar, tea or coffee if desired.	Av. ---	....	....	....	....	....	....	84.2	....	94.4	....	....	Subjects, young men, both active and sedentary. Series of 139 experiments made. Experimental periods of 15-25 days subdivided into separate successive 3-day periods in which bread from flours of 54-, 70-, 85-, and 100-percent extractions were fed in simple diets. Authors' customary experimental procedure followed.	96
100	Graham	Bread, milk. Average daily intake: 140 gm. protein, 3,750 gross calories.	CWS ---	....	....	50	10	77	55	77.5	51.3	92.4	88.0	84.8	Subjects, young men. Experimental period, 2 days. Marker, lampblack, fed with meal of milk which preceded and followed experimental period. Subject FHM in negative N-balance, averaging −5.1 gm. per day; other 3 subjects in positive N-balance, averaging +9.7 gm. per day.	193
			FHM ---	....	....	44	8	73	49	77.0	36.3	93.2	88.0	84.8		
			CDH ---	....	....	33	5	62	38	79.3	54.7	92.3	88.4	85.2		
			PFF ---	....	....	39	7	69	45	70.3	37.9	91.2	85.2	82.4		
			Av. ---	....	....	42	8	70	47	76.0	45.0	92.3	87.4	84.3		
101	Graham	Bread, milk, butter, sugar	AJP 62	1.6	63.5	59	16	78	53	80.7	83.9	92.7	87.8	85.1	See remarks, item 100. Average N-balance of 2 subjects, −1.4 gm. per day.	
			OWK 62	1.4	60.7	50	11	65	42	77.3	84.6	92.3	87.0	84.3		
			Av. 62	1.5	62.1	54	14	72	48	79.0	84.2	92.5	87.4	84.7		
102	Graham*	Frozen pudding (containing raw graham flour, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 40 gm. protein, 2,085 calories.	ATM ---	....	....	(50)	(2)	44	....	[1] 74.1	....	96.4	....	....	Subjects, young women. Experimental period, 3 days. Marker, carmine taken at beginning of experimental period, lampblack with following period on regular diet, 3-4 days.	97
			CM ---	....	....	(46)	(4)	54	....	[1] 81.9	....	97.3	....	....		
			RLP ---	....	....	(46)	(4)	47	....	[1] 78.7	....	98.0	....	....		
			Av. ---	....	....	47	3	48	....	78.2	....	97.2	....	....		

103	100-pct. extraction, coarsely ground. Part of bran removed with a 16-mesh sieve, size commonly used in the home.	Bread (recipe: 15 c. wheat meal, 1¾ c. molasses, 1 c. lard, 2 qts. water, 3¼ tsp. salt, 3¾ tsp. soda, 5 tsp. ginger), potato, applesauce, butter, sugar. Average daily intake: 53 gm. protein, 99 gm. fat, 402 gm. carbohydrate.	DGG				89		(50)		[1]71.6		93.6			For details of experiment, see remarks, item 88.	93
			RLS				87		(55)		[1]87.3		98.1				
			OES				88		(50)		[1]65.3		93.2				
			RFT				88		(45)		[1]78.7		96.4				
			Av.				88		50		75.7		95.3				
104	100-pct. extraction	Bread (containing 5 pct. nonfat milk solids), butter, 4x cream, lettuce, french dressing, applesauce, orange juice, corn sirup, sugar, coffee. Average daily intake: 6 gm. N, 2,914 calories. (Consumption by any subject varied less than 1 pct. for protein, 2-3 pct. for fat and carbohydrate.) 80 pct. of the protein from egg or bread, 10 pct. from butter and cream, 10 pct. from remaining foods.	RR	69	.5		80		50		[1]65.7					Subjects, 10 young men, on diets in which 80 pct. of protein was supplied by egg or bread in alternate periods of 6 days each. Charcoal marker taken with 1st meal of each period. Urines analyzed for last 4 days of each period. Apparent digestibility of protein calculated from reference (127), using the approximate amounts of N from the several foods in diet as reported by authors.[34] Digestibility of fat and carbohydrate taken from reference (155). N-balance for whole-wheat period averaged −1.1 gm. per day.	127 155
			THL	54	.5		80		50		[1]69.7						
			DF	65	.5		80		50		[1]69.2						
			JPL	81	.5		80		50		[1]68.4						
			DHB	77	.5		80		50		[1]77.4						
			CDK	68	.6		80		50		[1]72.8						
			ESN	78	.6		80		50		[1]78.5						
			RAB	80	.6		80		50		[1]75.9						
			FLT	58	.6		80		50		[1]73.3						
			LEE	68	.6		80		50		[1]73.9						
			Av.	70	.6		80		50		72.5	97.1	96.7				
105	100-pct. extraction: (a) Medium grind.	Bread (1 oz. yeast, 1¼ oz. salt, 6 lb. flour), 37 gm. margarine, 72 gm. marmalade, ½ pt. milk, ½ pt. beer, tea and coffee ad lib., 50 gm. ascorbic acid.) Saccharin for some of subjects. Average daily intake: 114 gm. protein, 61 gm. fat, 3,360 calories.	JSDB								88.9	74.3	89.4	88.2	[2]83.7	Subjects, 6 young men. Preperiod, 3 days; experimental period, 7 days; postperiod, 1-4 days. Carmine marker taken beginning and end of experimental period. Authors assumed other foods in diet completely digested. Three flours, 100-pct. extraction (a) and (b), item 105, and 73 pct. extraction, item 144, used in this study and fed in 3 separate periods to the 6 men in random order. Normal diet for 1 wk. between experiments.	110
			GWF								89.6	69.7	89.2	88.0	[2]83.4		
			JCDH								83.1	76.6	89.3	87.0	[2]82.7		
			EIMcD								87.4	71.2	89.1	87.5	[2]82.9		
			TFM								86.8	71.4	87.5	86.2	[2]81.9		
			KCS								78.5	74.9	88.6	85.4	[2]81.4		
			Av.				90	30		75	85.7	73.0	88.9	87.1	82.7		
	(b) Fine grind, from same grist as (a) above.	Diet same as that described for item 105 (a). Average daily intake: 111 gm. protein, 61 gm. fat, 3,280 calories.	JSDB								88.8	80.9	89.5	88.7	[2]84.1		
			GWF								89.1	74.7	88.9	87.9	[2]83.3		
			JCDH								82.2	74.7	88.2	85.8	[2]81.6		
			EIMcD								84.5	75.7	88.5	86.7	[2]82.3		
			TFM								85.0	75.4	88.8	87.0	[2]82.6		
			KCS								82.5	75.5	87.5	86.0	[2]81.2		
			Av.				90	31		74	85.3	76.2	88.6	86.9	82.5		
106	Whole meal,* milled from Canadian wheat (high protein).	Bread (25 gm. fresh yeast and 25 gm. salt to each kg. flour, baked in rectangular loaves), small amounts of golden sirup, bramble and marmalade jelly, weak tea, water.	EG	86	1.9	47.3	100	100		97	81.1	74.9		86.2		Subjects, 3 men and 3 women. Ages of men: EG, 33; RM, 48; PJ, 35 yr. Ages of women: AH, 21; DH, 25; CW, 22 yr. 11 days on experimental diet: 3 days preliminary period, 7 days during which feces and urine were collected, 12-30 hr. postperiod. Carmine marker taken before 1st meal of 7-day period and before 1st meal of postperiod. 3-day interval between experiments when subjects took normal diet. Complete digestibility assumed for other foods in diet. 5 of 6 subjects in positive balance on diet with Canadian wheat and 5 subjects in negative N-balance on diet with English wheat. Authors gave as probable reason that subjects had not had time in preperiod to come to N-equilibrium.	104
			AH	46	1.9	49.9	100	100		92	84.5	58.8		89.0			
			DH	66	1.6	41.0	100	100		93	86.7	56.1		88.0			
			PJ	66	1.6	45.5	100	100		86	85.7	53.6		89.8			
			RM	57	2.4	60.2	100	100		100	86.3	62.6		87.3			
			CW	52	1.6	42.7	100	100		94	85.3	67.0		88.3			
			Av.	62	1.8	47.6	100	100		94	84.9	62.2		88.0			
107	Whole meal,* milled from English wheat (low protein).	Diet same as described for item 106, except that bread was made from English wheat and baked in flat cakes.	EG	86	1.0	44.6	100	100		97	66.2	59.1		87.4			
			AH	46	1.0	47.2	100	100		92	78.0	51.2		89.7			
			DH	66	.8	38.8	100	100		93	77.1	49.7		89.5			
			PJ	66	.9	43.2	100	100		86	72.6	59.4		90.4			
			RM	57	1.3	56.6	100	100		100	73.8	48.5		88.1			
			CW	52	.9	40.3	100	100		94	77.3	55.6		89.5			
			Av.	62	1.0	45.0	100	100		94	74.2	53.9		89.0			

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Calculated from authors' data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[32] Omitted by author from average.

[33] Mixture contained 20 percent choice hard spring (largely Marquis), 25 percent 58-lb. spring, 15 percent velvet chaff, 25 percent slightly smutty spring, 10 percent durum, and 5 percent Kansas and Oklahoma wheats.

[34] "Bread fecal N" reported, but actually was fecal N from total diet. Authors made no allowance for fecal N from the other foods (personal communication from one of authors).

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight		Proportion of total intake supplied by test food				Coefficient of apparent digestibility of test food				Portion of gross energy available	Remarks	Reference No.
					Protein	Gross energy	Protein	Fat	Carbohydrate	Gross energy	Protein	Fat	Carbohydrate	Energy			
	GRAINS, GRAIN PRODUCTS—Con.																
	Wheat, Wheat Products (*Triticum aestivum*)—Continued																
	Flours, whole-grain and nearly whole grain—Continued																
108	Whole meal,* ground by subject.	Cakes or porridge made of whole-wheat meal and water:		*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	Subject A, a physician. Successive experimental periods of (1) 8 days with 16 oz. whole meal eaten daily, (2) 14 days with 20 oz. meal daily, (3) 7 days with 28 oz. meal daily. Subject O took 16-22 oz. meal daily for 7-day period. Collection of feces last 3 days.	28
		16-oz. meal eaten daily	A	55	1.0		100	100	100	100	81.0	69.5					
		20-oz. meal eaten daily	A	54	1.2		100	100	100	100	82.2	77.8					
		28-oz. meal eaten daily	A	55	1.7		100	100	100	100	83.6	36.0					
		16-22-oz. meal eaten daily as cakes or porridge, olive oil.	O	55	1.2		100	27	100		89.6						
109	100-pct. of wheat kernel* "wheat meal flour."	Bread, beer. Average daily intake of bread, 990 gm.	D								69.5	48.9	92.6			Subject, 1 man. Experimental period, 3 days.	146
110	"Peeled wheat," only thin epidermis of wheat berry removed.	Diet and daily intake as described for item 104.	*Av.*				80		50		[1]73.0	97.1	99.1			Subjects, young men. 10 used for period on peeled wheat, item 110; 5 for period on item 111. For details of experiment and note on calculations see remarks, item 104. Average N-balance for subjects, −1.0 gm. per day.	127 155
111	"Peeled wheat," only thin epidermis of wheat berry removed.	Diet and daily intake as described for item 104.															
		(a) Bread (with ordinary yeast)	*Av.*				80		50		[1]74.5	97.1	98.6				
		(b) Bread (with high vitamin yeast).	*Av.*				80		50		[1]76.3	97.0	98.5				
	Flours, intermediate extractions:																
112	"Entire wheat,"* part of bran removed. Milled from hard spring wheat, Scotch Fife.	Bread, milk	1	72	1.1	29.7	41	7	70	45	78.1	55.6	93.5	87.6	84.4	For experimental details see remarks, item 92. 3 subjects in negative N-balance, averaging −2.9 gm. per day.	164
			2	64	1.1	29.9	50	10	78	55	83.9	48.1	94.6	89.6	86.1		
			3	77	1.1	28.8	43	8	72	47	79.1	63.6	94.1	89.4	86.1		
			Av.	71	1.1	29.5	45	8	73	49	80.4	55.8	94.1	88.9	85.5		
113	"Entire wheat,"* part of bran removed. Milled from hard spring wheat, Scotch Fife.	Bread (made of flour, yeast, salt, and water), milk.	1	76	2.2	52.5	51	2	80	56	83.4		96.2	93.0	89.1	For experimental details, see remarks, item 93. 3 subjects in positive N-balance, averaging +4.9 gm. per day.	166
			2	71	2.4	58.0	42	1	74	48	86.5		96.5	[93.9]	90.0		
			3	73	2.9	68.2	42	1	74	48	88.8		95.9	94.3	[89.4]		
			Av.	73	2.5	59.6	45	1	76	51	86.2		96.2	93.7	89.5		
114	"Entire wheat,"* part of bran removed. Milled from hard spring wheat, Scotch Fife.[20]	Bread (made with yeast), milk, butter, sugar.	PHM	82	1.2	48.1	75	16	83	60	81.9	78.6	97.0	91.9	88.7	For experimental details see remarks, item 94. Average N-balance of 3 subjects, −1.3 gm. per day.	195
			JCT	54	1.2	62.6	77	9	81	49	78.7	61.6	94.5	86.4	83.4		
			WBW	66	.9	40.8	75	11	86	55	81.8	78.4	96.4	91.2	88.0		
			Av.	67	1.1	50.5	76	12	83	55	80.8	72.9	96.0	89.8	86.7		
115	"Entire wheat,"* larger portion of coarse bran removed, shorts and germ retained. Milled from Oregon white winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	82	1.4	32.1	24	6	73	45	66.9		93.8	88.9	87.0	For experimental details see remarks, item 96. Subjects 1 and 2 in positive N-balance, +0.3 and +2.7 gm.; subject 3 in negative N-balance, −1.7 gm. per day.	168
			2	72	1.5	40.4	34	9	82	58	77.5		94.6	91.6	89.5		
			3	72	1.0	27.4	35	9	83	59	68.9		93.8	88.6	86.7		
			Av.	75	1.3	33.3	31	8	79	54	71.1		94.1	89.7	87.7		
116	"Entire wheat,"* 86-pct. of wheat. Milled from hard winter Weissenburg wheat from Oklahoma.	Bread (made of flour, yeast, salt, and water), milk.	1	79	2.3	56.8	53	7	76	54	75.7		89.6	85.6	81.9	For experimental details see remarks, item 96. Subjects 1 and 2 in positive N-balance, +0.3 and +0.6; subject 3 in negative N-balance, −0.2 gm. per day.	
			2	71	1.7	42.7	54	7	76	55	84.4		92.0	90.6	86.5		
			3	70	1.5	37.5	44	5	68	45	78.7		90.0	86.7	82.9		
			Av.	73	1.8	45.7	50	6	73	51	79.6		90.5	87.6	83.8		

117	"Entire wheat," * a small portion of the bran removed. Had characteristics of a finely pulverized graham flour. Milled from Indiana soft winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	74	2.6	71.8	46	7	78	52	89.5		90.3	90.2	85.2	Experimental period, 3 days. For other details of experiment see remarks, item 93. All 3 subjects in positive N-balance averaging +5.8 gm. per day.	166
			2	75	2.6	71.3	45	6	77	51	84.9	76.0	89.8	87.9	84.5		
			3	68	2.4	66.4	46	7	78	52	79.3		88.8	86.1	82.9		
			Av.	72	2.5	69.8	46	7	78	52	84.6		89.6	88.1	84.2		
118	"Entire wheat," * milled from Michigan soft winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	76	2.2	61.8	46	8	77	53	86.8		92.2	91.3	87.9	In this experiment all 3 subjects in positive N-balance, averaging +2.8 gm. per day.	
			2	76	2.2	62.3	45	8	76	52	82.8	71.1	93.2	90.0	86.8		
			3	68	2.4	67.9	46	8	77	53	87.4		93.4	92.7	89.4		
			Av.	73	2.3	64.0	46	8	77	53	85.7		92.9	91.3	88.0		
119	"Entire wheat"	Bread, milk. Average daily intake: 159 gm. protein, 4,190 gross calories.	CWS				47	4	76	52	79.2		96.0	90.4	87.1	For experimental details see remarks, item 100. Average N-balance for 3 subjects, +7.0 gm. per day. Subject AJP in positive N-balance, +0.1 gm. per day; OWK in negative N-balance, −1.1 gm. per day.	193
			PFF				47	3	76	52	88.6	48.4	97.9	95.5	91.6		
			ABO				45	3	75	50	86.3	11.6	96.9	93.6	90.0		
			Av.				46	3	76	51	84.7		96.9	93.2	89.6		
120	"Entire wheat"	Bread, milk, butter, sugar	AJP	60	1.6	64.1	60	10	74	46	88.8	84.0	97.3	[93.0]	89.3		
			OWK	62	1.5	64.4	59	9	67	43	90.4	88.2	96.0	93.8	90.0		
			Av.	61	1.6	64.2	60	10	70	44	89.6	86.1	97.6	93.4	89.6		
121	92 pct. of the wheat, coarse brown.	750–800 gm. bread, 600 cc. milk, 30 gm. filtered butterfat, 20 gm. sugar.	II	82	1.0		78				72.8					Subjects, men. Experimental period, 3 days. 4 meals daily. Marker, carbon. Average N-balance of 2 subjects, −4.8 gm. per day.	133
			IV	62	1.3		78				80.7						
			Av.	72	1.2		78				76.8						
122	92 pct. of the wheat; 8 pct. of branny part removed. Milled from English wheat.	Bread, milk, butter, sugar. Average daily intake: 81 gm. protein, 3,100 calories.					78			62	[1] 77.6					Subjects, 4 male research students. Experimental period, 3 days.	192
123	90-pct. extraction,* from English wheat. Reconstituted for this experiment by members of Cereals Research Station, St. Albans, England.	Wheat flour made largely into bread; some made into pastries and cakes. Butter, bacon fat, bramble and marmalade jelly, weak tea or water if desired. 50 mg. ascorbic acid taken daily if remembered.	MC	58	0.8	46.9				78	81.5					Subjects, 2 men, 4 women. Experiment in 4 parts in which were tested flours of 90- and 80-pct. extraction from both English and Manitoba wheats. For each flour there was a 3-day preperiod, 7-day test period, and a postperiod. Carmine marker taken before 1st meal of test period and of postperiod. Feces collected in test period between appearances of carmine. Experiment planned to minimize effects of season, habits, etc.	106
			RM	60	1.5	69.2				93	81.7						
			RT	78	0.8	42.7				81	81.2						
			BW	52	0.9	47.7				79	78.8						
			CW	55	0.9	46.7				80	77.5						
			EW	64	0.5	26.0				80	78.2						
			Av.	61	0.9	46.2	[31] 100			82	80.0						
124	90-pct. extraction,* from Manitoba wheat. Reconstituted by members of Cereals Research Station, St. Albans.	Diet same as described for item 123	MC	58	1.3	46.7				78	87.7						
			RM	60	2.2	67.8				93	88.0						
			RT	78	1.2	41.2				81	88.7						
			BW	52	1.3	47.8				79	86.0						
			CW	55	1.3	45.9				80	84.8						
			EW	64	1.0	34.0				78	89.0						
			Av.	61	1.3	46.9	[31] 100			81	87.2						
125	88 pct. of the wheat	Bread, milk, filtered butterfat, sugar. For amounts, see item 121.	II	82	1.0		78				78.9					For experimental details see remarks, item 121. Average N-balance, −1.7 gm. per day.	133
			IV	62	1.3		77				81.9						
			Av.	72	1.2		78				80.4						
126	88 pct. of the wheat, 12 pct. branny part removed. Milled from English wheat.	Bread, milk, butter, sugar. Average daily intake: 82 gm. protein and 3,020 calories.					77			62	[1] 81.4					For experimental details see remarks, item 122.	192
127	85-pct. extraction, "National wheat meal."	One-half of the mixed diet of the preliminary period [32] with bread (made of the National wheat meal) eaten in unrestricted amounts, jam. Average daily intake: 3,450 calories.	1	68	1.7		78				87.6					Subjects, men of military age. Preliminary period of 1 wk. on mixed diet followed by 1-wk. period with bread replacing half of mixed diet. Marker, carmine. Feces and food analyzed in weekly periods.	86
			2	64	1.5		75				89.9						
			3	58	2.0		76				89.5						
			4	64	1.7		80				91.6						
			Av.	64	1.7		77				89.4						
128	85-pct. extraction (patent, 1st and 2d clear, red dog, and shorts).[33]	472 gm. bread (made of flour, yeast, salt, and water), oranges, butter, sugar, tea or coffee if desired.									87.1		96.5			For experimental details see remarks, item 99.	96

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[30] Ground from same lots of wheat and in same mill as those used by Snyder in experiments reported in references (*164*) and (*166*).

