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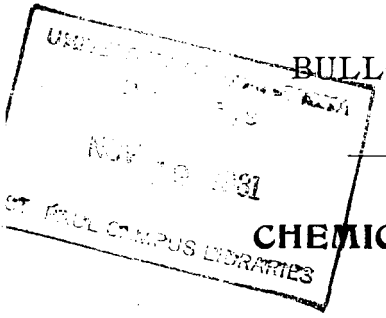

BULLETIN No. 86.

CHEMICAL DIVISION.

MARCH, 1904.

1. THE FOOD VALUE OF SUGAR.
2. THE DIGESTIVE ACTION OF MILK.

ST. ANTHONY PARK, RAMSEY CO., MINNESOTA.

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THE FOOD VALUE OF SUGAR.

HARRY SNYDER.

Object of Experiments. In order to determine the nutritive value of sugar in a ration, two series of experiments with men were undertaken. In the first series, sugar with other foods was fed to working men, and in the second series with the same men it was omitted. Oatmeal, white bread, milk, cheese, butter, eggs and berries, with and without sugar, constituted the rations. The object of the experiment was to determine the value of sugar as a food and its influence in a liberal ration consisting of a number of foods and containing the various nutrients as protein, fat and carbohydrates in approximately the amounts prescribed in dietary standards.

Plan of Experiments. The experiments were carried on for a period of four days each and were preceded by a preliminary feeding period. Weighed amounts of analyzed foods were used, and all of the indigestible and waste products from the body were weighed and analyzed. The digestibility of the food was determined from the difference between the nutrients in the foods consumed and those voided in an undigested form. Three men were used in the experiments. Man 1 was employed at indoor labor similar to shop work; Man 2, at active outdoor farm labor, and Man 3 at more severe outdoor labor. All of the subjects were young men in normal health.

Common granulated sugar, testing 99.2 per cent purity, was used to the extent of five ounces per day in the first series of experiments but omitted from the second series. With the exception of the sugar the foods were such as can easily be produced upon a farm, the milk, berries, eggs and butter being obtained from the University Farm.

Digestibility of Rations. The ration with sugar contained approximately .25 of a pound of protein, .34 of a pound of fat, and .98 of a pound carbohydrates, while the ration without sugar contained the same amount of protein and fat but .30 of a pound less carbohydrates. The foods used had the following composition:

TABLE XIX. Composition of Foods Used in Experiments.

Name of Food.	Dry Matter Per cent.	Protein Per cent.	Fat Per cent.	Carbohydrates Per cent.	Ash Per cent.	Calories per gram Determined.
Oatmeal	91.00	15.35	7.74	66.20	1.71	4.424
Bread Lot 1	70.20	10.32	1 33	57.92	.63	3.112
Bread Lot 2	65.97	9.39	1.20	54.65	.73	2.930
Milk	13.28	3.18	4.44	4.76	.90	0.809
Cheese Lot 1	63.81	26.27	34.65		2.89	4.630
Cheese Lot 2	63.25	25.46	34.44		3.35	4.550
Butter	89.66	.82	86.45		2.39	8.098
Eggs	25.70	12.76	11.80		.99	1.961
Raspberries	14.20	1.24		12.47	.49	0.631
Sugar				99.20		3.995

The daily ration consisted of approximately four ounces each of oatmeal and cheese, twelve ounces of bread, three ounces of butter, five ounces of sugar, two ounces of raspberries, with one pint of milk and two eggs. The oatmeal (common rolled oats purchased in bulk) was thoroughly cooked for four hours in a double boiler. From each meal, samples of the food were saved for analysis.

The total amount of nutrients in the ration and the amount supplied by the different foods are given in the following table which is obtained by multiplying the weight of food consumed by the percentage of nutrients present.

TABLE XX. Nutrients in Ration for one day.

	Lbs.	Protein Lbs.	Fat Lbs.	Carbohydrates Lbs.	Cost of Materials Cts.
Oat Meal	.25	.04	.02	.17	.0125
Cheese	.25	.07	.09		.0400
Bread	.75	.08	.01	.43	.0210
Butter	.19		.16		.05
Sugar	.32			.31	.02
Raspberries	.12			.02	.03
Milk	1.00	.03	.04	.05	.025
Eggs (2)		.03	.02		.030
Total		.25	.34	.98	.229