[33] Mixture contained 20 pct. choice hard spring (largely Marquis), 25 pct. 58-lb. spring, 15 pct. velvet chaff, 25 pct. slightly smutty spring, 10 pct. durum, and 5 pct. Kansas and Oklahoma wheats.

[31] Authors stated that for all practical purposes the wheat flour constituted the sole source of N.

[32] The mixed diet eaten in the preliminary period included meat, fish, butter, margarine, bacon, cheese, milk, potatoes, vegetables, and small amounts of rice and porridge, furnishing about 71 gm. protein and 1,850 calories per day.

* Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
				Kg.	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
	GRAINS, GRAIN PRODUCTS—Con.																
	Wheat, Wheat Products (*Triticum aestivum*) Continued Flours, intermediate extractions—Continued																
129	85-pct. extraction	550 gm. bread made from 85-pct. extraction flour, fed in a mixed diet of meat, vegetables, paste, rice, lard, cheese, butter, sugar, cafe au lait, and wine.	T	68							76.7					Subjects, men, ages 22-37 yr. Flours described in this item and items 133 and 143 tested in the following order in consecutive 5-day periods: 75-pct., 85-pct., 75-pct., and 80-pct. extraction. Subjects took diet with 75-pct. extraction flour in 5-day intervals between periods with 85- and 80-pct. flours to eliminate after effects of 85-pct. flour on fecal loss. Feces and urine analyzed daily.	138
			A	70							85.1						
			D	61							85.0						
			S	61							83.1						
			I	58							81.8						
			F	69							77.9						
			Av.	65	1.7	48.5	45		62	46	81.6						
130	"Standard" meal, about 20 pct. of bran removed.	750-800 gm. bread, 600 cc. milk, 30 gm. filtered butterfat, 20 gm. sugar.	I	60	1.2	54.4	75			63	84.4					Subjects, men. Experimental period, 1 wk. with 4 meals daily in which "standard" meal bread was fed. 3-wk. interval between this and preceding experiment of 1 wk. in which patent flour was test food. Marker, carbon. N-balance of subject I, +0.5 gm.; other 3 subjects in negative N-balance, averaging −1.3 gm. per day.	133
			II	82	1.0	42.3	75			65	85.1						
			III	80	1.0	45.0	77			66	87.5						
			IV	62	1.1	51.9	74			62	86.4						
			Av.	71	1.1	48.4	75			64	85.8						
131	80-pct. extraction,* milled commercially from English wheat.	Wheat flour made largely into bread; some made into pastries and cakes. Butter, bacon fat, bramble and marmalade jelly, weak tea or water if desired. 50 mg. ascorbic acid taken daily if remembered.	MC	58	.8	49.3				79	79.4					For details of experiment, see remarks, item 123.	106
			RM	60	1.5	73.8				93	84.5						
			RT	78	.8	44.1				82	82.9						
			BW	52	.9	47.5				78	85.0						
			CW	55	.9	48.8				80	86.3						
			EW	64	.5	30.7				79	79.5						
			Av.	61	.9	48.8	[11] 100			82	83.4						
132	80-pct. extraction,* milled commercially from Manitoba wheat.	Diet same as described for item 131	MC	58	1.3	46.5				78	91.0						
			RM	60	2.3	70.2				92	90.8						
			RT	78	1.2	43.1				82	91.8						
			BW	52	1.3	49.1				77	89.3						
			CW	55	1.3	47.5				80	88.1						
			EW	64	.9	32.5				80	91.5						
			Av.	61	1.4	47.9	[24] 100			82	90.9						
133	80-pct. extraction	550 gm. bread made from 80-pct. extraction flour, fed in a mixed diet of meat, vegetables, paste, rice, lard, cheese, butter, sugar, cafe au lait, and wine.	T	68							84.0					For details of experiment, see remarks, item 129.	138
			A	70							90.6						
			D	61							88.5						
			S	61							88.1						
			I	58							86.9						
			F	69							82.9						
			Av.	65	1.7	48.5	45		62	46	86.8						
134	(80-pct. extraction), 20 pct. of branny portion removed. Milled from English wheat.	Bread, milk, butter, sugar. Average daily intake: 69 gm. protein, 3,390 calories.					76			64	[1] 86.8					Subjects, 4 male research students. Experimental period, 7 days.	192

	Flours, lower extractions:															
135	Standard patent,* included 1st and 2d patents, about 72.6 pct. of the screened wheat. Milled by roller process from hard spring wheat, Scotch Fife.	Bread and milk	1	72	0.9	24.2	49	7	78	54	86.7	65.2	97.4	93.5	90.0	For experimental details, see remarks item 92. Average N-balance for 4 subjects on 1st diet, −2.7 gm. per day; for 3 subjects on full ration, +4.9 gm., and on ⅔ ration, +2.1 gm. On the ½ ration, subjects 1 and 3 averaged −8.0 gm., subject 2, +1.9 gm. per day.	164
			2	64	1.0	29.8	51	7	80	56	86.3	52.6	97.9	93.7	[90.3]		
			3	75	1.0	28.3	44	6	75	50	82.8	51.3	97.1	92.3	[89.1]		
			4	71	1.3	36.5	36	4	69	41	90.3		97.4	95.8	92.2		
			Av.	70	1.0	29.7	45	6	76	50	86.5	56.4	97.4	93.8	90.4		
		Bread and milk, full ration	1	69	2.2	62.9	51	1	81	57	85.6	....	98.6	96.1	92.6		
			2	68	2.3	63.1	40	1	73	45	87.7	....	96.7	94.9	91.4		
			3	73	2.3	65.3	47	1	78	52	90.2	....	97.0	95.6	92.0		
			Av.	70	2.3	63.8	46	1	77	51	87.8	....	97.4	95.5	92.0		
		Bread and milk, ⅔ ration	1	69	1.5	42.0	56	1	83	61	88.6	....	97.7	95.3	91.8		
			2	70	1.4	38.7	45	1	76	50	85.5	....	97.2	94.9	91.5		
			3	73	1.5	43.0	52	1	80	57	87.8	....	98.0	96.0	92.5		
			Av.	71	1.5	41.2	51	1	80	56	87.3	....	97.6	95.4	91.9		
		Bread and milk, half ration	1	70	1.4	37.4	43	1	75	49	93.3	....	98.0	97.0	93.3		
			2	70	1.1	30.0	42	1	76	48	91.1	....	97.9	96.5	92.9		
			3	72	1.2	33.1	48	1	80	54	91.7	70.0	97.5	95.4	91.8		
			Av.	71	1.2	33.5	44	1	77	50	92.0	....	97.8	96.3	92.7		
136	Straight patent* (or standard patent) included 1st and 2d patents and 1st clear. About 72 pct. of the wheat. Milled from hard spring wheat, Scotch Fife.	Bread (made of flour, yeast, salt, water), milk.	1	75	1.9	48.0	44	(0)	72	46	85.5	....	97.9	94.8	90.9	For details of experiment see remarks, item 93. 3 subjects in positive N-balance, averaging +3.7 gm. per day.	166
			2	69	2.3	57.2	43	(0)	72	46	88.4	....	98.1	95.5	91.4		
			3	69	2.7	64.7	40	1	73	46	91.1	....	97.0	94.5	90.3		
			Av.	71	2.3	56.6	42	....	72	46	88.3	....	97.7	94.9	90.9		
137	Straight patent,* included 1st and 2d patents and 1st clear. 72 pct. of the wheat. From same lot of wheat as item 135.[10]	Bread (made with yeast), milk, butter, and sugar.	PHM	83	1.4	50.5	65	12	81	56	94.7	93.5	99.7	97.9	94.2	For details of experiment see remarks, item 94. Subjects PHM and WBW in negative N-balance, averaging −0.9 gm.; subject JCT in positive N-balance, +0.9 gm. per day. Subjects on half ration in negative N-balance, averaging −4.3 gm. per day.	195
			JCT	55	1.3	57.0	70	9	79	50	91.2	88.5	98.2	94.8	91.2		
			WBW	66	1.2	44.5	63	10	83	52	95.5	95.9	98.8	97.0	93.2		
			Av.	68	1.3	50.6	66	10	81	53	93.8	92.6	98.9	96.6	92.9		
		Bread (made with yeast), milk, butter, and sugar, one-half ration.	PHM	80	.4	19.0	73	8	80	62	77.3	34.4	94.1	82.8	79.8		
			JCT	53	1.0	38.8	66	10	81	56	85.2	66.9	96.7	93.6	90.4		
			Av.	66	.7	28.9	70	9	80	54	81.2	50.6	96.4	88.2	85.1		
138	Standard patent* or straight grade, about 70 pct. of the wheat. Milled from Oregon white winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	79	1.3	44.4	34	5	78	50	85.6	....	98.0	96.9	94.8	For details of experiment see remarks, item 96. For diet (item 138), subjects 1 and 3 in negative N-balance, averaging −2.1 gm.; subject 2 in positive N-balance, +2.8 gm. per day. For diet (item 139), subjects 1 and 2 averaged −1.6 gm. and subject 3, +1.3 gm. per day.	168
			2	69	1.5	52.8	41	7	83	58	89.4	....	98.9	96.5	96.3		
			3	70	1.1	41.2	42	7	84	59	79.8	....	97.8	95.9	94.0		
			Av.	73	1.3	46.1	39	6	82	56	84.9	....	98.2	97.1	95.0		
139	Standard patent* or straight grade. About 70 pct. of the wheat. Milled from hard winter Weissenburg wheat from Oklahoma.	Bread (made of flour, yeast, salt, and water), milk.	1	79	2.2	55.0	52	5	77	57	90.2	....	96.7	94.8	90.7		
			2	71	1.7	43.2	55	6	80	61	91.9	....	98.2	97.5	93.3		
			3	69	1.7	43.2	56	6	80	61	90.6	....	98.1	96.3	92.2		
			Av.	73	1.9	46.7	54	6	79	60	90.9	....	97.7	96.2	92.1		
140	Standard patent* or straight grade. Largely straight flour with some lower grades and a little germ. Milled from Indiana soft winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	73	2.6	71.6	42	4	77	51	94.2	62.1	95.6	93.9	90.4	Experimental period, 3 days. For other details of experiment see remarks, item 93. All subjects in positive N-balance, averaging +4.7 gm. per day on diet (item 140), and +3.7 gm. on diet (item 141).	166
			2	74	2.2	62.5	47	5	81	56	89.4	64.4	96.6	93.6	90.4		
			3	69	2.1	59.2	48	5	81	57	83.0		95.8	93.5	90.4		
			Av.	72	2.3	64.4	46	5	80	55	88.9	63.2	96.0	93.7	90.4		
141	Standard patent* or straight. Contained somewhat less than 72 pct. of wheat kernel. Milled from Michigan soft winter wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	75	2.1	60.5	44	3	78	52	93.0	....	97.6	97.3	93.4		
			2	75	2.1	61.8	41	2	76	49	94.4	....	98.3	98.5	95.1		
			3	69	2.0	58.8	45	3	79	54	90.9	....	98.2	97.4	94.1		
			Av.	73	2.1	60.4	43	3	78	52	92.8	....	98.0	97.7	94.2		

[1] Calculated from author's data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[10] Ground from same lots of wheat and in same mill as those used by Snyder in experiments reported in references (*164*) and (*166*).

[11] Authors stated that for all practical purposes the wheat flour constituted the sole source of N.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight		Proportion of total intake supplied by test food				Coefficient of apparent digestibility of test food				Portion of gross energy available	Remarks	Reference No.
					Protein	Gross energy	Protein	Fat	Carbohydrate	Gross energy	Protein	Fat	Carbohydrate	Energy			
	GRAINS, GRAIN PRODUCTS—Con.																
	Wheat, Wheat Products (*Triticum aestivum*)—Continued																
	Flours, lower extractions—Continued			Kg.	Gm.	Cal.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		
142	Standard patent. 70 pct. extraction. Included patent, 1st clear, and small portion of 2d clear. Milled from wheat mixture.[33]	564 gm. bread (made of flour, yeast, salt, and water), oranges, butter, sugar, tea or coffee if desired.	*Av.*								90.1		99.9			For details of experiment see remarks, item 99.	96
143	75-pct. extraction	550 gm. bread made from 75-pct. extraction flour, fed in a mixed diet of meat, vegetables, paste, rice, lard, cheese, butter, sugar, café au lait, and wine.	T	68	1.6	46.3					87.4					For details of experiment see remarks, item 129.	138
			A	70	1.6	45.0					92.2						
			D	61	1.9	51.6					90.9						
			S	61	1.9	51.6					92.2						
			I	58	1.9	54.3					88.6						
			F	69	1.6	45.7					83.7						
			Av.	65	1.7	48.5	45		62	46	89.2						
144	Straight run, 73-pct. extraction. From same grist as item 105.	Diet same as described for item 105. Average daily intake: 110 gm. protein, 56 gm. fat, 3,410 calories.	JSDB								94.1	79.3	98.7	96.8	[2] 92.3	For details of experiment see remarks, item 105.	110
			GWF								92.0	79.4	99.0	96.5	[2] 92.0		
			JCDH								88.2	76.7	98.8	95.4	[2] 91.1		
			EIMcD								92.3	80.6	98.8	96.5	[2] 92.0		
			TFM								89.7	75.2	98.5	95.5	[2] 91.1		
			KCS								90.5	82.3	98.5	96.0	[2] 91.5		
			Av.				90	23		75	91.1	80.6	98.7	96.1	91.7		
145	70 pct. of wheat kernel.* Middle-grade flour. Milled from mixture of Girka and Minnesota wheats.	Bread and beer. Daily intake: 880 gm. bread.	D								75.4	37.2	97.4			Subject, 1 man. Experimental period, 3 days.	146
146	1st patent,* milled from a hard spring wheat, Scotch Fife.	Bread and milk	4	72	1.3	35.0	35	3	68	41	90.5		98.0	96.4	92.8	For details of experiment see remarks, item 92. N-balance of subject 4 on 1st patent flour was +1.8 gm. and on 2d patent flour, −3.1 gm. per day.	164
147	2d patent*	Bread and milk	4	71	1.3	35.2	40	4	72	46	91.4		98.7	97.1	93.5		
148	Patent,* milled from a hard spring wheat, Scotch Fife.	Bread, eggs, butter		72	1.3		64	16	100		[1] 86.9	[1] 93.0	[1] 96.8			Subject, 22-yr.-old man. Experimental period, 2 days. Marker, charcoal. Author's usual laboratory procedure followed. Subject in positive N-balance in both experiments, averaging +0.6 gm. per day.	170
149	Patent, baker's grade.* Milled from Scotch Fife.	Bread, eggs, butter		75	1.4		67	13	100		[1] 88.0	[1] 91.5	[1] 96.8				
150	Patent, a high-grade white flour.	750–800 gm. bread, 600 cc. milk, 30 gm. filtered butterfat, 20 gm. sugar.	I	60	1.3	52.2	75			63	91.3					Subjects, 4 men. Experimental period, 1 wk., 4 meals per day. Marker, carbon. Subject I in positive N-balance, +0.8 gm. per day; others in negative N-balance, averaging −1.9 gm. per day.	133
			II	82	1.0	39.4	75			65	89.5						
			III	80	1.0	42.1	77			66	86.9						
			IV	62	1.2	50.9	75			64	89.5						
			Av.	71	1.1	46.2	76			64	89.3						

151	Patent*	Frozen pudding (containing raw patent flour, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 44 gm. protein, 2,060 calories.	ATM				(50)	(2)	52		[1] 69.0		100			For details of experiment, see remarks, item 102.	97
			CM				(50)	(2)	51		[1] 91.2		100				
			RLP				(50)	(2)	44		[1] 85.6		100				
			Av.				(50)	(2)	49		81.9		100				
152	Patent, enriched. Contained 11.7 pct. protein.	Test food with basal diet of sugar-cornstarch-lard cookies, sucrose, lactose, fondant, jelly, butterfat, lemon juice, applesauce, lettuce, french dressing.					95				81.6					For each test food, used 4 or 5 subjects (young women) and 7-13 experimental periods. Experimental period continued until N output in urine was reasonably constant for 3 or more days. Average length experimental period, 7.6 days. Feces collected for period of 3-5 days. Marker, either Fe_2O_3 or Cr_2O_3, given in 0.3-0.5 gm. doses.	31
153	Patent	Baking powder biscuits [27]									88.2		97.4			Subjects, young men. Experimental period, 3-4 days. 3 experiments for each food with following exceptions: Piecrust, 5 experiments; Boston crackers, 9 experiments. Results summarized from experiments at Minn. Agr. Expt. Sta. by Snyder, and experiment on piecrust at Off. Home Econ., USDA. Experimental methods used in the 2 laboratories were essentially the same.	48
		Yeast breads:															
		Currant buns [27]									88.0		98.1				
		Rolls [27]									88.6		97.7				
		Biscuits [27]									88.2		96.8				
		Cakes, cookies:															
		Ginger cakes [27]									85.6		97.8				
		Ginger snaps [28]									85.2		97.7				
		Molasses cakes [27]									84.6		97.9				
		Sugar cakes [27]									88.4		98.0				
		Crackers:															
		Boston [27]									87.7		97.9				
		Boston butter [27]									93.0		96.7				
		Sea biscuits [27]									94.1		98.8				
		Soda [27]									92.7		98.4				
		Doughnuts [27]									91.8		96.8				
		Pancakes [27]									86.3		96.5				
		Piecrust [27]									[29] 76.9		99.5				
		Pretzels [28]									88.2		98.0				
154	Patent, milled from a blend of English and foreign wheats.	Bread, milk, butter, sugar. Daily intake: 70 gm. protein, 3,220 calories.					75			65	[1] 89.8					Subjects, 4 male research students. Experimental period, 7 days.	192
155	Patent, 54-pct. extraction. Milled from a wheat mixture. [31]	600 gm. bread (made of flour, yeast, salt, and water), oranges, butter, sugar, tea or coffee if desired.									87.7		99.7			For details of experiment, see remarks, item 99.	96
156	White flour, (presumably a patent).	Bread and a small amount of beef tea. Average daily intake: 43 gm. protein, 1,620 gross calories.	HBS	66	1.1	35.2					90.9	82.3	98.3	96.2	92.7	For details of experiment see remarks, item 100. Average N-balance of 4 subjects: −5.7 gm. per day on bread and beef tea diet, −0.9 gm. on bread and milk diet, +0.8 gm. on diet (item 157). Subject OWK on diet (item 158), −3.4 gm. per day.	193
			HBS	66	.6	21.3					80.0	65.6	98.9	94.1	91.2		
			LHH								81.7	67.5	97.7	93.3	90.3		
			LWF								75.4	67.2	98.7	93.5	90.7		
			Av.				(100)	(100)	(100)	(100)	82.0	70.6	98.4	94.3	91.2		
		Bread and milk. Average daily intake: 108 gm. protein, 3,020 gross calories.	LHH				63	33	87	70	79.6	70.8	98.0	97.0	94.3		
			HBS	66	1.3	38.4	49	17	79	57	83.2	63.1	97.6	92.9	89.9		
			CWS				62	10	85	66	88.2	50.9	97.9	94.6	90.7		
			PFF				49	6	77	54	80.1		97.8	89.7	86.1		
			Av.				56	16	82	62	82.8	61.6	97.8	93.6	90.2		
157	White flour (presumably a patent).	Bread, milk, butter, sugar	AJP	62	2.1	78.0	46	8	74	51	94.5	89.9	99.1	97.2	94.2		
			BRM	75	1.8	64.5	57	8	74	48	87.2	45.0	98.4	91.9	88.3		
			AJP	61	1.9	63.0	44	9	69	43	92.2	89.6	98.2	95.2	91.5		
			OWK	61	1.9	62.0	44	9	67	43	92.1	91.2	98.1	95.2	91.6		
			Av.	65	1.9	66.9	48	8	71	46	91.5	78.9	98.4	94.9	91.4		
158	White flour (presumable a patent).	Bread, milk, butter, sugar. Partially fasting.	OWK	67	.8	27.6	46	5	71	43	97.7	99.1	98.9	98.7	94.7		
159	White flour (presumable a patent).	Bread (made with water), eaten in simple and mixed diets.[4]									85.6		98.9	94.0		Subjects, young men. Experimental period, 6 days; also see remarks, item 14.	120

[1] Calculated from authors' data, using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Calculated from authors' data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[4] Simple diet, milk, sugar and/or butter; mixed diet, meat and canned peaches in addition.