The bread supplied about one-third of the protein and two-fifths of the carbohydrates of the ration. On the basis of total nutrients, it was by far the cheapest food used, as it cost less than one-tenth of the total, and supplied a larger amount of nutrients than any other food. The oatmeal contributed materially to the protein and carbohydrates of the ration; the

amount consumed, .25 of a pound, is on the basis of the uncooked oatmeal. The sugar contributed slightly less than one-third of the carbohydrate and added about one-tenth to the cost of the ration. The cheese supplied about one-fourth of the protein and fat and added a little more than one-third to the cost. The raspberries did not supply any appreciable amount of nutrients although they added three cents to the

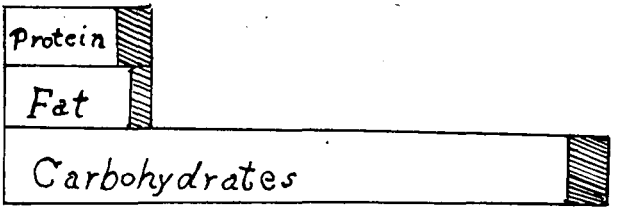

Fig. 130. Nutrients of a ration without sugar.

cost of the ration. Other fruit could have been used more economically. In the case of fruits, particularly berries, it is hardly just to compare them with other foods on the basis of nutrients, because they are valuable in other ways than just for the nutrients which they contain. They impart palatability to the ration and undoubtedly assist functionally in the digestion of the food. Some fruits contain sufficient organic acids and salts to act beneficially as mild intestinal antiseptics. The

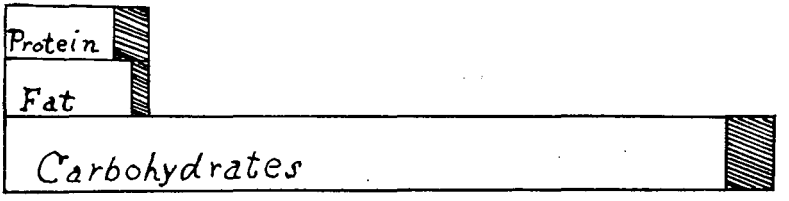

Fig. 131. Nutrients of a ration with sugar.

use of fruits in the ration, although they may add materially to the cost, is desirable and should be encouraged. The production and use of home grown fruits, however, lessens the cost of food. In this investigation the part which sugar takes in the availability of the nutrients and energy was the object of study and will therefore receive special consideration.

The digestibility of the rations with sugar were found to be as follows:

TABLE XXI. Digestibility of Nutrients of Rations.

	Protein Per cent.	Fat Per cent.	Carbohydrates Per cent.	Available Energy Per cent.
With sugar				
Man 1	93.81	96.00	95.33	90.04
Man 2	90.59	96.17	96.59	91.33
Man 3	93.81	96.00	95.33	91.32
Average (omitting Man 1)	92.20	96.08	95.96	91.32
Without sugar				
Man 1				
Man 2	91.10	95.88	94.82	88.99
Man 3	92.81	97.86	97.37	89.69
Average	91.95	96.87	96.09	89.34

There is no material difference in the completeness of digestion of the various nutrients of the two rations, the nutrients of the ration with sugar being equally as digestible as those of the ration from which it was omitted. It is noticeable that the addition of sugar did not sensibly increase or decrease the digestibility of the other nutrients of the ration. The sugar evidently was absorbed and oxidized without interfering with the digestibility of the other foods with which it was combined. The high degree of digestibility of the carbohydrates, approximately 96 per cent, is a noticeable feature. Over 98.9 per cent of the total energy of the sugar as determined by the calorimeter was available to the body, as will be observed in the following table:

TABLE XXII. Energy of Rations.

Total Calories	In food.	In sugar.	In feces.	In urine.	Per cent available from	
					Entire food.	Sugar.
Without sugar						
Man 2	10011.3		673.6	428.9	88.99	
Man 3	9941.6		598.6	427.5	89.69	
With sugar						
Man 2	11732.9	2265.0	625.0	393.34	91.32	98.98
Man 3	12759.1	2265.0	657.0	447.17	91.33	98.95

The digestibility of the individual foods was determined in former investigations (Bulletin No. 74, Univ. of Minn. Agr. Ex. Sta.). When the average digestibility of these rations is

calculated from the digestion coefficients of the different foods, as obtained in former work, the following results are obtained:

	Digestibility of Rations: Calculated.	Determined.
Protein	90.0	92.07
Fat	94.5	96.48
Carbohydrates	95.1	96.02

The difference between the calculated and the determined digestibility is small. The calculated digestibility being slightly lower than was the actual digestibility obtained by experiment. In making the calculations, both the milk and the sugar were considered as entirely digested. In a former bulletin (Minn.