[31] Mixture contained 20 percent choice hard spring (largely Marquis), 25 percent 58-lb. spring, 15 percent velvet chaff, 25 percent slightly smutty spring, 10 percent durum, and 5 percent Kansas and Oklahoma wheats.

[27] Type of diet not reported.

[28] Bread included in the diet. No further description given.

[29] According to the author this value presumably was unduly low since the protein intake was so small that accurate results could not be expected.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.																
	Wheat, Wheat Products (*Triticum aestivum*)—Continued																
	Flours, lower extractions—Continued			*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
160	White flour (presumably a patent).	A lean white bread, No. 1 from a chain store, eaten in diet as described for item 104.					80		50	29	[1] 81.1		97.4	99.7		Subjects, 10 young men. For details of experiment and note on calculations see remarks, item 104. Average N-balance for the 3 periods was −1.0 gm. per day.	127, 155
161	White flour (presumably a patent).	Bread (made with 5 pct. nonfat milk solids and high-vitamin yeast) eaten in diet as described for item 104.					80		50	29	[1] 78.6		97.0	99.8			
162	White flour (presumably a patent).	A lean white bread, No. 2 from a chain store, eaten in diet as described for item 104.					80		50	29	[1] 80.4		97.2	99.8			
163	30 pct. of the wheat kernel,* milled from mixture of Odessa, California, and English wheats.	Bread and beer. Average daily intake: 900 gm. bread.	D								79.3	55.3	98.9			Subject, man. Experimental period 3 days.	146
	Flours, other:																
164	Semolina.* Included all the flour and middlings except dark-colored break flour, i. e., 1st, 2d, and coarse middling flours, and break flour. Milled from durum wheat, Kubanka.	Macaroni and bread (both made from semolina) 1:1, with milk.	1	79	1.3	38.0	44	6	77	52	89.8		98.4	97.2	93.9	For details of experiment see remarks, item 96. For diets (item 164) subject 1 in 1st experiment and subject 3 in 2nd experiment in negative N-balance, averaging −2.0 gm. per day. In the other trials, subjects were in positive N-balance, averaging +1.7 gm. For diet (item 165) subjects 1 and 2 averaged +2.8 gm. per day, subject 3, −3.9 gm.	168
			2	81	1.7	48.6	48	6	80	55	89.7		97.3	95.0	91.7		
			3	64	1.8	53.3	55	8	84	62	86.3		96.6	94.9	91.7		
			Av.	75	1.6	46.6	49	7	80	56	88.6		97.4	95.7	92.4		
		Macaroni and bread (both made from semolina) 2:1, with milk.	1	79	1.6	44.9	40	5	76	48	87.5		97.8	96.7	93.5		
			2	81	1.8	50.1	44	6	79	52	91.3		97.4	96.5	93.1		
			3	64	1.7	47.6	49	7	82	57	83.7		97.7	95.4	92.3		
			Av.	75	1.7	47.5	44	6	79	52	87.5		97.6	96.2	93.0		
165	Semolina,* milled from Kubanka wheat as described for item 164.	Macaroni and milk	1	68	1.0	30.2	54	6	83	62	82.0		97.3	94.4	91.6		
			2	83	1.0	30.5	54	6	83	62	88.9		97.1	95.2	91.7		
			3	83	.9	28.5	52	6	82	60	82.0	56.2	97.0	92.8	[90.0]		
			Av.	78	1.0	29.7	53	6	83	61	84.3		97.1	94.1	91.1		
166	Flour, used in making pastes.	Macaroni noodles cooked in salted water. Fat added. Daily intake: 62 gm. protein, 72 gm. fat, 462 gm. carbohydrate.	D	74	.8		100		100		82.9	94.3	98.5			Subject, 43-yr.-old man. Experimental period, 2 days each on macaroni noodle diets and 3 days on spaetzel diet. N-balances for the 3 periods: −7.0, +2.2 and −4.4 gm. per day.	144
167	Flour, gluten added; used in making pastes.	Macaroni noodles cooked in salted water. Fat added. Daily intake: 129 gm. protein, 73 gm. fat, 418 gm. carbohydrate.	D	74	1.7		100		100		88.8	93.0	97.7				
168	Flour, used in making pastes.	Spaetzels.[20] Daily intake: 68 gm. protein, 558 gm. carbohydrates.	D	74	.9		100		100		[21] 79.5		98.4				
169	Flour, used in making pastes. Best quality flour.	Macaroni used in a thick soup [22]									91.2	87.6	97.5			Subject, 48-yr.-old farmer. Experimental period, 3 days with 6 meals. Feces from 2d day used for analyses.	74
170	Flour, used in making pastes.	Macaroni used in a thick soup [22]									90.8	86.2	96.3				
171	Flour used in making pastes. From durum wheat.	Macaroni used in a thick soup [22]	*Av.*								86.9	87.9	97.4			Subjects, 3 men. Study by E. Capelletti, in *(168, pp. 55, 77, 78)*.	168

	Flour mixtures:																
172	Mixture of 80 pct. standard patent flour and 20 pct. wheat starch. Similar to many low-protein flours on market.	Bread and milk, "two-thirds ration".	1	70	1.3	41.9	51	1	84	62	86.6	....	98.0	96.2	93.4	For details of experiment see remarks, item 92. Subject 1 in negative N-balance, −3.6 gm. per day. Subjects 2 and 3 in positive N-balance, averaging +3.2 gm. per day.	164
			2	70	1.3	39.2	40	1	77	52	82.4	....	97.9	95.5	92.8		
			3	73	1.4	43.2	46	1	81	58	83.4	....	97.8	95.5	92.9		
			Av.	71	1.3	41.4	46	1	81	57	84.1	....	97.9	95.7	93.0		
173	"Bran flour,"* a mixture of 86 pct. straight-grade flour and 14 pct. very finely ground bran (amount removed in milling). Milled from hard winter Weissenburg wheat.	Bread (made of flour, yeast, salt, and water), milk.	1	83	2.0	49.0	39	4	74	42	83.2	....	93.0	90.2	86.3	For details of experiment see remarks, item 96. Bran or germ added to straight flour to determine their effect on completeness of digestibility. Subject 2 on bran flour diet in negative N-balance, −4.6 gm.; subjects 1 and 3 in positive N-balance, averaging +2.1 gm. per day. Subject 1 on germ flour diet in negative N-balance, −0.1 gm.; subjects 2 and 3 in positive N-balance, averaging +3.6 gm. per day.	168
			2	70	1.6	39.1	46	5	80	49	84.4	....	92.8	90.8	86.8		
			3	72	1.6	39.0	43	4	78	46	90.0	....	94.3	93.9	89.7		
			Av.	75	1.7	42.4	43	4	77	46	85.9	....	93.4	91.6	87.6		
174	"Germ flour,"* a mixture of 93 pct. straight-grade flour and 7 pct. finely ground germ (amount removed in milling). Milled from hard winter Weissenburg wheat.	Bread (made of flour, yeast, salt and water), milk.	1	82	2.2	54.3	49	7	72	50	87.6	....	97.0	94.8	90.5		
			2	70	2.1	51.8	54	8	76	55	91.1	....	97.9	96.8	92.3		
			3	69	1.8	43.9	53	8	75	54	91.3	....	97.9	96.2	91.7		
			Av.	74	2.0	50.0	52	8	74	53	90.0	....	97.6	95.9	91.5		
	Wheat breakfast foods: Whole-grain and partially refined:																
175	Flaked.* Whole-grain, 89.5 pct.; cane sugar, 7 pct.; salt, 3 pct.; malt sirup, 0.5 pct.; steam-cooked and toasted.	Wheat flakes, fruits, cream, lettuce, coffee or beer. 1 vitamin B-complex tablet. Average intake: 2,930 calories, 5.84 gm. N. 78 pct. of N from wheat flakes, 11 pct. from cream and butter, 11 pct. from remaining foods.	*Av.*	71	.5	41.3	78	....	....	....	[1] 68.2	....	....	....	....	Subjects, 10 young men. For details of experiment and note on calculations see remarks, item 32. Average N-balance, −0.9 gm. per day.	129
176	Flaked	Wheat flakes, sucrose or butter. (Butter not eaten by AF, sucrose not eaten by CK and GS.)	AF	86	.7	....	100	....	....	....	[1] 74.4	....	....	....	....	Subjects, 3 men. For details of experiment see remarks, item 28. Average N-balance, −1.2 gm. per day.	88
			CK	78	.7	....	100	....	....	....	[1] 73.9	....	....	....	....		
			GS	75	.7	....	100	....	....	....	[1] 73.8	....	....	....	....		
			Av.	80	.7	37.5	100	....	....	....	74.0	....	....	....	....		
177	Flaked, whole-grain, 89.5 pct.; cane sugar, 7 pct.; salt, 3 pct.; malt sirup, 0.5 pct.; steam-cooked and toasted.	Wheat flakes in diet as described for item 29.	*Av.*	71	.5	45.0	80	....	....	....	[1] 64.8	....	....	....	....	Subjects, 11 men. For details of experiment and note on calculations see remarks, item 29. Subjects in negative N-balance during this period.	40
178	Meal, from hard red spring wheat.	Wheat meal cooked with water and salt, 1 hr. at 15 lb. pressure, sucrose, butter. (Butter not eaten by AF.)	AF	86	.7	....	100	....	....	....	[1] 72.8	....	....	....	....	Subjects, 3 men. For details of experiment see remarks, item 28. Average N-balance, −0.7 gm. per day.	88
			CK	78	.7	....	100	....	....	....	[1] 77.4	....	....	....	....		
			GS	75	.7	....	100	....	....	....	[1] 76.9	....	....	....	....		
			Av.	80	.7	37.5	100	....	....	....	75.7	....	....	....	....		
179	Meal,* some of bran removed, granulated and toasted.	Wheat meal, cooked; fruits, cream, lettuce, coffee or beer. 1 vitamin B-complex tablet. Average intake, see diet, item 175.	*Av.*	71	.5	41.3	78	....	....	....	[1] 58.6	....	....	....	....	Subjects, 10 young men. For details of experiment and note on calculations see remarks, item 32. Average N-balance per day: for period of test food, item 179, −0.6 gm.; item 180, −1.0 gm.	129
180	Meal,* coarser parts of bran removed. 5 pct. added wheat germ. Finely granulated.	Diet and intake same as described for item 179; except average N-intake, 6.04 gm.	*Av.*	71	.5	41.3	78	....	....	....	[1] 66.2	....	....	....	....		

[1] Calculated from authors' data, using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[30] Stiff paste prepared from flour, water, milk, and eggs, forced through a large-holed sieve into boiling water, cooked quickly, and drained.

[31] Value applies to spaetzels; no correction made by author for digestibility of egg and milk in the spaetzels.

[32] Other ingredients of soup not given; assumed they were in too small amounts to introduce errors of any significance in the digestibility of macaroni.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.																
	Wheat, Wheat Products—(*Triticum aestivum*—Continued Wheat breakfast foods: Whole-grain and partially refined—Con.																
				Kg.	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
181	Meal (description, see item 180).	Wheat meal, cooked; cream, butter, prunes, bananas.	JM	92	0.4		80				[8] 56					Experimental period, 4 days, preceded by 3-day period in which milk protein replaced cereal protein. Charcoal and carmine markers used alternately for the 2 periods.	128
			JC	70	.5		80				[8] 64						
			RA	80	.5		80				[8] 67						
			GS	66	.4		80				[8] 58						
			Av.	77	.4		80				61						
182	Meal* (description, see item 180).	Wheat meal, cooked; sugar, cream, coffee.[4]					80						96			Details of experiment not given. Authors reported "coefficient of utilization" of protein 87.2 pct.; not included in this table since not clear if value is for true or apparent digestibility.	126
183	Puffed	Puffed wheat, sucrose, butter. (Butter not eaten by AF.)	AF	86	.7		100				[1] 74.6					Subjects, 3 men. For details of experiment see remarks, item 28. Average N-balance, −2.2 gm. per day.	88
			CK	78	.7		100				[1] 73.6						
			GS	75	.7		100				[1] 70.7						
			Av.	80	.7	37.5	100				73.0						
184	Puffed,* whole grain	Puffed wheat in diet as described for item 175, except average N intake was 5.94 gm.	*Av.*	71	.5	41.3	78				[1] 62.6					Subjects, 10 young men. For details of experiment and note on calculations see remarks, item 32. Average N-balance, −1.3 gm. per day.	129
185	Rolled*	Rolled wheat, cooked 20 min.; cream, sugar. Average daily intake: 25 gm. protein, 2,010 gross calories.	FAC				80	5	70	46	[1] 71.5		94.8	[1] 91.3	[2] 89.3	Subjects, young men. Experimental period, 4 days. Marker, lampblack given before 1st and after last meal of period.	62
			WJH				78	5	68	43	[1] 75.0		95.1	[1] 92.6	[2] 90.4		
			CBT				76	4	65	39	[1] 76.0		94.6	[1] 94.1	[2] 92.2		
			Av.				78	5	68	43	74.2		94.8	92.8	90.6		
186	Rolled	Rolled wheat, cooked; cream, sugar	*Av.*								85.0			90.7		3 experiments	119
187	Rolled,* part of bran removed. From durum wheat.	Rolled wheat, cooked, cream	1	70	.6	25.8	67	11	89	60	70.8	76.2	88.5	82.8	80.2	For details of experiment see remarks, item 96. All subjects in negative N-balance, averaged −2.9 gm. per day.	168
			2	83	.7	28.3	67	11	89	60	76.1	73.0	86.9	82.1	79.5		
			3	84	.8	33.9	67	11	89	60	72.2	62.5	89.9	84.4	81.9		
			Av.	79	.7	29.3	67	11	89	60	73.0	70.6	88.4	83.1	80.5		
188	Shredded	Shredded wheat, cream, sugar									57.7			84.1		3 experiments	119
189	Shredded*	Shredded wheat in a simple mixed diet (description of diet, see item 104). Average daily intake: 6 gm. N, 2,910 calories.	*Av.*				80				[1] 62.9	95.7	97.6			Subjects, 10 young men. For details of experiment and note on calculations see remarks, item 104. Average N-balance for shredded wheat period −1.4 gm. per day.	127 155
190	Shredded*	Shredded wheat fed in a simple mixed diet (description of diet and average intake, see items 32, 175).	*Av.*	71	.5	41.3	78				[1] 58.8					Subjects, 10 men. For details of experiment and note on calculations see remarks, item 32. Average N-balance, −0.9 gm. per day.	129

	Refined:																
191	Endosperm, granulated.	Wheat endosperm, cooked; cream, butter, prunes, bananas. Average daily intake, 5.6 gm. N, 2,900 calories.	JM	92	.4		80				[3]82					Subjects, men. For details of experiment see remarks, item 31.	128
			JC	70	.5		80				[3]74						
			RA	80	.5		80				[3]84						
			GS	66	.4		80				[3]74						
			Av.	77	.4		80				78						
192	Endosperm,* granulated.	Wheat endosperm, cooked, fed in a simple mixed diet. Diet and average intake same as for items 32 and 175, except N intake was 5.87 gm.	*Av.*	71	.5	41.3	78				[1]83.2					Subjects, 10 men. For details of experiment and note on calculations see remarks, item 32. Average N-balance, −0.7 gm. per day.	129
193	Endosperm,* granulated.	Wheat endosperm, cooked; sugar, cream, coffee.[5]					80						96.3			Details of experiment not given. Authors reported "coefficient of utilization" of protein, 94 pct.; not included in this table since not clear if value is for true or apparent digestibility.	126
194	Endosperm,* farina.	Farina, cooked 20 min.; cream, sugar. Average daily intake: 34 gm. protein, 2,200 gross calories.	RJM				80	5	72	50	80.1		99.1	[1]96.8	[2]94.4	Subjects, young men. Experimental period, 4 days. Marker, lampblack given before 1st meal and after last meal of period.	62
			HCW				79	5	74	50	71.9		98.2	[1]94.5	[2]92.2		
			Av.				80	5	73	50	76.0		98.6	95.6	93.3		
		Farina, cooked 8 hr.; cream, sugar. Average daily intake: 32 gm. protein, 1,900 gross calories.	CM				68	4	66	43	65.8		97.6	[1]91.2	[2]89.1		
			FM				66	3	65	41	68.1		98.8	[1]94.8	[2]92.6		
			HCW				74	5	73	48	77.9		98.7	[1]95.6	[2]92.7		
			Av.				69	4	68	44	70.6		98.4	93.9	91.5		
195	Endosperm,* farina.	Farina, cooked 20 min.; cream, sugar. Average daily intake: 30 gm. protein, 1,990 gross calories.	WJH				79	4	72	48	78.1		99.0	[1]96.7	[2]94.3		
			JD				75	3	72	48	75.2		98.3	[1]94.2	[2]92.0		
			MFC				72	3	67	45	60.7		97.1	[1]87.6	[2]85.7		
			Av.				75	3	70	47	71.3		98.1	92.8	90.7		
		Farina, cooked 8 hr.; cream, sugar. Average daily intake: 31 gm. protein, 1,900 gross calories.	JD				72	4	68	49	75.7		97.1	[1]94.5	[2]92.2		
			FMC				68	3	68	44	76.9		97.5	[1]97.1	[2]94.8		
			WJH				74	4	74	48	68.5		98.0	[1]91.7	[2]89.4		
			Av.				71	4	70	47	73.7		97.5	94.4	92.1		
196	Endosperm,* farina.	Frozen pudding (raw farina, milk, oil, sugar, salt, flavoring), oranges, sugar, tea or coffee if desired. Average daily intake: 45 gm. protein, 1,950 calories.	ATM				(50)	(2)	52		[1]78.8		99.8			Subjects, women. Experimental period, 3 days. Marker, carmine for experimental period, lampblack for following period of 3-4 days on regular diet.	97
			RJ				(50)	(2)	53		[1]88.4		100.0				
			CM				(50)	(2)	53		[1]94.8		100.0				
			RLP				(50)	(2)	47		[1]98.1		100.0				
			Av.				(50)	(2)	51		90.0		100.0				
	Wheat breakfast food mixtures:																
197	Wheat and barley malt.	Wheat and barley malt breakfast food, cream, sugar.	*Av.*								76.1			89.4		3 experiments	119
198	Wheat and barley malt.*	Wheat and barley malt breakfast food, milk, cream, sugar.	ABA	70	1.2	54.6	35	1	53	27	69.6		91.3	[1]87.8	85.3	Subjects, young men. Experimental period, 3-4 days. Marker, lampblack taken with 1st meal of and 1st meal after experimental period. Diets containing items 198 and 201 accompanied by fermentation, with intestinal irritation and pain.	9
			RDM	75	1.0	44.0	41	1	60	32	67.9		91.8	[1]88.2	85.8		
			EO	70	1.0	45.7	32	1	56	25	72.8		91.5	[1]90.3	87.7		
			Av.	72	1.1	48.1	36	1	56	28	70.1		91.5	88.8	86.3		
199	Wheat, whole grain, and barley malt.* "Force."	Whole wheat and barley malt breakfast food, milk, cream, sugar.	HCS	66	1.4	42.7	32	4	65	41	71.0		89.5	[1]85.5	83.2		
			EO	70	.9	33.1	30	3	56	33	68.6		93.3	[1]75.8	73.5		
			Av.	68	1.2	37.9	31	4	60	37	69.8		91.4	80.6	78.4		
200	Wheat, whole grain, and barley malt.* "Force."	Whole wheat and barley malt breakfast food, cream, sugar. Average daily intake: 36 gm. protein, 2,110 gross calories.	MFC				69	6	68	44	68.2		96.1	[1]91.1	[2]88.9	Subjects, young men. Experimental period, 4 days. No preexperimental period. Marker, lampblack.	62
			CM				76	8	75	53	50.0		92.5	[1]84.4	[2]82.8		
			Av.				72	7	72	48	59.1		94.3	87.8	85.8		
201	Wheat and barley malt. "Malta Vita." Resembles "Force" in appearance and general character.	Wheat and barley malt breakfast food, milk, cream, sugar.	HCS	66	1.5	46.6	36	4	65	37	71.6		89.2	[1]84.1	81.3	Subjects, young men. For details of experiment see remarks, item 198.	9
			RDM	75	1.1	50.3	44	3	58	31	73.8		91.7	[1]88.8	85.8		
			JAR	64	1.3	55.2	45	3	60	33	71.1		89.9	[1]86.1	83.2		
			EO	70	1.4	61.0	37	2	60	27	72.0		89.2	[1]86.2	83.4		
			Av.	69	1.3	53.3	40	3	61	32	72.2		90.0	86.3	83.4		

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Calculated from authors' data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[3] Authors gave two reasons for low digestibility: (1) low level at which protein was fed; (2) the rather liberal fruit intake.

[5] Diet as described by Clough, Carmen, and Austin, in Jour. Nutr. 3: 1-15, 1930.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

493-791 O - 73 - 6

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
	GRAINS, GRAIN PRODUCTS—Con.																
	Wheat, Wheat Products (*Triticum aestivum*)—Continued			*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
202	Wheat bran: Branny portion,* fraction of 73–95 pct.[33]	Wheat bran fed with basal diet of fruit, canned meat and fish, potatoes, bread, butter, cheese, turnips.	1								87					Subjects, 4 students. For details of experiment, see remarks, item 85.	30
			2								100						
			3								67						
			4								67						
			Av.								80						
203	Branny portion,* fraction of 82–95 pct.[33]	Wheat bran with basal diet as described for item 202.	1								60						
			2								69						
			3								59						
			4								62						
			Av.								63						
204	Commercial bran: (a) Ground quite fine in experimental mill. All but 2 pct. passed through a 109-mesh sieve.	Bran bread[34] with a simple mixed diet of potatoes in limited quantities, fruit, butter, sugar, tea or coffee. Average daily intake: 32 gm. protein, 134 gm. fat, 265 gm. carbohydrate.	DGG				81				18.0		38.4			Subjects, 5 men, ages 20 to over 40 yr. Experimental period, 3 days. Marker, charcoal, taken with 1st meal of and 1st meal following experimental period. Subjects' reports on bran diets varied from occasional slight pains after eating to extreme laxative effect, but author of article found no apparent relationship between these observations and digestibility.	71
			AJH				79				(35)		69.2				
			RLS				81				(35)		28.8				
			OES				81				(35)		37.6				
			DGG				83				56.8		71.0				
			AJH				71				43.2		67.5				
			PK				80				50.1		65.3				
			RLS				83				55.7		74.7				
			Av.				80				45.0		56.6				
	(b) Unground, flakes.	Bran bread[34] with simple mixed diet as described for item 204(a). Average daily intake: 24 gm. protein, 103 gm. fat, 237 gm. carbohydrate.	DGG				76				13.4		45.4				
			AJH				74				(35)		45.8				
			RLS				82				(35)		59.4				
			OES				77				35.6		60.3				
			DGG				80				16.7		41.5				
			AJH				74				49.7		72.1				
			RLS				80				31.1		58.4				
			OES				75				21.8		60.7				
			Av.				77				28.0		55.4				
205	"Prepared bran"	Bran fed with basal ration of wafers (made of starch, lactose, and butter); milk, sugar, cream, grape juice, apples.	F	58	0.5		22				45					Subjects, 2 women. Experimental period, 9 days, with preliminary period of 3 days on the experimental diet. Marker, carmine. Both subjects in negative N-balance.	60
			M	68	.5		22				59						
	Wheat starch:																
206	Starch	Frozen pudding (made of raw wheat starch, milk, oil, sugar, salt, flavoring) fed with oranges, sugar, tea or coffee if desired. Average daily intake: 22 gm. protein, 2,138 calories.	PC						52				99.8			Subjects, women. For details of experiment, see remarks, item 19.	91
			HLG						62				98.6				
			ELM						48				98.4				
			JFS						48				100.0				
			Av.						52				99.2				
207	Starch	Diet as described for item 206. Average daily intake: 21 gm. protein, 1,825 calories.	ATM						58				100.0			Subjects, women. For details of experiment, see remarks, item 18.	97
			CM						58				100.0				
			RB						57				100.0				
	Wild rice (*Zizania aquatica*):																
208	Wild rice products (whole grain; parched wild rice).[3]										77.8		93.8	86.4		Subjects, men. See remarks, item 3.	196

	LEGUMES AND NUTS																
	Beans, dry:																
209	Common white (*Phaseolus vulgaris*).	Cooked or baked beans in a mixed diet.		56	1.4	48.2	68				77.9					Subject, 1 man. Mixed diet, 4 days. Beans replaced 68.2 pct. total N in diet for next 5 days. Collections made last 4 days of bean diet.	117
210	Common white,* navy beans.	Beans, boiled several hours with fat salt pork, replacing part of basal ration of bread, butter, bananas, sugar. Daily intake of beans: Subject B, 375 gm.; subject H, 438 gm.; subject K, 375 gm.	B	67	1.3	34.8	81	19	64	63	73	[1] 45	96			Subjects, young men. 4 days on basal ration supplying 112 gm. protein and 3,000 calories per day, followed by 4-day experimental period in which part of basal ration was replaced by test food. Each experiment preceded by meal of bread and milk night before to give feces characteristic consistency. Lampblack taken before 1st meal of and after last meal of experimental period. Calculations based on customary assumption of digestibility of other foods in diet.	184
			H	62	1.5	41.2	83	23	68	67	78	[1] 57	95				
			K	69	1.2	33.7	81	19	64	63	78	[1] 57	95				
			Av.	66	1.3	36.6	82	20	65	64	76	51	95				
211	Common white,* navy beans. Mixture of 2 samples in equal amounts.	Beans, boiled several hours with fat salt pork, replacing part of basal ration of bread, butter, bananas, sugar. Daily intake of beans: Subject B, 300 gm.; subject H, 350 gm.; subject K, 300 gm.	B	67	1.7	46.7	56	11	37	38	78	[1] 64	99				
			H	62	2.0	53.6	60	12	41	41	80	[1] 46	96				
			K	69	1.6	45.6	56	10	37	37	81	[1] 51	97				
			Av.	66	1.8	48.6	57	11	38	39	80	54	97				
212	Common white,* navy beans, skins removed.	Beans boiled 20 min., skins removed, baked with salt and butter. Fed with bread and milk.	1								86.8	81.4	96.0			Subjects, 3 men	165
			2								72.3	85.7	95.9				
			3								81.6	72.4	96.8				
			Av.								80.2	79.8	96.2				
213	Common white,* navy beans.	500 gm. beans, cooked until soft, mixed with small amount of flour, browned in fat and a little vinegar. 1 liter beer. Daily intake: 112 gm. protein.									69.8					Subject, 1 man. Experimental period, 3 days.	137
214	Common white, navy beans.	Bean purée (beans soaked overnight, salted, cooked until soft, 4–5 hr. in 250° F. oven; sieved) fed with a simple diet.[33] Average daily intake: 30 gm. protein, 2,150 calories.	A			36.0	92				66.9					Subjects, women students. 2 series in which bean puree and baked beans, respectively, were eaten. Each series subdivided into 2 experiments, 1 with and 1 without added cystine. Each experiment consisted of a preliminary period of 3 days and collection period of 10 days (2 periods of 5 days each). Diet inadequate to maintain N-equilibrium for any length of time. No significant improvement when cystine was added.	135
			B			38.0	90				66.8						
			C			37.7	92				49.5						
			Av.			37.2	91				61.1						
		Diet above with cystine added in proportion of 2 pct. of weight of calculated protein.	A			36.0	92				68.8						
			B			38.0	90				60.1						
			C			37.7	91				60.6						
			Av.			37.2	91				63.2						
		Baked beans (soaked overnight, salted, and baked 10 hr. at 350–375° F.). Fed in simple diet.[33] Average daily intake: 30 gm. protein, 2,390 calories.	C			42.4	92				56.3						
			D			39.6	95				65.1						
			E			40.4	93				66.1						
			Av.			40.8	93				62.5						
		Baked bean diet described above with cystine added in proportion of 2 pct. of weight of calculated protein.	C			42.4	91				59.6						
			D			39.6	93				73.7						
			E			40.4	92				61.7						
			Av.			40.8	92				65.0						
215	Kidney beans* (*Phaseolus vulgaris*).	Beans, boiled several hours, replacing part of basal ration of bread, milk, butter, bananas, sugar. Hl consumed 300–375 gm.; Hr and S, 250 gm. each; and B, 375–400 gm. beans daily. Milk omitted from subject B's diet.	Hl	67	1.8		81	18	58		75	[1] 60	92			For details of experiment see remarks, item 210.	184
			Hr	56	1.5		74	12	48		71	[1] 69	93				
			S	60	1.4		74	12	48		81	[1] 26	95				
			B	74	1.6		81	13	52		81	[1] 50	96				
			Hl	67	1.9		77	11	51		75	[1] 77	93				
			S	60	1.5		69	8	41		79	[1] 72	95				
			Hl	67	1.6		71	9	44		73	[1] 72	92				
			B	74	1.6		87	26	61		77	[1] 47	95				
			Av.	66	1.6		77	14	50		76	59	94				

[1] Calculated from author's data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Coefficients of digestibility estimated for "products" were considered by authors of article to be applicable to these items.

[30] The wheat was milled to 73 pct. and the branny fraction obtained from the remaining portion of the grain. (Refers to original grain with 5 pct. loss from cleaning.)

[32] Recipe consisted of 15 c. bran, 3¾ tsp. soda, 1⅞ c. molasses, 3¾ tsp. salt, 5 tsp. ginger, 1 c. lard, and 1⅞ qt. hot water.

[31] Negative results, the fecal protein from bran exceeding that of the bran intake.

[33] Diet consisted of purified butterfat, sucrose, lactose, grape juice, and lemon juice.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: Energy	Portion of gross energy available	Remarks	Reference No.
	LEGUMES AND NUTS—Continued																
	Beans, dry—Continued			*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
216	Tepary beans (*Phaseolus acutifolius* var. *latifolius*).	Beans, soaked overnight and cooked 1 hr. at 15 lb. pressure; bread, butter, fruit, sugar. Average daily intake: 70 gm. protein, 2,475 calories.	1								84.8		97.9			Subjects, men. Experimental methods used were those followed in digestion experiments by U. S. Dept. Agr. described in early publications.	49
			2								74.4		100.0				
			3								74.6		98.4				
			4								67.1		98.4				
			5								78.7		97.4				
			Av.				57				75.9		98.0				
217	Variety not given, 1901 harvest year.	Bean meal and butterfat were salted and used in a soup or in purée. 1-2 bottles light beer added to daily diet.	Sch				100				78.0					Subjects, men. 20 experiments. Experimental period, 4 days. 1st and 4th days served to mark feces; 2d and 3d days, experimental period proper. 1st marking of feces by means of milk and cheese, 2d with bread made of groats (bruised grain), both yielding feces of physical characteristics quite different from feces of experimental diet. Separation sharp for all but 1 experiment.	189
218	Variety not given, 1902 harvest year.	Diet same as that described for item 217.	We				100				83.3						
			Sch.				100				81.1						
219	Variety not given	Diet same as that described for item 217.	Sch.				100				71.0						
			F				100				80.5						
			Sch.				100				84.2						
220	Variety not given	Diet same as that described for item 217.	Sch.				100				77.8						
	Cowpeas, dry (*Vigna sinensis*):																
221	Clay*	Cowpeas boiled several hours with fat salt pork, replacing either 20 pct. or 50 pct. of basal ration of bread, milk, butter, bananas, sugar. Daily intake of cowpeas for the two legume periods, respectively: Subject B and K; 175 gm., 454 gm.; subject H; 210 gm., 478 gm.	B	67	1.5	48.7	39	3	23	21	[69]		84	[37] 73	[2] 67	Details for experiments, (items 221, 223) same as described in remarks, item 210, except basal ration period followed by 2 legume periods; also calculation of digestibility of test food based on digestibility of the composite basal ration as determined in preperiod, assuming that digestibility of reduced basal ration of experimental period would be same percentagewise as full ration of preperiod. Details for experiments (items 222, 224, 227, 228) same as for item 221, except that basal ration period followed by 1 legume period. For experiment (item 225) experimental details same as for item 221, except quantities of total nutrients and energy of basal ration obtained by analysis of composite sample instead of by analysis and weight of each food separately. For experimental details for item 226, see remarks, item 210.	184
			B	67	2.2	50.6	73	10	56	52	71	50	[88]	[37] 80	[2] 74		
			H	62	2.1	64.3	37	3	22	21	79		92	[37] 88	[2] 82		
			H	62	2.6	62.1	68	11	50	49	71	[86]	88	[37] 81	[2] 75		
			K	69	1.5	47.3	39	3	23	21	[76]	60	86	[37] 81	[2] 75		
			K	69	2.1	48.4	73	10	57	53	75	73	85	[37] 80	[2] 74		
			Av.	66	2.0	53.6	55	7	38	36	74	67	87	80	74		
222	Clay*	Diet as described for item 221, except cowpeas replaced about 40 pct. of basal ration. Daily intake of cowpeas: 325 gm. for each subject.	Ba	66	1.8	50.7	59	7	43	38	70	[43]	85	[37] 77	[2] 72		
			G	66	1.8	50.7	59	7	43	38	72	60	88	[37] 81	[2] 76		
			R	68	1.8	49.2	59	7	43	38	82	78	90	[37] 85	[2] 80		
			Av.	67	1.8	50.2	59	7	43	38	75	60	88	81	76		
223	Lady*	Diet as described for item 221, cowpeas replaced either 25 pct. or 50 pct. of basal ration in 1st 6 experiments, and 40 pct. of the basal ration in last 2 experiments. Daily intake of cowpeas in order of experiment: Subject B; 175 gm., 400 gm.; subject H; 210 gm., 500 gm.; subject K; 175 gm., 400 gm.; subject H; 320 gm.; subject K; 260 gm.	B	67	1.7	46.0	40	3	24	23	82		97	[37] 88	[2] 81		
			B	67	2.2	47.7	69	11	53	50	82	[32]	95	[37] 87	[2] 81		
			H	62	2.3	60.9	38	4	23	22	84	100	93	[37] 90	[2] 84		
			H	62	3.0	63.9	68	13	51	51	80	60	93	[37] 86	[2] 80		
			K	69	1.6	44.6	40	3	24	23	86	100	99	[37] 96	[2] 89		
			K	69	2.1	46.3	69	11	53	50	84	64	95	[37] 90	[2] 83		
			H	62	2.6	64.9	50	6	32	32	87	91	95	[37] 90	[2] 83		
			K	69	1.9	47.4	51	5	34	32	89	78	95	[37] 91	[2] 84		
			Av.	66	2.2	52.7	53	7	37	35	84	75	95	90	83		
224	Lady*	Diet as described for item 221. Cowpeas replaced 40 pct. of basal ration. Daily intake of cowpeas: 340 gm. for each subject.	Fa	69	1.9	49.9	59	7	45	39	84	50	94	[37] 88	[2] 82		
			Fx	65	2.0	52.9	59	7	45	39	79	71	91	[37] 85	[2] 80		
			Ky	85	1.5	40.5	59	7	45	39	80	54	92	[37] 86	[2] 80		
			Av.	73	1.8	47.8	59	7	45	39	81	58	92	86	81		
225	Lady*	Diet as described for item 221. Cowpeas replaced 50 pct. of basal ration. Daily intake of cowpeas: 425 gm. for each subject.	Fa	69	2.2	49.0	68	16	50	50	83	37	[94]	[37] 88	[2] 82		
			Fx	65	2.3	52.1	68	16	50	50	86	77	95	[37] 90	[2] 84		
			Ky	85	1.8	39.8	68	16	50	50	82	30	93	[37] 87	[2] 81		
			Av.	73	2.1	47.0	68	16	50	50	84	48	94	88	82		