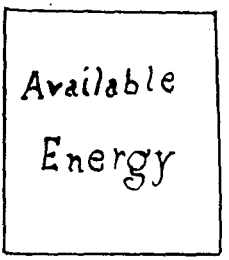

Fig. 132. Ration without sugar.

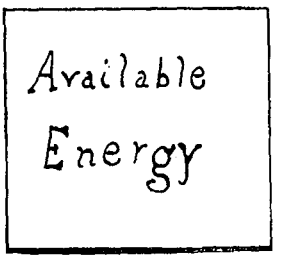

Fig. 133. Ration with sugar.

Bul. No. 74, p. 169) it was shown that the presence of milk in a ration exerted a favorable influence upon the digestibility of other foods. In these rations, the amount of milk used was small; nevertheless the difference between the calculated and determined digestible nutrients is in favor of the latter, suggesting that, as found in former work, the milk favorably influenced the digestion of the foods with which it was combined.

Nitrogen Balance. The income and outgo of the nitrogen in the two rations was determined and the following nitrogen balance obtained:

	Nitrogen in Food Grams	Total Nitrogen in Feces & Urine Grams	Gain to Body Grams
Ration with Sugar.			
Man 2	75.90	44.9	31.00
" 3	84.40	47.9	36.50
Average			33.75
Ration without Sugar.			
Man 2	80.4	52.7	27.7
" 3	81.0	55.7	25.3
Average			26.5

Sugar Caused a More Economic Use of the Proteids in the Ration. It is significant that from the ration with sugar there was a larger amount of nitrogen retained in the body than from the ration without sugar. Seven and two-tenths grams more of nitrogen, equivalent to about forty-five grams of protein, were retained in the body when sugar was used. This saving of nitrogen is accounted for by the fact that when sugar was omitted more of the proteids were used for fuel purposes. In the ration where sugar was present, the sugar was utilized for fuel purposes, thus saving some of the proteid nutrients to be stored up in the body. In experiments with animals, it has been observed that the addition of sugar to the ration decreases the excretion of urea and results in the retention of more nitrogen in the body. (See experiments by Voit reported in Armsby's "Principles of Animal Nutrition," page 116).

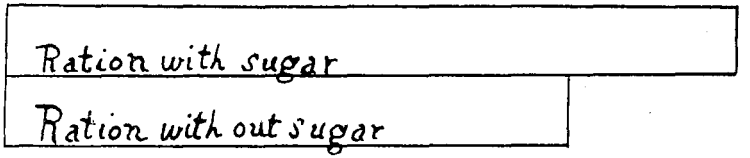

Fig. 134. Nitrogen retained in body.

In these experiments the sugar was practically all digested, as 98.9 per cent of its total energy was available to the body. Its addition to the ration did not affect the digestibility of the other foods, but did effect a saving of the proteids, and also widened the nutritive ratio, that is, the ratio between proteids and carbohydrates. The nutritive ratio of the ration without sugar was 1 to 5.7 and with sugar it was about 1 to 7. The ratio of 1 to 7 appeared to give better results than the narrower ratio 1 to 5.7. The addition of the five ounces of sugar per day to the ration was beneficial.

In both of the series of experiments, those with and those without sugar, no meat was supplied. In place of meat an equivalent amount of nutrients in the form of eggs, cheese and milk was furnished. Previous to the experiments, all of the subjects had been receiving meat in some form twice a day. As far as could be observed the substitution of the eggs, cheese and milk for meat did not cause any loss of ability on the part of the men to perform their daily labors, suggesting that like amounts of similar nutrients from different sources are equally valuable and can replace one another in a ration.

Sugar as a Nutrient. In the dietary, sugar is too frequently regarded as a condiment instead of a nutrient, to be used for imparting palatability rather than for purposes of nutrition. While sugar is valuable for improving the taste of foods, its main worth is as a nutritive substance. From the caloric determinations of the foods used, of the feces, and of the unoxidized products of the urine, it is estimated that 98.9 per cent of the sugar was oxidized and made available to the body. Thus for all practical purposes, sugar may be regarded as entirely digested. Being composed of the elements carbon, hydrogen and oxygen, it forms when burned or oxidized carbon dioxid and water and as a result heat is liberated. The sugar used in these experiments, when burned in the calorimeter, yielded 3.995 calories or heat units per gram, or approximately 1800 calories per pound, which is about the fuel value of starch and allied carbohydrates. As a heat and energy producing nutrient it is fully equal to starch, and is more readily absorbed by the body.