226	Whippoorwill*	Basal ration as described for item 210. Cowpeas replaced part of basal ration. Daily intake of cowpeas in order of experiments: Subject B, 375 gm.; H, 475 gm.; K, 375 gm.; B, 300 gm.; H, 400 gm.; and K, 300 gm.	B	67	1.5	34.8	84	22	64	66	68	[1] 40	87				
			H	62	2.0	44.4	87	25	69	70	68	[1] 40	86				
			K	69	1.5	33.9	84	21	64	65	71	[1] 57	85				
			B	67	1.8	47.4	58	9	38	38	72	[1] 55	[89]				
			H	62	2.3	58.2	65	12	45	46	73	[1] 82	90				
			K	69	1.7	46.1	58	9	38	38	70	[1] 56	91				
			Av.	66	1.8	44.1	73	16	53	54	70	55	88				184
227	Whippoorwill*	Basal ration as described for item 221. Cowpeas replaced 35 pct. of basal ration. Daily intake of cowpeas: 275 gm. for each subject.	B	67	1.6	49.0	51	4	38	33	[68]	94	[87]	[17] 79	[2] 75		
			H	62	1.7	53.0	51	4	38	33	71	100	89	[17] 83	[2] 79		
			K	69	1.6	47.6	51	4	38	33	74	[69]	88	[17] 83	[2] 78		
			Av.	66	1.6	49.9	51	4	38	33	71	88	88	82	77		
228	Whippoorwill*	Diet, see item 221. Cowpeas replaced 40 pct. of basal ration. Daily intake of cowpeas: 350 gm. for each subject.	Fa	69	1.8	49.8	60	7	47	41	72	75	88	[17] 79	[2] 74		
			Fx	65	1.9	52.9	60	7	47	41	71	83	88	[17] 82	[2] 77		
			Ky	85	1.5	40.4	60	7	47	41	61	[58]	82	[17] 74	[2] 70		
			Av.	73	1.7	47.7	60	7	47	41	68	72	85	78	74		
	Lentils, dry (*Lens culinaris*):																
229	Lentils	250 gm. lentils, soaked overnight, cooked until tender in 1¾ liters meat broth, with salt and 20 gm. butter added.									59.8					Subject, 1 man. Feces for experimental period were easily identified by undigested seed skins.	176
230	Lentils										74					Study by Potthast in (*117, p. 454*).	117
231	Lentils, 1901 harvest year.	Lentil meal and butterfat used in a soup or porridge, salt added. 1-2 bottles light beer.	Sch				100				77.1					Subjects, men. For experimental details see remarks, item 217.	189
			Sch				100				69.5						
232	Lentils	Diet, see item 231	Sch				100				81.1						
			F				100				84.2						
233	Lentils, 1902 harvest year.	Diet, see item 231	Wa				100				76.3						
			Sch				100				82.1						
	Peas, dry (*Pisum sativum*):																
234	Peas	Peas, cooked 12 hr., forming a porridge or thick soup; rice, sugar, milk.	*Av.*				32	3	22	19	80.0		96.2			Subjects, 3 men. Experimental period, 3 days. Usual experimental procedure in author's laboratory followed. All subjects in positive N-balance, averaging +0.6 gm. per day.	167
235	Peas*	Peas, cooked 2-3 hr., sieved; 1 liter beer. Daily intake: 960 gm. peas.	D				100	100	100	100	72.2	25	92.7			Subject, 1 man. Experimental period, 2 days.	145
236	Peas*	Diet, see item 235. Daily intake: 600 gm. peas.	D				100	100	100	100	82.5	36.1	96.4				
237	Peas*	Peas, cooked in distilled water, puréed. Daily intake: 137 gm. protein.									89.8	87.6	[17] 94.6			Subjects, men. Experimental period, 2 days. More digestive disturbance from peas cooked in hard water.	140
		Peas, cooked in hard water, puréed. Daily intake: 137 gm. protein.									83.2	58.9	[17] 96.4				
238	Peas, split*	548 gm. peas and 75 gm. butter cooked into porridge; 1 liter beer. Daily intake: 129 gm. protein, 68 gm. fat, 338 gm. carbohydrate.					99	6	100		84.7		95.8			Subject, 1 man. Experimental period, 2 days. Fecal marker, lampblack.	113
		575 gm. peas, cooked into porridge; 1 liter beer. Daily intake: 134 gm. protein, 4 gm. fat, 354 gm. carbohydrate.					100	100	100		86.2		95.9				
239	Peas, 1901 harvest year.	Pea meal and butterfat used in a soup or porridge, salt added; 1-2 bottles light beer.	Sch				100				85.3					Subjects, men. For experimental details see remarks, item 217.	189
			F				100				85.8						
240	Peas	Diet, see item 239	Sch				100				85.1						
241	Peas	Diet, see item 239	Wa				100				89.8						
242	Peas, 1902 harvest year.	Diet, see item 239	Sch				100				83.3						
243	Peas	Diet, see item 239	Sch				100				86.2						
			We				100				84.5						

[1] Calculated from author's data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.
[2] Calculated from author's data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.
[17] Calculated from author's data.
*Indicates that composition, and in some cases also heat of combustion, was reported by the author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion: Fat	Proportion: Carbohydrate	Proportion: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient: Fat	Coefficient: Carbohydrate	Coefficient: Energy	Portion of gross energy available	Remarks	Reference No.
	LEGUMES AND NUTS—Continued																
	Soybeans, Soybean Products, dry (*Glycine max*):			*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
244	Soybeans, run-of-the-mill.	Soybeans, autoclaved for 1 hr. at 15 lb. pressure; cream, starch, crackers, lettuce, salad dressing, orange juice, margarine, apples, dextrimaltose, sucrose, vitamin supplement. Protein level of intake kept at or near 5 pct. of total calorie intake. About 80 pct. of total N intake from soybeans, 10 pct. from cream, 10 pct. from remaining foods.	WC	68	0.4	38.1	80				[1]74.2					Subjects, young men. Experimental method of Murlin et al., 1941 (*127*), followed. Test food or egg supplied about ⅘ of the food N. Soybeans, soy flour, and soy milk tested in series of experiments planned so that an egg period always preceded and followed a soy products period. Experimental periods, 6 days. Marker, charcoal, taken with 1st meal of each period. N-balance of subjects positive in egg period, averaging +0.8 gm. per day; negative in soybean period, averaging −0.1 gm. per day. To calculate apparent digestibility of test food, N-intake and fecal N from the other foods were estimated from amounts in sample diet reported by authors.[7]	34
			RC	87	.5	43.7	80				[1]69.0						
			JG	64	.6	46.7	80				[1]74.7						
			FG	61	.6	52.1	80				[1]68.9						
			JH	68	.6	47.1	80				[1]64.9						
			SK	76	.5	47.3	80				[1]71.1						
			KP	67	.6	53.6	80				[1]70.9						
			RR	62	.5	41.8	80				[1]75.7						
			GV	90	.4	35.2	80				[1]72.8						
			JY	74	.6	47.4	80				[1]68.2						
			Av.	72	.5	45.3	80				71.0						
245	Soybeans	Soybeans boiled ½ hr., salt and tomatoes added to resultant mush; potatoes, fruit, milk, sugar, butter, cereal, coffee or tea.	...	57	1.3	42.1	90				85.3					Subject, 24-yr.-old man. Experimental period, 6 days, preceded by 5 days on a mixed diet. In positive N-balance, +1.7 gm. per day.	117
246	Soybeans, Mammoth, yellow variety.	Soybeans, cooked 2 hr. at 15 lb. pressure until soft and tender. Eaten with simple mixed diet of bread, butter, sugar, oranges, tea or coffee. Average daily intake: 103 gm. protein 3,100 calories.	PK	...							74.8					Subjects, men 19–24 yr. old. Experimental period, 3 days.	72
			JCM	...							76.0						
			WO'C	...							82.7						
			JFC	...							82.9						
			TGH	...							80.0						
			FAK	...							83.4						
			Av.	...			65				79.9						
247	Soybean flour, about 8 pct. fat. From press cake, expeller-type process used.	Baking powder biscuits made of soybean flour and patent wheat flour in equal proportions; fruit, butter, sugar. Average daily intake: 84 gm. protein, 92 gm. fat, 268 gm. carbohydrate.	AF	...			82				[1]88.9					Subjects, 4 men, ages 20–40 yr. Experimental period, 3 days. No attempt made to maintain a uniform body weight of subjects or N-equilibrium.	70
			PK	...			83				[1]80.3						
			JCM	...			83				[1]82.5						
			AAR	...			82				[1]88.3						
			PK	...			83				[1]91.1						
			JCM	...			83				[1]86.1						
			AAR	...			81				[1]85.9						
			Av.				82				86.2						
248	Soybean flour,[4] 6.5 pct. fat (reported as meal).	Soybean meal prepared as porridge, cooked 5 hr.; milk, butter, sugar.	...	73	1.2	23.3	72	10	24	27	[1]88.4		[1]98.9			Subject, 1 man, aged 38 yr. Experimental period, 3 days. Fecal marker, lampblack.	29
249	Soybean flour,[4] 3.3 pct. fat (reported as meal).	Yeast bread (200 gm. soybean meal, 400 gm. patent wheat flour, 10 gm. sugar); milk, butter, sugar.	...	73	1.1	29.7	36	2	11	11	[1]88.8		[1]96.0				
250	Soybean flour, 43.8 pct. protein.	Soybean flour fed with basal ration as described for item 152.					95				70.3					Subjects, 4 or 5 young women. For experimental details see remarks, item 152.	31

251	Soybean flour	Soybean flour, mixed with water and salt, autoclaved for 1 hr. Eaten with simple mixed diet as described for item 244. Protein level of intake kept at or near 5 pct. of total calorie intake.	RC	88	.5	44.2	80				[1] 73.2					Subjects, young men. For experimental details and note on calculations see remarks, item 244. Subjects in positive N-balance during both egg and soy flour periods, averaging +0.8 gm. and +0.3 gm. per day, respectively.	34
			BC	78	.5	46.1	80				[1] 69.3						
			AF	71	.5	46.5	80				[1] 76.2						
			FG	62	.6	51.5	80				[1] 74.7						
			JH	69	.5	46.5	80				[1] 70.5						
			SZ	63	.6	47.4	80				[1] 70.4						
			Av.	72	.5	47.0	80				72.4						
252	**Soybean products, other:** Soybean curd* (Tofu)	Soybean curd with a small amount soy sauce (shoyu).	N								89.2	95.3	98.2			Subject, 1 man. Experimental period, 1 day. Buckwheat containing black husk used as fecal marker.	134
253	Soybean curd	Soybean curd eaten with basal diet of lotus starch, sugar, lard, turnip, carrot, cabbage, salted turnip. To basal diet was added small amount of fresh orange or pear at each meal, cod-liver oil and wheat bran once every 2 days.	C	57	.5	50					98					Subjects, Chinese men, 25-37 yr. old. No digestive disturbances, but subjects in negative N-balance during 6-day preperiod and period in which soybean curd was added. N-intake in preperiod averaged +0.89 gm., or 0.54 pct. protein level.	39
			L	55	.6	50					98						
			H	52	.6	50					98						
254	Soybean curd	246 gm. soybean curd, 150 gm. starch, 45 gm. dextri-maltose, 75 gm. lactose, 73 gm. butterfat, 230 gm. apple.	D	50	.5	40.0	98				75.8					Subject, young woman. 4 consecutive experimental periods of 3 days each. N-intake kept constant for all 4 periods. Daily N-balance for the 4 periods: −0.3, −0.2, +0.4, and +0.2 gm.	143
255	Soybean curd	1 lb. soybean curd eaten with a basal diet of rice, tur dhal black gram, Bengal gram, vegetables, fat (a typical South Indian diet). Average daily intake: 56 gm. protein in basal ration; 66 gm. protein in soybean curd period; 2,880 calories both periods.	KB				15				[37] 89.3					Subjects, 16-21 yr. old. Experimental period, 7 days. Last 4 days served as collection period for feces and urine. 5-day rest period followed by 7-day basal ration period. Method of marking feces not given. Subjects in positive N-balance, +3-4 gm. per day.	46
			MN				16				[37] 99.8						
			MV				16				([37] [38])						
			SM				15				([37] [38])						
			KS				16				([37] [38])						
256	Soybean milk	Soybean milk, cream, starch crackers, lettuce, salad dressing, orange juice, margarine, apples, dextri-maltose, sucrose, vitamin supplement. Protein level of intake kept at or near 5 pct. of total calorie intake.	WC	68	.5	38.3	80				[1] 69.5					Subjects, young men. For experimental details and note on calculations see remarks, item 244. Subjects in positive N-balance during egg period, averaging +0.8 gm., and in negative N-balance during soybean milk period, averaging −0.2 gm. per day.	34
			RC	87	.5	43.7	80				[1] 70.9						
			FG	61	.6	52.1	80				[1] 67.8						
			JH	68	.6	47.2	80				[1] 65.2						
			SK	76	.6	47.5	80				[1] 74.7						
			KP	67	.6	53.8	80				[1] 71.5						
			RR	62	.5	42.0	80				[1] 76.3						
			GV	90	.4	35.2	80				[1] 68.0						
			JY	74	.6	47.3	80				[1] 67.0						
			Av.	73	.5	45.2	80				70.1						
257	Soybean milk	Soybean milk. Average daily intake: 57.5 gm. protein.	LM				100				[37] 92.0					6 Chinese subjects, 1-3 yr. old. Experimental period, 7 days. Feces and urine collected last 5 days. Method of marking not given. Subjects all in positive N-balance, averaging +5.6 gm. per day.	47
			AC				100				[37] 91.0						
			SM				100				[37] 92.4						
			PF				100				[37] 90.2						
			HS				100				[37] 91.7						
			NS				100				[37] 90.9						
			Av.				100				91.4						
258	Soybean milk	Soybean milk, cane sugar, cornstarch, calcium lactate, salt, cod-liver oil. Cabbage water added to H's diet in 2d experiment; orange juice added to diets of S, Hsu, and C in all experiments.	H	4.0	5.9	151	100				79.5					Subjects, Chinese infants. Ages during period of experiment: H, 1½-3 mo.; S, 4-4½ mo.; Hsu, 9-10 mo.; C, 6½-8 mo. Fecal marker, carmine (information from Tso et al., Chinese Jour. Physiol. 2: 409-414, 1928). All subjects in positive N-balance.	181
			H	4.4	3.7	137	100				76.2						
			S	5.0	5.0	121	100				80.5						
			S	5.2	3.0	126	100				81.6						
			S	5.3	2.4	127	100				76.4						
			Hsu	5.4	4.5	119	100				79.0						
			C	5.5	4.9	118	100				81.9						
			C	5.6	3.7	123	100				83.4						
			C	5.8	2.8	120	100				83.4						
			C	5.9	2.4	122	100				81.1						
			Av.	5.2	3.8	126	100				80.3						

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[7] Authors apparently made no correction for N of foods other than test food in total N intake or fecal N.

[37] Calculated from authors' data.

[38] Value higher than 100 percent; omitted here.

*Indicates that composition, and in some cases also heat of combustion, was reported by the author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Fat	Carbohydrate	Gross energy	Coefficient of apparent digestibility of test food: Protein	Fat	Carbohydrate	Energy	Portion of gross energy available	Remarks	Reference No.
	LEGUMES AND NUTS—Continued															
	Ground nuts or Peanuts (*Arachis hypogaea*):															
259	Peanuts*	Peanuts, Japanese persimmons, tomatoes, granose (a wheat preparation), olive oil, milk.	*Kg.* WSM 56	*Gm.* 1.7	*Cal.* 50.6	*Pct.* 74	*Pct.* 84	*Pct.* 9	*Pct.* 50	*Pct.* [1]87.4	*Pct.* [1]88.3	*Pct.*	*Pct.*	*Pct.*	Subject, man, 60 yr. old. Accustomed to diet of fruit and vegetables. Experimental period, 4 days. Marker, charcoal. Subject in positive N-balance, averaging +3.9 gm. per day for the 2 experiments.	75
		Peanuts, apples, dates, tomatoes, olive oil, granose, milk.	WSM 58	1.3	52.4	73	79	5	38	[1]75.6	[1]81.4					
260	Peanuts, skins removed.	Peanuts, half kernels, salted and cooked 2 hr. under 15 lb. pressure, until very soft. Eaten in a simple mixed diet of bread, butter, sugar, oranges, tea or coffee. Average daily intake: 92 gm. protein, 162 gm. fat, 354 gm. carbohydrate, 3,240 calories.	JFC							92.7					Subjects, men, 19–41 yr. old. Experimental period, 3 days. Large intake of peanuts caused no digestive disturbance.	72
			JJD							94.0						
			TBH							89.7						
			FAK							95.9						
			PK							90.0						
			WO'C							94.4						
			Av.							92.8						
261	Peanut flour,* partially defatted. Prepared by McMath Howard process.	Peanut flour added to biscuit mix and baked. Eaten in a simple mixed basal diet.[19] Distribution of calories in basal diet was about 3 pct. from protein, 62 pct. from carbohydrate, and 35 pct. from fat.	*Av.* 69	.4	42.8	96				[1]77.9					Subjects, 9 men and women, 21–28 yr. old. Peanut flour one of several protein foods tested in series of 15 periods, from 4 to 7 days each. Peanut flour used in 14th period of 6 days; was preceded by wheat gluten period of 5 days, during which subjects were in slightly negative N-balance. They continued in negative N-balance during peanut flour period; averaging −0.1 gm. N per day. Marker, carmine or ferric oxide. Urines collected for 7 days, analyzed for last 3 days.	64
262	Peanut flour. Fat removed by cold expression. Red skins not removed. Resulting press cake ground.	Baking powder biscuits made from equal parts of peanut and wheat patent flours; fruit, butter, sugar. Average daily intake: 106 gm. protein, 117 gm. fat, 224 gm. carbohydrate, 2,370 calories.	PK			62				[1]92.2					Subjects, 4 men, 20–40 yr. old. Experimental period, 3 days. No attempt made to maintain uniform weight or N-balance of subjects.	70
			JCM			61				[1]90.3						
			AAR			61				[1]90.0						
			WET			60				[1]93.3						
			Av.			61				91.4						
263	Peanut flour. Peanuts blanched, roasted, red skins and fat removed. Resulting press cake ground.	Baking powder biscuits made from 1 part peanut flour and 2 parts wheat patent flour, fruit, butter, sugar. Average daily intake in 1st 3 experiments was 54 gm. protein, 79 gm. fat, 280 gm. carbohydrate, 2,050 calories. In remaining 4 experiments average daily intake was 102 gm. protein, 94 gm. fat, 374 gm. carbohydrate, 2,745 calories.	PK			42				[1]100						
			JCM			41				[1]83.2						
			CJW			41				[1]68.2						
			AAF			42				[1]99.7						
			PK			42				[1]93.7						
			JCM			42				[1]99.7						
			CJW			42				[1]94.9						
			Av.			42				91.3						

	Tree Nuts:															
264	Almonds* (*Prunus amygdalus*).	Almonds, bananas	CPH 63	.6	29.7	54	96	10	44	[1] 57.1	[1] 84.5				Subjects (CPH and WSM) men 60 yr. old, accustomed to fruitarian and vegetarian diets; subject AV, young man. CPH ate 2 meals per day; the others, 3. Experimental period, 4 days. Marker, charcoal. On 3 almond diets, CPH showed average daily N-balance of −0.9, +0.2, and +4.1 gm.; on brazil nut diet, −0.8 gm. AV on almond diet, −0.4 gm. WSM in positive N-balance, +2.4 and +3.6 gm. per day on the 2 brazil nut diets.	75
		Almonds, apples	CPH 64	.7	33.5	83	94	25	69	[1] 72.2	[1] 88.1					
		Almonds, apples, bananas	CPH 64	1.1	50.4	81	97	27	71	[1] 78.7	[1] 91.9					
		Almonds, bananas, oranges	AV 69	1.3	55.0	49	96	11	45	[1] 61.4	[1] 83.4					
			Av. 65	.9	42.2	67	96	18	57	67.4	87.0					
265	Brazil nuts* (*Bertholletia excelsa*).	Brazil nuts, grapes (mainly cornichon), small amounts of honey, milk, and olive oil.	WSM 56	.9	44.2	79	95	9	63	[1] 83.8	[1] 91.4					
		Brazil nuts, grapes (mainly cornichon), granose, small amounts of tomatoes, milk, and olive oil.	WSM 56	1.2	49.9	35	88	3	30		[1] 83.5					
266	Brazil nuts*	Brazil nuts, apples, bananas	CPH 64	.6	33.4	59	90	4	46	[1] 68.7	[1] 91.6					
267	Chestnuts,* fresh (*Castanea sativa*): (a) Flakes, raw	500 gm. raw chestnut flakes, 68 gm. dried egg, 125 gm. butter, 188 gm. fried beef. Average daily intake: 12.1 gm. N, 124 gm. fat, 193 gm. carbohydrate.				36	6	99		[1] 67.8		[1] 98.0			6 experiments: 2 on raw chestnut flakes, 2 days each; 3 on peeled boiled chestnuts, 3 days each; 1 on roasted chestnuts, 3 days. Marker, carmine. Because carbohydrate in feces was reported as reducing substance, the coefficient of digestibility of carbohydrate may be somewhat in error.	67
						36	6	99		[1] 73.0		[1] 99.0				
	(b) Peeled, boiled	833 gm. peeled boiled chestnuts used in thick soup. In 1st two experiments 33 gm. sugar and 33 gm. butter added. Average daily intake: 7.2 gm. N, 40 gm. fat, 353 gm. carbohydrate. In 3d experiment, 100 gm. sugar and 85 gm. butter added; average daily intake: 7.3 gm. N, 83 gm. fat, 420 gm. carbohydrate.				99	29	91		[1] 72.5		[1] 98.8				
						99	29	91		[1] 70.6		[1] 98.2				
						99	14	76		[1] 79.2		[1] 99.9				
	(c) Roasted	600 gm. roasted chestnuts, 55 gm. butter, 117 gm. white bread. Average daily intake: 6.6 gm. N, 55 gm. fat, 296 gm. carbohydrate.				79	15	78		[1] 73.5		[1] 96.5				
268	Chestnut flour* (*Castanea dentata*).	Chestnut flour, bread, potatoes, milk (whole and skim), sugar.	ERM 62	1.6	47.6	19	55	45	40	[1] 51.2	[1] 57.5	[1] 98.1	[1] 89.2	[2] 88.2	Subjects, young adults, 23–34 yr. old. Experimental period, 3 days. During this period ERM lost 2¼ lb.; HAM, 1½ lb.	120
			HAM 59	1.7	50.0	19	55	46	40	[1] 78.7	[1] 75.6	[1] 99.6	[1] 95.3	[2] 93.8		
269	Coconuts,* (*Cocos nucifera*).	Coconut, pears, with small amounts of cottage cheese, tomatoes, and olive oil.	WSM 57	.6	56.6	36	83	14	45		[1] 91.5				See remarks, item 264. Subject WSM on coconut diet in negative N-balance, averaging −1.6 gm. per day. Both subjects on pecan diet in negative N-balance. WSM averaged −0.05 gm. per day; CPH averaged −3.3, −3.1, −1.7 and −2.4 gm. per day for the 4 experiments, respectively. On walnut diets, WSM in positive N-balance, averaging +2.3 gm. per day; CPH in slightly negative N-balance during 1st 2 experiments, averaging −0.3 gm., and in positive N-balance during last 2 experiments, averaging +2.5 gm. per day. JER in negative N-balance, averaging −1.9 gm. per day.	75
270	Pecans,* (*Carya illinoensis*).	Pecans, apples, dates, with small amounts of granose (a wheat preparation) and cottage cheese.	WSM 59	.8	56.0	49	96	2	35	[1] 66.0	[1] 91.6					
		Pecans, apples, bananas	CPH 64	.6	32.3	50	92	3	43	[1] 54.1	[1] 88.0					
		Pecans, apples, bananas, granose	CPH 65	.7	30.8	29	94	2	33		[1] 80.9					
		Pecans, oranges, bananas	CPH 65	.6	30.9	57	98	5	55	[1] 59.9	[1] 90.0					
		Pecans, oranges, bananas, granose	CPH 64	.8	33.7	23	92	2	26		[1] 81.6					
271	Walnuts* (presumably Persian or English). (*Juglans regia.*)	Walnuts, grapes, granose	WSM 56	1.0	40.8	78	92	5	55	[1] 78.5	[1] 89.5					
		Walnuts, pears, with small amounts of granose and milk.	WSM 57	1.3	55.0	66	91	3	45	[1] 83.6	[1] 91.4					
		Walnuts, apples, dried figs, with small amounts of granose and milk.	WSM 58	1.1	51.9	63	94	3	40	[1] 62.3	[1] 88.0					
		Walnuts and bananas	CPH 63	.7	26.6	62	97	3	46	[1] 70.3	[1] 84.6					
		Walnuts and apples	CPH 63	.7	26.6	62	94	9	69	[1] 58.9	[1] 82.8					
		Walnuts, apples, bananas	CPH 64	.8	34.1	70	93	4	51	[1] 70.2	[1] 90.2					
		Walnuts, dried prunes, oranges	CPH 66	.7	32.7	73	97	3	47	[1] 82.8	[1] 88.3					
		Walnuts, bananas, dates, small amount of sugar.	JER 77	.6	28.3	69	98	3	43	[1] 62.6	[1] 75.5					
		Walnuts, bananas, oranges, small amount of sugar.	JER 75	.6	25.4	67	97	4	50	[1] 64.5	[1] 73.8					

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.
[2] Calculated from author's data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[n] Basal diet included butter, sirup, biscuit mix with arrowroot starch, lettuce (iceberg heart leaves), carrot, pickle, french dressing, orangeade (artificial), applesauce, vitamin supplements (all vitamins), coffee, kola-type beverage.
*Indicates that composition, and in some cases also heat of combustion was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight		Proportion of total intake supplied by test food				Coefficient of apparent digestibility of test food				Portion of gross energy available	Remarks	Reference No.
					Protein	Gross energy	Protein	Fat	Carbohydrate	Gross energy	Protein	Fat	Carbohydrate	Energy			
	VEGETABLES, VEGETABLE PRODUCTS																
	Arrowroot starch (see items 316, 317).																
				Kg.	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
272	Beans, snap* (*Phaseolus vulgaris*).	Snap beans, cooked,[40] rewarmed 30 min. in steam bath before eating; bread, butter, milk.	1								26		[3] 77.6			Subjects, 2. 3-day preliminary and 2-day collection period.	57
			2								59		[3] 91.4				
273	Beans, green (presumably snap beans).	540 gm. beans, 53 gm. butter. Daily intake: 8.8 gm. protein.	A								49.1		84.6			Subject, 1 man. Experimental period, 2 days.	145
274	Beets* (*Beta vulgaris*)	Beets in mixed diet of meat, bread, butter, milk, sugar.	B	66	1.0	33.7	18	3	32	20	[80.1]		[96.4]	93.9	[3] 91.0	Subjects, 3 men, ages 28–33 yr. Preliminary period on basal diet 3 days, followed by experimental period of 3 days when test food was added to basal ration (except for subject M, on beet experiment 1 day plus 2 meals). Subjects varied in total amounts of basal ration eaten but proportions of foods kept constant. Marker, lampblack. Urine collected for last 24 hr. of experimental period. B and W in positive N-balance in beet experiment, +0.1 and +7.3 gm. per day, respectively. In cabbage experiment, B averaged −2.6 gm.; M, +1.4 gm.; W, +5.2 gm. N per day.	33
275	Beets*	Beets in mixed diet of meat, bread, butter, milk, sugar.	M	74	1.4	41.7	8	1	11	7	56.2		[96.5]	78.6	[3] 76.0		
			W	53	2.5	66.2	17	1	26	16	[87.3]		97.2	96.6	[3] 92.3		
276	Cabbage* (*Brassica oleracea* var. *capitata*).	Cabbage in mixed diet of meat, bread, butter, milk, sugar.	B	66	1.0	31.0	10	3	10	8	[41.8]		77.2	59.1	[3] 57.0		
277	Cabbage*	Cabbage in mixed diet of meat, bread, butter, milk, sugar.	M	74	1.1	36.2	9	2	8	6	63.8		[85.6]	[76.7]	[3] 73.0		
278	Cabbage*	Cabbage in mixed diet of meat, bread, butter, milk, sugar.	W	53	1.8	42.8	7	1	11	7			80.8	42.8			
279	Cabbage	Cabbage, cooked,[40] rewarmed 30 min. in steam bath before eaten; bread, butter, milk.	1								48		[3] 68.7			Subjects, 2. 3-day preliminary and 2-day collection period.	57
			2								39		[3] 81.2				
280	Cabbage, savoy*	8.4 lb. cabbage boiled with salt and 65.5 gm. fat for ½ hr. Average daily intake: 13.2 gm. N, 87.5 gm. fat, and 247 gm. carbohydrate.	F				100	25	100		81.5		84.6			Subject, 1 man. Experimental period, 3 days. Milk, taken before and after experimental period, served as fecal marker. Subject in negative N-balance, −6.9 gm. per day.	144
	Canna starch (see item 318).																
281	Carrots* (*Daucus carota*)	555 gm. carrots, 60 gm. soy sauce	DK										95.2			Subject, 1 man. Experimental period, 1 day. Good separation of feces by use of buckwheat flour and raw red adzuke beans.	134
282	Carrots*	5.6 lb. carrots cooked with 42 gm. fat and salt. Average daily intake of 2.5 gm. N, 45 gm. fat, 282 gm. carbohydrate.	F				100	11	100		61.0		81.8			Subject, 1 man. Experimental period, 2 days. Milk, taken after each experimental period, served as fecal marker. Subject nauseated after 2d day and experiment terminated. In negative N-balance, −8.6 gm. N per day.	144

	Cassava starch (see item 319).															
283	Collards* (*Brassica oleracea* var. *acephala*).	Collards, cooked,[40] rewarmed 30 min. in a steam bath before eaten; bread, butter, milk.	1								66		[9] 53.3			Subjects, 2. 3-day preliminary and 2-day collection period.	57
			2								72						
284	Corn, green* (*Zea mays*)	Corn in a mixed diet of meat, bread, butter, milk, sugar.	W	53	2.3	56.4	24	9	29	22	83.9		96.6	[86.9]	[3] 82.3	See remarks, item 274	33
285	Mushrooms	887 gm. mushrooms combined with small amounts of Liebig extract, curry powder, salt and butter.	A	90	.5		100				69.2					Subject, healthy man; 31 yr. old. Experimental period, 2 days. Preperiod and postperiod on milk diet, used as fecal marker. Fecal separation described as very complete.	152
286	Potatoes, white* (*Solanum tuberosum*).	Potatoes in mixed diet of meat, bread, butter, milk, sugar.	B	66	1.2	36.8	19	1	38	24	[98.4]		99.9	98.9	[3] 95.7	See remarks, item 274. Subjects in positive N-balance while on potato experiments, averaging +0.6 gm. per day. Subject W on experimental diet 4 days.	33
287	Potatoes, white*	Potatoes in mixed diet of meat, bread, butter, milk, sugar.	M	74	1.4	43.4	14	1	27	17	78.5		[98.9]	96.2	[3] 93.7		
288	Potatoes, white*	Potatoes in mixed diet of meat, bread, butter, milk, sugar.	W	53	1.7	44.6	13	3	31	20	47.4		98.0	85.6	[3] 84.1		
289	Potatoes, white	Potatoes (steamed unpeeled, fried, mashed, or in salad with a little oil), butter or pork fat, a few fruits (apples, pears), tea or black coffee and sugar taken occasionally. Fat intake varied from 120-150 gm. daily. Average daily N intake: Subject A, 5.7 gm., subject B, 3.8 gm.	A	64	.5		100				[37] 69.6					Subjects: A, 25-yr.-old man; B, 28-yr.-old woman. Experimental diet continued for 167 days. 4 collection periods during this time, each of 4 days except the 4th for subject A, which was 6 days. Both fecal and urinary N determined. N-balance positive for A in all periods, averaging +0.6 gm. per day, and for B in 4th collection period, averaging +0.1 gm. per day; negative for B during 1st 3 periods, averaging −1.0 gm. N per day. Body weight remained nearly constant.	83
			A	62	.6		100				[37] 63.5						
			A	63	.6		100				[37] 66.2						
			A	61	.6		100				[37] 65.4						
			Av.	62	.6		100				66.2						
			B	63	.3		100				[37] 48.0						
			B	63	.4		100				[37] 67.4						
			B	62	.4		100				[37] 59.2						
			B	61	.4		100				[37] 75.1						
			Av.	62	.4		100				62.4						
290	Potatoes, white	1,587 gm. potatoes, 8 eggs (hard-boiled), 710 cc. milk, 237 cc. cream.		62	1.8	40.5	33	1	89	48	71.9		93.0	[41] 83.6	[42] 81.2	Subject, 22-yr.-old man. 3-day preliminary period on experimental diet followed by experimental period of 4½ days with 13 meals. Marker, charcoal, taken at beginning and end of experimental period. Subject in positive N-balance.	162
291	Potatoes, white*	Potatoes, eaten boiled with salt or butter or in salad with vinegar and oil, or sliced and fried. Average daily intake of 6¾ lb. potatoes, peeled, supplying about 72 gm. protein and 718 gm. carbohydrate; oil and butter, about 144 gm. fat.	E	72	1.0		100		100		67.8		92.3			Subject, active 23-yr.-old man accustomed to a high potato diet. Experimental period, 3 days. Marker, milk, taken at beginning and end of experimental period. In negative N-balance, averaging −1.0 gm. per day.	144
292	Potatoes, white*	1,700 gm. potatoes, cooked in water and pureed; 100 gm. butterfat, 12 gm. salt, 500 cc. beer.		74	.6		91		93		80.5		[9] 99.0			Subject, 1 man. Experimental period, 3 days. Marker, milk taken at beginning and end of experimental period.	42

[3] Calculated from authors' data allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[9] Calculated from author's data for N-free extract and crude fiber.

[37] Calculated from authors' data.

[40] Cooked approximately 30 min., or until tender, seasoned with salt, "sterilized" in fruit jars in a steam oven for 1 hr., and stored until needed.

[41] Based on gross calories of foods and feces, as calculated from their composition by applying the factors 5.5 calories per gram protein, 9.3 calories per gram fat, and 4.1 calories per gram carbohydrate.

[42] Calculated from author's data, using author's estimated gross calories (see footnote 41) and allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

*Indicates that composition, and in some cases also heat of combustion, was reported by the author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight		Daily intake per kilogram body weight		Proportion of total intake supplied by test food				Coefficient of apparent digestibility of test food				Portion of gross energy available	Remarks	Reference No.
					Protein	Gross energy	Protein	Fat	Carbohydrate	Gross energy	Protein	Fat	Carbohydrate	energy			
	VEGETABLES, VEGETABLE PRODUCTS—Continued			*Kg.*	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
293	Potatoes, white*	1,120 gm. potatoes, 90 gm. shoyu (soya sauce). Intake: 21.4 gm. protein, 0.7 gm. fat, 194 gm. carbohydrate.	KY						100				91.5			Subject, 1 man. Experimental period, 1 day. Marker, whole buckwheat flour and red pepper skin, presoaked to extract the irritating principle. Author disregarded nutrients from shoyu in making calculations of digestibility. Study by S. Kano and S. Iishima in (*134, pp. 168, 171*).	134
294	Potatoes, white*	Potatoes, boiled and eaten with butter, also served fried. Cooking water used as soup. Fat and sometimes onions added to diet. Average daily intake: 47 gm. protein, 3,560 calories.	M	74	0.6	46.8	100		100	65	84.5		99.3	[37] 97.3	[3] 95.1	Subjects, strong, healthy men. Ages: M, 26 yr.; VM, 20; H, 50. On potato diet over 9-mo. period except for short periods when low-N foods were added for variety. 1st 6 mo. under conditions of moderate activity: M, 3 collection periods of 36, 8, and 18 days; VM, 3 collection periods of 13, 8, and 6 days; H, 2 collection periods of 12 and 16 days. 3 mo. under conditions of strenuous activity: M on potato diet with 95-day collection period. Subjects showed following N-balances during collection periods: M: 36-day period, −0.5 gm.; 8-day period, +1.9 gm.; 18-day period, −0.7 gm.; 95-day period, −0.4 gm. VM: 13-day period, −0.2 gm.; 8-day period, +0.5 gm.; 6-day period, +2.4 gm. H: 12-day period, −0.9 gm.; 16-day period, −0.4 gm.	69
295	Potatoes, white*	See diet for item 294, average daily intake: 51 gm. protein, 3,510 calories.	M	73	.7	48.1	100		100	64	82.0		98.6	[37] 96.4	[3] 94.0		
296	Potatoes, white*	See diet for item 294. Average daily intake: 33 gm. protein, 3,610 calories.	M	73	.5	49.4	100		100	66	84.1		99.2	[37] 97.8	[3] 96.4		
297	Potatoes, white*	See diet for item 294. Average daily intake: 41 gm. protein, 3,300 calories.	VM				100		100	63	81.1		98.9	[37] 96.6	[3] 94.6		
298	Potatoes, white*	See diet for item 294. Average daily intake: 50 gm. protein, 3,440 calories.	VM				100		100	64	85.5		98.7	[37] 96.7	[3] 94.4		
299	Potatoes, white*	See diet for item 294. Average daily intake: 51 gm. protein, 3,800 calories.	VM				100		100	59	83.5		98.7	[37] 96.3	[3] 93.9		
300	Potatoes, white*	See diet for item 294. Average daily intake: 18 gm. protein, 2,450 calories.	H	65	.3	37.7	100		100	59	74.5		99.0	[37] 96.9	[3] 95.8		
301	Potatoes, white*	See diet for item 294. Average daily intake: 19 gm. protein, 2,650 calories.	H	65	.3	40.8	100		100	56	70.9		98.9	[37] 96.4	[3] 95.3		
302	Potatoes, white*	See diet for item 294. Average daily intake: 53 gm. protein, 4,900 calories.	M	72	.7	68.1	100		100	64	85.4		99.3	[37] 98.0	[3] 96.2		
303	Potatoes, white	1,430 gm. potatoes, 56 gm. butter, 34 gm. sugar and 10 gm. agar agar.		50	.6		99.9				73.6					Subject, healthy young woman. Experimental period, 10 days. In N-equilibrium during last 7 days. Feces and urine collected daily.	142
304	Potatoes, white, mixture of new and old.	Daily intake, 1,363 gm. new and 1,076 gm. old potatoes, eaten partly as mashed, partly as boiled, 20 gm. butter, 10 gm. salt, supplying 2,076 calories and 7.29 gm. N.					100		100	100	84.6			94.4	92.1	Details of method not reported.	148
305	Potatoes, white, new	Daily intake, 2,756 gm. peeled boiled new potatoes, 20 gm. butter, 10 gm. salt supplying 2,294 calories.					100		100	100	85.2			96.0	93.6		

306	Potatoes, white	2,618 gm. boiled peeled potatoes eaten daily with a little salt.	M	78	.7	34.4	100	100	100	100	72.1			93.4		Subject, a strong muscular man. Experimental period, 6 days. No other details given.	151
307	Potato starch	Frozen pudding (raw potato starch, milk, oil, sugar, salt, flavoring); oranges, sugar, tea and coffee as desired. Average daily intake: 23 gm. protein, 76 gm. fat, 357 gm. carbohydrate. 2,210 calories. 194 gm. starch eaten daily.	HLG						58				74.5			Subjects, men. Experimental period, 3 days. Authors followed their usual experimental procedure published in earlier reports. Assumed about 96.5 percent digestibility for carbohydrate of the other foods in diet. Subjects noted excessive gas formation and frequent intestinal cramps.	91
			ELM						55				74.3				
			PC						45				64.3				
			WVD						54				91.3				
			HLG						60				85.4				
			ELM						58				62.3				
			JFS						49				95.2				
			Av.						54				78.2				
308	Potato starch	Frozen pudding (21 pct. raw potato starch, 63 pct. milk, 8.7 pct. peanut oil, 7.3 pct. sucrose); fruit juices, tea and coffee as desired. Average daily intake: 1,281 gm. of the starch diet of which 269 gm. were potato starch. Composition of diet essentially same as that for item 307.	JB										75.8			Subjects, 10 men. Marker, carmine, taken with 1st and last meal of experimental period. Greater flatulence and cramplike pains experienced when pudding was frozen, also less undigested starch in feces. Authors of opinion that bacterial fermentation accounted for decomposition of much of the starch during passage through alimentary tract. Readjustment period of 1 mo. for each subject between experiments.	24
			JJ										76.4				
			RM										60.8				
			HG										75.8				
			RB										81.5				
			Av.										74.1				
		Diet same as preceding diet except it was not frozen.	JB										61.8				
			JJ										57.8				
			RM										47.0				
			HG										57.5				
			RB										72.0				
			Av.										59.2				
309	Potato starch	Frozen pudding, oranges, sugar, tea and coffee if desired (see diet, item 307). Average daily intake: 17 gm. protein, 40 gm. fat, 212 gm. carbohydrate, 1,280 calories. 59 gm. starch eaten daily.	CJG										99.7			Subjects, young men. Experimental period, 3 days. Marker, carmine with lampblack to mark feces in following period of 3-4 days on subjects' regular diet.	92
			ELM										94.5				
310	Potato starch	Frozen pudding, oranges, sugar, tea and coffee as desired (see diet, item 307). Average daily intake: 20 gm. protein, 37 gm. fat, 230 gm. carbohydrate, 1,330 calories. 68 gm. raw potato starch eaten daily.	ATM						24				([27])			Subjects, women. Experimental period, 3 days. Marker, carmine with lampblack to mark feces in following period of 3-4 days on subjects' regular diet.	97
			CM						36				79.4				
			RLP						27				94.5				
			EM						35				49.2				
311	Pumpkin* (*Cucurbita pepo*).	1,692 gm. pumpkin, 90 gm. shoyu (soy sauce).	KY	45	.8						88.7	66.5	98.5			Subjects, 2 men: KY, 50 yr.-old; KK, 30. Satisfactory separation of feces with marker of whole buckwheat flour with black husk in pumpkin experiment and black sesame seed in sweetpotato experiment. Author disregarded nutrients from shoyu in making calculations of digestibility. Pumpkin study by S. Kano and S. Ushima, *pp. 168, 171*, and sweetpotato study by Y. Kaji, *pp. 173, 174*, in *184*).	134
312	Sweetpotatoes (*Ipomoea batatas*), partially dried.	Sweetpotatoes, skins removed, cooked with soy sauce.	KY	45	1.1						57.1		97.6				
			KK	46	1.2						51.6		98.5				
313	Taro, dasheen (*Colocasia esculenta*), immature, harvested 6 wk. before usual harvesting time.	Dasheens, parboiled, baked, skins removed, riced. Eaten with milk, fruit, butter, and tea or coffee. Average daily intake: 40 gm. protein, 128 gm. fat, 229 gm. carbohydrate.	AJH				23	.5	74				[1] 96.6			Subjects, strong, healthy men. Ages, 20-40 yr. Experimental period, 3 days. Marker, lampblack. No attempt made to maintain a uniform body weight and no record of weight kept.	95
			PK				25	1	69		[1] 74.4		([1] [28])				
			HRG				33	1	76		[1] 30.6		[1] 98.0				
			AJH				25	.5	73		[1] 28.9		[1] 95.6				
			PK				32	1	71		[1] 62.0		([1] [28])				
			CJW				35	1	72		[1] 50.7		[1] 99.2				
314	Taro, dasheen, mature	See diet, item 313. Average daily intake: 41 gm. protein, 129 gm. fat, 231 gm. carbohydrate.	HRG				25	1	67		[1] 29.5		[1] 98.0				
			AJH				25	1	72		[1] 58.6		([1] [28])				
			PK				31	1	71		[1] 70.3		([1] [28])				
			CJW				30	1	68		[1] 20.5		[1] 96.2				

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.

[2] Calculated from author's data, allowing a urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.

[27] Calculated from author's data.

[28] Value higher than 100 percent; omitted here.

*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

TABLE 23.—*Apparent digestibility and available energy of foods of plant origin for human subjects*—Continued

Item No.	Test food, description	Diet	Subject and weight	Daily intake per kilogram body weight: Protein	Daily intake per kilogram body weight: Gross energy	Proportion of total intake supplied by test food: Protein	Proportion of total intake supplied by test food: Fat	Proportion of total intake supplied by test food: Carbohydrate	Proportion of total intake supplied by test food: Gross energy	Coefficient of apparent digestibility of test food: Protein	Coefficient of apparent digestibility of test food: Fat	Coefficient of apparent digestibility of test food: Carbohydrate	Coefficient of apparent digestibility of test food: energy	Portion of gross energy available	Remarks	Reference No.
	VEGETABLES, VEGETABLE PRODUCTS—Continued															
			Kg.	*Gm.*	*Cal.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
315	Taro starch, granules extremely small, 1-7 microns.	Frozen pudding, oranges, sugar, tea and coffee as desired. (See diet, item 307.) Average intake: 19 gm. protein, 47 gm. fat, 271 gm. carbohydrate, 1,580 calories.	HJD									98.1				
			HLG									99.5				
	Vegetable starch, other:															
316	Arrowroot, true (*Maranta arundinacea*). Granules measured 22-53 microns.	See diet, item 307. Average daily intake: 17 gm. protein, 56 gm. fat, 265 gm. carbohydrate, 1,640 calories. 124 gm. raw arrowroot starch eaten daily.	HJD									92.1				
			ELM									99.3				
317	Arrowroot, so-called commercial (*Zamia floridana*). Granules, 42-70 microns.	See diet, item 307. Average daily intake: 19 gm. protein, 58 gm. fat, 297 gm. carbohydrate, 1,790 calories. 68 gm. raw arrowroot starch eaten daily.	HLG									82.5			Subjects, young men. For experimental details see remarks, item 309. Authors noted a direct relationship between size of starch granules and digestibility, the starches having larger granules being less digestible.	92
			ELM									65.7				
			JFS									99.3				
318	Canna, Hawaiian (*Canna edulis*). Granules 42-95 microns.	See diet, item 307. Average daily intake: 22 gm. protein, 80 gm. fat, 248 gm. carbohydrate, 1,800 calories. 109 gm. raw canna starch eaten daily.	HJD									43.0				
			HLG									56.5				
			ELM									60.3				
319	Cassava (*Manihot esculenta*) commercial product. Granules much smaller than those of potato and arrowroot and somewhat smaller than wheat or maize starch.	See diet, item 307. Average daily intake: 18 gm. protein, 48 gm. fat, 246 gm. carbohydrate, 1,490 calories. 140 gm. raw cassava starch eaten daily.	PHC									97.9				
			HLG									98.4				
			JFS									100.0				
320	Treefern, Hawaiian (*Cibotium menziesii*). Granules about 9 microns.	See diet, item 307. Average daily intake: 23 gm. protein, 71 gm. fat, 314 gm. carbohydrate, 1,990 calories. 150 gm. raw treefern starch eaten daily.	HLG									90.2				
			ELM									96.5				
	FRUITS															
321	Applesauce (*Malus sylvestris*).	Applesauce (sugar added) with a mixed diet of meat, bread, butter, milk, sugar.	B 66	0.9	42.5	6	9	57	37	[29.0]		99.2	97.6		For experimental details see remarks, item 274. B in slightly negative N-balance, −0.01 gm., and W in positive N-balance, +0.7 gm. per day.	33
			W 53	1.8	63.4	2	1	47	28	28.4		99.6				
322	Bananas,* common (*Musa paradisiaca* var. *sapientum*).	Bananas	CPH 62	.4	20.6	100	100	100	100	76.1	18.9	[1] 96.8	92.3	[2] 89.8	Experimental period for CPH, 3 days; for WSM, 4 days. For other experimental details see remarks, item 264. Both subjects in negative N-balance. Average for CPH, −1.3 gm.; for WSM, −3.7 gm. N per day.	75
323	Grapes* (*Vitis spp.*), mixture of Tokay, Muscat, and Cornichon.	Grapes (4,835 gm. Tokay, 649 gm. Muscat, 4,305 gm. Cornichon) eaten with small amounts of olive oil, tomatoes, and olives.	WSM 56	.2	21.9	94	16	99	84	44.5		[1] 94.4	[1] 85.0	[2] 84.3		
	MISCELLANEOUS															
	Cocoa (Theobroma cacao):															
324	Commercial	115 gm. cocoa, 50 gm. sugar, 175 gm. white bread, 200 gm. meat, 20 gm. butter. Daily intake: 14 gm. N, 54 gm. fat, 211 gm. carbohydrate.	HC			25	70	7		27.9	95.4				Subject, the author. Experimental period, 4 days. Average N-balance, −1.7 gm. per day.	41

325	Partially defatted	195 gm. cocoa, cooked with water; beer or wine. Daily intake: 6.4 gm. N, 53.2 gm. fat, 40.2 gm. carbohydrate.	HW	...			100				[4] 12.7					Subject, 1 man. Experiment, 2 days. Data from Weigmann in (*84, p. 244*).	84
326	3 kinds, 2 from Holland	188 to 304 gm. cocoa and 165 to 212 gm. sugar, cooked with water.	...	65			100				41.1	96.1				Subject, 1 man. Data from Lebbin in (*84, p. 245*).	84
			...	65			100				45.2	97.2					
			...	65			100				41.6	96.7					
327	Cocoa	20 gm. cocoa, milk (2-3 cups yield)									83.9	100.0				Subjects, men. Experiment usually continued 1 wk.	56
		60 gm. cocoa, milk (8 cups yield)									77.4	93.9					
	Yeast:																
328	Brewer's	Yeast added to basal ration of butter, french dressing, lettuce, sugar, marmalade, biscuit (arrowroot starch), orangeade (artificial), candy, coffee, tea, kola drink, omelet, oil, applesauce, supplements of vitamins and minerals. Daily intake: 3.7 gm. N. Estimated calorie intake, about 3,000 (*124*, p. 535).					(95)				[1] 57.1					Subjects, 11 men. 3-day period on a "no-protein" diet (the mixed basal diet with egg omitted) followed by 5-day experimental period in which yeast was added to diet. Urine collected in last 2 or 3 days of each period. In 5-day period following yeast period an amino acid mixture replaced yeast protein in the total diet. Average N-balance for "no-protein" diet period, −3.4 gm. and for yeast period, −1.0 gm. per day. 5 pct. of total N intake as approximate amount of N from other foods for calculating apparent digestibility of yeast.	125
329	Dried (anerobic yeast preparation).	Yeast eaten in mixed diet of apples, bananas, oranges, tomatoes (or soup), sauerkraut, onions, bread, rice, teabiscuit, sugar, chocolate, butter, tea. (Not all food items eaten every day.)	1	78			(79)				[1] 77.1					Subjects, 4 men, ages 20-38 yr. Experimental period, 11-13 days. Marker, charcoal, taken at beginning of period. Yeast period followed by period on diet of white rice, white bread, and butter. Feces from this period changed from brown to light yellow, serving as marker for end of yeast period. Subjects in negative N-balance.	59
			2	68			(80)				[1] 74.8						
			3	66			(83)				[1] 61.7						
			4	64			(81)				[1] 58.5						
330	Yeast,* dried, color somewhat yellow, acceptable flavor.	Preperiod: 36 gm. dried milk, 8 gm. cocoa, 120 gm. zweiback, 90 gm. cakes, 50 gm. butter, 60 gm. salami, 38 gm. cheese, 76 gm. marmalade, 66 gm. sugar, 50 gm. dried soup, 40 gm. tomato pulp. Yeast period: 59 gm. dried yeast replaced salami and cheese in diet above.	Pü	65	1.1	40.4	40			10	86.4			85.7		Dry yeast series: preperiod, 5 or 8 days followed by yeast period, 4 days and postperiod, 3 or 4 days. Fresh yeast series: preperiod, 6 days, yeast period, 4 days. Marker, carmine. Urine collection began 3d day of preperiod, continued through yeast and postperiod. Pü in positive N-balance in both series. K in positive N-balance in dried yeast series but in slight negative N-balance in fresh yeast series. Pe was in slight negative N-balance.	87
			K	62	1.1	42.2	40			10	94.4			92.4			
331	Yeast,* fresh compressed	Preperiod diet same as for item 330, except for minor changes in amounts of several foods. Yeast period: 144-153 gm. fresh yeast replaced salami and cheese in diet above.	Pü	64	1.0	38.7	35			8	47.7			34.1			
			K	62	1.0	39.5	35			8	57.8			43.6			
			Pe	68	1.0	41.8	33			8	52.0			33.6			

[1] Calculated from authors' data using coefficients of digestibility for foods in remainder of diet as shown in table 13, p. 25.
[3] Calculated from author's data, allowing urinary loss of 1.25 calories per gram of digested protein as shown in table 13, p. 25.
[5] Calculated from author's data for N-free extract and crude fiber.
[41] Calculated from data in article. Author reported 41.5 percent after correction for metabolic nitrogen.
*Indicates that composition, and in some cases also heat of combustion, was reported by author. See table 24.

Composition and Heat of Combustion of Foods

Composition and heat of combustion data are recorded in table 24 for test foods used in digestion experiments described in table 23 whenever such data were reported. Composition data are useful in identification of a food item and in interpretation of experimental results in digestion experiments in which that item is used.

For ease in using the data the test foods with composition reported carry the same item number in both tables 23 and 24. The composition data are recorded as reported by the authors and the factors they used for converting nitrogen to protein are noted in footnotes. More complete description of the food items is given in table 23.

TABLE 24.—*Composition and heat of combustion of food items used in experiments on human digestibility (table 23)*

Test food, description	Water	Protein	Fat	Carbohydrate: Total (by difference)	Carbohydrate: Fiber	Ash	Heat of combustion per gram	Ref. No.
GRAINS, GRAIN PRODUCTS								
Barley Products (*Hordeum vulgare*):	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	
1 Barley, flaked	9.79	[1] 8.87	1.24	79.22	0.77	0.88		62
2 Barley, germinated, flaked	10.18	[1] 10.62	1.21	76.89	1.27	1.10		62
Buckwheat Products (*Fagopyrum esculentum*):								
5 Flour	11.34	[2] 8.13	1.22	77.69		1.62		134
Corn, Corn Products (*Zea mays*):								
8 Hominy	10.96	*9.44	.67	78.61	.37	.32	3.986	120
9 (Hominy), hulled using alkali, steamed	0	[2] 9.96	5.30	76.77	1.51	7.97	4.440	121
	0	[2] 8.92	5.00	77.96	.69	8.12	4.164	
	0	[2] 10.05	5.65	76.67	.78	7.63	4.625	
11 Meal	9.52	[1] 6.87	.65	82.67	.46	.29		62
14 Meal, granulated:								
a	11.79	*8.50	.98	78.25	.46	.48	3.823	120
b	7.77	*8.69	1.92	81.12	.40	.50	4.023	
15 Meal, waxy variety of maize imported from China	10.54	*8.88	4.24	75.04	1.67	1.3		57
16 Meal, white	9.88	*10.63	6.17	71.52	1.83	1.80		97
20 Corn endosperm, toasted, added sugar and salt	7.49	[2] 7.38	1.68	80.38		3.07	3.869	126
Oats, Oat Products (*Avena sativa*):								
25 Rolled oats	8.66	[2] 14.69	6.96	67.89		1.80	4.560	164
27 Rolled oats	11.02	[3] 15.69	7.23	64.23		1.83		126
28 Rolled oats	7.90	[3] 15.10						88
32 Rolled oats, quick-cooking	7.36	[2] 16.13	6.14	68.53	.90	1.84		129
33 Meal, granulated or pinhead	7.51	[1] 12.43	6.31	72.23	1.94	1.52		62
34 Meal	7.35	[1] 13.17	7.53	70.23	1.04	1.72		62
35 Meal, rolled	7.45	[1] 12.21	7.27	71.37	1.15	1.70		62
36 Meal	8.12	[1] 13.25	7.28	69.57	1.12	1.78		62
38 Meal:								
a. Coarsely ground pinhead	15.	[3] 11.70	7.21	64.47	.85	1.62		102
b. Medium ground	15.	[3] 8.60	7.78	67.15	.93	1.47		
Average	15.	10.10	7.50	65.86	.89	1.54		
Rice, Rice Products (*Oryza sativa*):								
49 Polished or white	(12.92)	*8.55	.31	77.89		.33	3.854	167
50 Undescribed	13.50	[4] 8.27	.3	77.26		.67		144
Rye, Rye Products (*Secale cereale*):								
54 Flour No. 18	9.25	*15.48	2.01	71.08		2.18		141
55 Flour III, a comercial flour	11.40	*14.92	1.89	69.82		1.97		141
56 Flour No. 17	10.96	*15.78	1.89	69.47		1.90		141
57 Flour No. 4	9.30	*15.67	1.78	71.38		1.87		141
58 Flour No. 16	10.06	*16.14	1.76	70.30		1.74		141
59 Flour No. 15	11.00	*15.38	1.71	70.22		1.69		141
60 Flour II	11.26	*15.33	1.89	69.84		1.68		141

[1] N × 5.7.
[2] N × 6.25.
[3] N × 5.83.
[4] N × 5.95.
*N-conversion factor not reported.

TABLE 24.—*Composition and heat of combustion of food items used in experiments on human digestibility (table 23)*—Continued

Test food, description	Water	Protein	Fat	Carbohydrate: Total (by difference)	Carbohydrate: Fiber	Ash	Heat of combustion per gram	Ref. No.
GRAINS, GRAIN PRODUCTS—Con.								
Rye, Rye Products (*Secale cereale*)—Con.								
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	
61 Flour, whole grain, most external layer removed	13.0	[3] (8.40)			[5] (2.03)	1.52		99
(Whole-grain Swiss rye before processing)[6]	(13.0)	[3] (8.28)			[5] (1.65)	(1.61)		
64 Flour, flours No. 6 and No. 18 blended in equal amounts	9.16	*12.42	1.30	75.72		1.40		141
65 Flour, finely ground flour commonly used in Wurzburg	11.6	[3] 9.33				1.24		99
66 Flour, flours 0 and III blended in equal amounts	11.32	*10.76	1.38	75.34		1.20		141
71 Flour, made by Steinmetz process from rye of Silesia	(13.0)	[3] (9.62)			[5] (1.57)	(1.18)		99
(Whole-grain rye of Silesia before processing)[7]	13.0	[3] (9.21)			[5] (2.71)	(1.84)		
72 Flour, made by "old process" of milling from Swiss rye	(13.0)	[3] (7.11)			[5] (.66)	(1.10)		99
73 Flour No. 13	11.19	*11.85	1.14	74.78		1.04		141
74 Flour No. 12	11.56	*11.42	1.69	74.37		.96		141
75 Flour, 75 percent yield	14.73	[3] 9.79				.86		99
77 Flour I	11.84	*10.22	1.00	76.13		.81		141
78 Flour No. 10	11.76	*10.81	.97	75.69		.77		141
79 Flour No. 2	12.14	*9.80	.73	76.60		.73		141
80 Flour No. 7	11.87	*9.31	.78	77.42		.62		141
81 Flour No. 6	9.07	*9.35	.59	80.37		.62		141
82 Flour, 62 percent yield	(13.0)	[3] (8.69)			[5] (.67)	(.55)		99
83 Flour 0	11.25	*6.59	.88	80.85		.43		141
84 Flour No. I	12.49	*5.36	.59	81.17		.39		141
85 Branny portion, fraction of 67–85 percent [8]	14.8	*20.2	3.3	58.9	2.9	2.8		30
86 Branny portion, fraction of 67–95 percent [8]	14.8	*18.5	3.4	59.6	4.6	3.7		30
87 Branny portion, fraction of 85–95 percent [8]	14.2	*16.2	3.6	61.1	7.5	4.9		30
Wheat, Wheat Products (*Triticum aestivum*):								
Flours, whole grain and nearly whole grain:								
92 Graham, 100-percent extraction, Scotch Fife, hard spring	8.61	[1] 12.65	2.44	74.58		1.72	4.148	164
(Whole grain before processing)[9]	8.50	[1] 12.65	2.36	74.69		1.80	4.140	
93 Graham, 100-percent extraction, Scotch Fife	13.21	[1] 14.21	2.01	68.56		2.01	3.971	166
(Whole grain before processing)[10]	10.41	[1] 15.50	2.28	69.88		1.93	4.023	
94 Graham, 100-percent extraction	10.51	[2] 14.00	2.52	70.97		2.00	4.004	195
96 Graham, milled from Oregon white winter wheat	8.15	[1] 8.18	1.68	80.27		1.72	3.990	168
(Whole grain before processing)[11]	8.99	[1] 8.32	1.83	79.10		1.76	4.008	
97 Graham, milled from hard winter Weissenburg wheat from Oklahoma	7.73	[1] 15.33	1.79	73.83		1.32	4.178	168
(Whole grain before processing)[12]	8.65	[1] 15.33	1.83	72.87		1.32	4.110	
98 Graham, milled from Michigan soft winter wheat	11.23	[1] 12.24	1.41	73.27		1.85	3.906	166
(Whole grain before processing)[13]	10.25	[1] 12.34	1.35	74.23		1.83	4.000	
102 Graham	11.82	*10.63	1.71	74.12	2.25	1.72		97

[1] N × 5.7.
[2] N × 6.25.
[3] N × 5.83.
[5] Reported as cellulose.
[6] Items No. 61 and 72 were prepared from this sample.
[7] Items No. 71 and 82 were prepared from this sample.
[8] The rye was milled to 67 percent and the branny fraction obtained from the remaining portion. Refers to original grain with 5 percent loss from cleaning.
[9] Items No. 92, 112, 135, 146, and 147 were prepared from this sample. Also from this wheat were prepared items No. 94, 114, and 137 appearing in another report.
[10] Items No. 93, 113, and 136 were prepared from this sample.
[11] Items No. 96 and 115 were prepared from this sample.
[12] Items No. 97, 116, 139, 173 and 174 were prepared from this sample.
[13] Items No. 98, 118, and 141 were prepared from this sample.
*N-conversion factor not reported.

TABLE 24.—*Composition and heat of combustion of food items used in experiments on human digestibility (table 23)*—Continued

Test food, description	Water	Protein	Fat	Carbohydrate: Total (by difference)	Carbohydrate: Fiber	Ash	Heat of combustion per gram	Ref. No.
GRAINS, GRAIN PRODUCTS—Con.								
Wheat, Wheat Products (*Triticum aestivum*)—Continued								
Flours, whole grain and nearly whole grain—Continued								
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	
106 Whole meal, milled from Canadian wheat	15.	[3] 15.40	2.23	([14])	2.36			104
107 Whole meal, milled from English wheat	15.	[3] 8.52	1.83	([15])	2.02			104
108 Whole meal	13.50	[3] 11.66	1.82	71.49		1.53		28
109 100 percent of wheat kernel	14.38	[2] 10.92	1.81	71.69		1.20		146
Flours, intermediate extractions:								
112 "Entire wheat"	10.81	[1] 12.26	2.24	73.67		1.02	4.032	164
113 "Entire wheat"	13.51	[1] 13.72	1.69	70.10		.98	3.877	166
114 "Entire wheat" milled from hard spring wheat, Scotch Fife	10.99	[2] 13.00	2.28	72.51		1.22	3.944	195
115 "Entire wheat" milled from Oregon white winter wheat	8.66	[1] 7.52	1.67	81.08		1.07	3.900	168
116 "Entire wheat" milled from hard winter Weissenburg wheat from Oklahoma	7.46	[1] 15.16	1.64	74.52		1.22	4.159	168
117 "Entire wheat" milled from Indiana soft winter wheat	9.60	[1] 12.80	1.54	74.40		1.66	4.020	166
(Whole grain before processing) [16]	8.09	[1] 13.16	1.52	75.38		1.85	4.090	
118 "Entire wheat" milled from Michigan soft winter wheat	11.01	[1] 12.01	1.53	74.17		1.28	3.860	166
123 90-percent extraction, milled from English wheat	15.	[1] 8.32			1.15			106
124 90-percent extraction, milled from Manitoba wheat	15.	[1] 13.51			1.15			106
131 80-percent extraction, milled from English wheat	15.	[1] 8.15			.17			106
132 80-percent extraction, milled from Manitoba wheat	15.	[1] 13.05			.24			106
Flours, lower extractions:								
135 Standard patent, milled from hard spring wheat, Scotch Fife	10.54	[1] 11.99	1.61	75.36		0.50	4.050	164
136 Straight patent, milled from hard spring wheat, Scotch Fife	12.38	[1] 13.60	1.30	72.04		.68	3.861	166
137 Straight patent, milled from hard spring wheat, Scotch Fife	11.55	[2] 12.75	1.43	73.67		.60	3.889	195
138 Standard patent, about 70 percent yield, milled from Oregon white winter wheat	8.94	[1] 6.90	1.25	82.47		.44	3.880	168
139 Standard patent, about 70 percent yield, milled from hard winter Weissenburg wheat from Oklahoma	9.93	[1] 13.74	.92	74.89		.52	4.040	168
140 Standard patent, milled from Indiana soft winter wheat	10.30	[1] 12.30	.93	75.94		.53	4.010	166
141 Standard patent, contained less than 72 percent wheat kernel milled from Michigan soft winter wheat	10.97	[1] 10.92	.50	77.15		.46	3.799	166
145 70 percent of wheat kernel, milled from a mixture of Girka and Minnesota wheats	15.02	[2] 11.57	.81	72.19		.41		146
146 1st patent, milled from hard spring wheat, Scotch Fife	10.55	[1] 11.08	1.15	76.85		.37	4.032	164
147 2d patent	10.49	[1] 11.14	1.20	76.75		.42	4.006	164
148 Patent, milled from hard spring wheat, Scotch Fife	12.36	*12.44	1.62	73.07		.51		170

[1] N × 5.7.
[2] N × 6.25.
[3] N × 5.83.
[14] Available carbohydrate 55.20 percent; undetermined matter (pentosans, etc.) 9.78 percent.
[15] Available carbohydrate 63.60 percent; undetermined matter (pentosans, etc.) 9.02 percent.
[16] Items No. 117 and 140 were prepared from this sample.
*N-conversion factor not reported.

TABLE 24.—*Composition and heat of combustion of food items used in experiments on human digestibility (table 23)*—Continued

Test food, description	Water	Protein	Fat	Carbohydrate		Ash	Heat of combustion per gram	Ref. No.
				Total (by difference)	Fiber			
GRAINS, GRAIN PRODUCTS—Con.								
Wheat, Wheat Products—Con.								
Flours, lower extractions—Con.								
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	
149 Patent, baker's grade, milled from Scotch Fife	8.01	*15.50	2.22	73.52	--------	.75	--------	170
151 Patent	11.07	*12.75	.90	74.84	.14	.44	--------	97
163 30 percent of wheat kernel, milled from a mixture of Odessa, California and English wheats	14.63	[2] 8.91	.96	75.18	--------	.32	--------	146
Flours, other:								
164 Semolina, milled from durum wheat, Kubanka	10.77	[2] 11.64	1.27	75.56	--------	.76	--------	168
(Whole grain before processing)[17]	8.76	[2] 12.37	2.07	74.92	--------	1.88	--------	
165 Semolina,[18] milled from durum wheat, Kubanka	7.57	[2] 11.57	0.89	79.06	--------	0.91	4.16	168
(Whole grain before processing)[19]	10.48	[2] 12.45	2.48	72.92	2.83	1.67	--------	
Flour mixtures:								
173 "Bran flour," a mixture of 86 percent straight grade and 14 percent very finely ground bran from hard Weissenburg wheat	9.69	[1] 13.96	1.48	73.62	--------	1.25	3.876	168
174 "Germ flour," a mixture of 93 percent straight grade flour and 7 percent finely ground germ milled from hard winter Weissenburg wheat	9.63	[1] 14.87	1.66	72.97	--------	.87	3.962	168
Wheat breakfast foods:								
Whole grain and partially refined:								
175 Flaked	2.72	[2] 11.69	1.49	79.13	1.88	4.97	--------	129
179 Meal	7.06	[2] 11.25	1.89	78.45	[20] 2.10	1.35	--------	129
180 Meal	8.08	[2] 16.32	1.47	72.68	[20] 2.07	1.45	--------	129
182 Meal	8.08	[2] 15.16	1.35	74.08	--------	1.33	--------	126
184 Puffed, whole grain	4.90	[2] 15.06	1.94	76.70	2.34	1.40	--------	129
185 Rolled	9.19	[1] 9.81	2.27	77.22	1.07	1.51	--------	62
187 Rolled	11.35	[2] 11.14	2.12	73.85	--------	1.54	4.020	168
189 Shredded	6.20	[1] 10.60	1.37	80.06	--------	1.77	--------	127 and 155
190 Shredded	5.62	[1] 9.97	1.35	81.27	2.42	1.79	--------	129
Refined:								
192 Endosperm, granulated	9.35	[1] 10.54	.85	78.76	.27	.50	--------	129
193 Endosperm, granulated	12.68	[2] 11.81	2.40	72.46	--------	.65	--------	126
194 Endosperm, farina	10.55	[1] 9.70	1.36	77.97	.44	.42	--------	62
195 Endosperm, farina	10.58	[1] 9.18	1.10	78.60	.36	.54	3.877	62
196 Endosperm, farina	11.37	*13.03	.77	74.27	.28	.56	--------	97
Wheat breakfast food mixtures:								
198 Wheat and barley malt	6.47	[1] 11.63	.77	78.96	--------	2.17	4.061	9
199 Wheat, whole grain and barley malt, "Force"	10.86	[1] 9.86	1.65	74.77	--------	2.86	3.822	9
200 Wheat, whole grain and barley malt mixture, "Force"	7.37	[1] 9.81	2.13	78.29	1.85	2.40	--------	62
201 Wheat and barley malt, "Malta Vita"	11.32	[1] 12.20	1.52	72.03	--------	2.93	3.841	9
202 Branny portion, fraction of 73–95 percent [21]	14.7	*15.7	4.2	61.1	7.6	4.3	--------	30
203 Branny portion, fraction of 82–95 percent [21]	14.3	*15.0	4.4	61.3	10.3	5.0	--------	30
LEGUMES AND NUTS								
Beans, dry (*Phaseolus vulgaris*):								
210 Common white, navy beans	11.21	[2] 18.25	1.63	64.89	--------	4.02	3.885	184
211 Common white, navy beans	11.19	[2] 20.69	1.58	62.54	--------	4.00	3.922	184

[1] N × 5.7.
[2] N × 6.25.
[17] Item No. 164 was prepared from this sample.
[18] Composition for macaroni, dry; used here for flour as Snyder found by previous analyses that flour and uncooked macaroni made from it have practically same composition.
[19] Items No. 165 and 187 were prepared from this sample.
[20] Estimated by authors of article.
[21] The wheat was milled to 73 percent and the branny fraction obtained from the remaining portion. Refers to original grain with a 5 percent loss from cleaning.
*N-conversion factor not reported.

TABLE 24.—*Composition and heat of combustion of food items used in experiments on human digestibility (table 23)*—Continued

Test food, description	Water	Protein	Fat	Carbohydrate: Total (by difference)	Carbohydrate: Fiber	Ash	Heat of combustion per gram	Ref. No.
LEGUMES AND NUTS—Continued								
Beans, dry—Continued	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	
212 Common white, navy beans, skins removed	13.32	*23.75	1.71	59.50	--	--	--	165
213 Common white, navy beans	12.82	*22.06	--	--	--	3.38	--	137
215 Kidney beans	11.25	[2] 25.38	1.41	58.38	--	3.58	--	184
Cowpeas, dry (*Vigna sinensis*):								
221 Clay	13.37	[2] 23.19	1.45	58.49	--	3.50	3.915	184
222 Clay	10.77	[2] 21.94	1.78	61.79	--	3.72	3.913	184
223 Lady	11.32	[2] 25.50	1.73	57.88	--	3.57	4.023	184
224 Lady	10.27	[2] 22.38	1.75	62.15	--	3.45	3.922	184
225 Lady	10.05	[2] 23.75	1.75	60.94	--	3.51	3.997	184
226 Whippoorwill	8.08	[2] 23.00	1.35	63.64	--	3.93	4.071	184
227 Whippoorwill	12.84	[2] 19.94	1.48	62.17	--	3.57	3.908	184
228 Whippoorwill	8.36	[2] 21.44	1.70	64.74	--	3.76	4.040	184
Peas, dry (*Pisum sativum*):								
235 Peas	13.0	[2] 21.2	1.2	61.9	--	2.7	--	145
236 Peas	13.2	[2] 21.2	1.2	61.8	--	2.6	--	145
237 Peas	11.53	[2] 22.81	1.51	61.71	--	2.44	--	140
238 Peas, split	12.61	[2] 23.44	.71	61.68	--	1.56	--	113
Soybeans, Soybean Products (*Glycine max*):								
248 Soybean flour, about 6.5 percent fat	4.17	[2] 49.31	6.50	34.22	5.10	5.80	3.716	29
249 Soybean flour, about 3.3 percent fat	6.5	[2] 44.1	3.3	40.4	5.9	5.7	3.480	29
252 Soybean curd (Tofu)	87.80	[2] 5.83	4.41	1.25	.11	.71	--	134
Ground nuts or peanuts (*Arachis hypogaea*):								
259 Peanuts	4.88	[2] 32.64	47.33	12.59	1.98	2.56	3.040	75
261 Peanut flour, partially defatted	4.44	*58.98	9.69	23.05	2.54	3.84	--	64
Tree nuts:								
264 Almonds (*Prunus amygdalus*)	4.42	[2] 17.28	54.30	21.22	2.58	2.78	3.129	75
265 Brazil nuts (*Bertholletia excelsa*)	4.33	[2] 19.78	63.31	8.96	2.96	3.62	3.125	75
266 Brazil nuts	5.28	[2] 18.00	66.07	8.00	4.22	2.65	3.397	75
267 Chestnuts, fresh (*Castanea sativa*)	--	[2] 5.4	1.4	38.3	--	--	--	67
268 Chestnut flour (*Castanea dentata*)	6.36	[2] 6.38	3.32	81.54	--	2.40	3.958	120
(Kernel before processing)[22]	44.89	[2] 3.85	2.10	47.75	--	1.41	2.372	
269 Coconuts (*Cocos nucifera*)	19.17	[2] 5.25	51.00	23.44	13.77	1.14	2.712	75
270 Pecans (*Carya illinoensis*)	4.30	[2] 15.67	71.52	6.96	3.17	1.55	3.551	75
271 Walnuts (*Juglans regia*) (presumably Persian or English)	3.97	[2] 24.58	62.92	6.62	1.87	1.91	3.318	75
VEGETABLES								
272 Beans, snap (*Phaseolus vulgaris*)	92.44	[2] 1.16	.13	5.44	1.04	.83	--	57
274 Beets (*Beta vulgaris*)	82.6	*1.9	.3	13.8	1.0	1.4	.673	33
275 Beets	85.4	*2.2	.2	10.8	--	1.4	.599	33
276 Cabbage (*Brassica oleracea* var. *capitata*)	94.7	*.9	.3	3.3	1.1	.8	.214	33
277 Cabbage	94.8	*1.0	.3	3.0	--	.9	.210	33
278 Cabbage	94.4	*.9	.1	3.7	--	.9	.203	33
280 Cabbage, savoy	89.4	[2] 2.1	.6	6.6	--	1.3	--	144
281 Carrots (*Daucus carota*)	90.53	[2] .86	.33	7.40	1.12	.88	--	134
282 Carrots	86.3	[2] 1.6	.2	11.0	--	.9	--	144
283 Collards (*Brassica oleracea* var. *acephala*)	88.44	[2] 3.13	.54	5.53	1.51	2.36	--	57
284 Corn, green (*Zea mays*)	76.0	*4.9	1.4	17.3	.5	.4	1.112	33
286 Potatoes, white (*Solanum tuberosum*)	79.5	*2.2	.1	17.4	.4	.8	.848	33
287 Potatoes, white	78.3	*2.3	.1	18.4	--	.9	.900	33
288 Potatoes, white	81.2	*1.9	.3	15.5	--	1.1	.782	33
291 Potatoes, white	73.4	*2.3	--	23.3	--	1.0	--	144
292 Potatoes, white	74.33	*2.38	.03	22.32	.28	.94	--	42
293 Potatoes, white	80.16	[2] 1.49	.07	17.35	.39	.93	--	134
294 Potatoes, white [23]	75.1	[2] 2.0	--	21.8	--	1.0	1.014	69
295 Potatoes, white	77.66	[2] 2.04	--	19.47	--	.84	--	69
296 Potatoes, white	74.80	[2] 1.20	--	23.19	--	.81	--	69

[2] N × 6.25.

[22] Item No. 268 was prepared from this sample.

[23] Average of several samples weighted by their consumption during period of digestion experiment.

*N-conversion factor not reported.

TABLE 24.—*Composition and heat of combustion of food items used in experiments on human digestibility (table 23)*—Continued

	Test food, description	Water	Protein	Fat	Carbohydrate: Total (by difference)	Carbohydrate: Fiber	Ash	Heat of combustion per gram	Ref. No.
	VEGETABLES—Continued	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*	
297	Potatoes, white	73.66	[3] 1.95		23.38		1.01		69
298	Potatoes, white	76.23	[3] 2.11		20.70		.96		69
299	Potatoes, white	77.66	[3] 2.04		19.47		.84		69
300	Potatoes, white	74.80	[3] 1.20		23.19		.81		69
301	Potatoes, white [22]	74.3	[3] 1.8		23.2		.8		69
302	Potatoes, white [22]	79.4	[3] 1.4		18.4		.9		69
311	Pumpkin (*Cucurbita pepo*)	84.01	[3] 1.94	.19	13.23	1.30	.63		134
312	Sweetpotatoes, partially dried (*Ipomoea batatas*)	4.96	[3] 1.71	.76	90.27	7.65	2.30		134
	FRUITS								
322	Bananas (*Musa paradisiaca* var. *sapientum*)	77.15	[3] 1.60	.24	20.20	.52	.81		75
323	Grapes (*Vitis spp.*),[24] mixture of Tokay, Muscat and Cornichon	86.8	[3] .7	.2	12.0	.5	.3		75
	MISCELLANEOUS								
330	Yeast, dried	6.82	[25] 47.25					4.478	87
331	Yeast, fresh compressed	69.92	[3] 15.20					1.443	87

[3] N × 6.25.
[22] Average of several samples weighted by their consumption during period of digestion experiment.
[24] Weighted average of 3 kinds of European type grapes used in the digestion experiment.
[25] N × 6.25. Authors also reported 7.05 percent protein N and 0.51 percent purine N.

U.S. GOVERNMENT PRINTING OFFICE : 1973 O—493-791