Consumption of Sugar. Sugar enters quite largely into the dietary of the average American. It is estimated from the amount produced and imported into this country that the per capita consumption in all forms amounts to about three and a half ounces per day. In addition to its use in the ordinary form of granulated sugar, it is the chief ingredient of other food articles, particularly of syrups, molasses and honey. Fruits, as apples, grapes, oranges and strawberries, contain appreciable amounts of sugar. A large amount of sugar is also consumed in the form of confectionery and candy; provided these are unadulterated, their moderate use is not objectionable. Manufacturers of confectionery have frequently noted that larger amounts of candy are sold and consumed in cold weather than in warm weather. According to statistics the consumption of sugar and of foods containing sugar is on the increase in this country.

Sorghum syrup when properly made is a cheap and valuable source of sugar. Analyses of Minnesota sorghums have shown from 60 to 68 per cent of total sugar, of which nearly two-thirds is in the form of sucrose or cane sugar. In composition, these syrups have been found equal to the best grades of sorghum produced in more southern latitudes. The production of sorghum syrup is an agricultural industry which has to a limited extent, been conducted on a co-operative basis. More sorghum could profitably be produced in this state and used in the dietary. At forty cents per gallon, sorghum compares favorably in nutritive value with granulated sugar at five cents per pound.

Sugar in the Dietary. Sugar has its place in the dietary. It not only serves for the production of heat and energy in the body, but is also valuable in enabling the proteids to be used more economically, as shown in these experiments. In reasonable amounts, it is particularly valuable in the dietary of growing children, as the proteids of the food are then utilized to better advantage for growth. The unique value of sugar in a ration depends upon its intelligent use and its proper combination with other foods, particularly those rich in the nitrogenous compounds or proteids. Sugar alone is incapable of sustaining life, but combined with other foods it is a valuable nutrient. The amount which can be advantageously used in a ration depends largely upon the individual. Ordinarily three to five ounces per day is sufficient, although some persons cannot safely consume as large an amount as this. In the case of diabetes mellitus, sugar must be excluded from the dietary. It is to be regretted that some of the specially prepared foods supposed to be reasonably free from sugar and starch and advertised as suitable for use by diabetic persons contain abnormal amounts of these compounds. One sample of flour analyzed in this laboratory called "Diabetic Flour" and sold for 15 cents per pound was found upon analysis to contain 68.90 per cent of carbohydrates, mainly in the form of starch. It was practically low grade flour.

Persons in normal health and engaged in outdoor work can use sugar to advantage. Some of the "harvest drinks" made largely from molasses with a little ginger and used extensively in some localities are not without merit, as they contain an appreciable amount of nutrients. Milk contains more sugar in the form of lactose or milk sugar than any other nutrient.

The craving for sugar by growing children and athletes is natural. Sugar, however, is often injudiciously used, and a perverted taste is established which can be satisfied only by excessive amounts. This results in impaired digestion and malnutrition.

In Farmers' Bulletin No. 93, U. S. Department of Agriculture (Sugar as Food) an account is given of experiments by Schomberg in which thirty grams (about one ounce) of sugar were administered when the subject experimented upon performed some exhausting labor. In a measure the sugar prevented fatigue, and restored the efficiency of the tired muscles. When a dilute solution of dulcite, a sweet tasting material resembling sugar but without food value, was used, the subject being unaware of the substitution, the difference was noticeable. The sweet solution of dulcite failed to prevent fatigue or to restore the efficiency of the tired muscles. "The explana-

tion given was that a little more or less sugar in the blood was of no consequence in ordinary exertion, but it was otherwise when the sugar stored up in the muscles was heavily drawn upon by exhausting labor. At such a time, the rapidity with which sugar is digested and absorbed proves of great advantage. The author states: 'The practical conclusion to be drawn is that sugar in small doses is well adapted to help men to perform extraordinary muscular labor.' ''

Cost of Sugar as a Nutrient. At five to six cents per pound, sugar compares favorably with other nutrients, although it is more expensive than starch in the form of cereal foods, as wheat flour, corn meal and oatmeal, which contain 65 to 80 per cent of carbohydrates and 10 to 14 per cent of proteids and cost from 2½ to 3½ cents per pound. The average cost of sugar in the daily ration ranges from 1 to 2 cents per day. Compared with some other foods, sugar is not an expensive item in the dietary.

SUMMARY.

1. In these digestion experiments, 98.9 per cent of the total energy of the sugar was available to the body.

2. The addition of five ounces of sugar per day to the ration of working men proved beneficial. It increased the available energy of the ration 25 per cent and did not affect the digestibility of the other foods with which it was combined. The various nutrients were equally as digestible with as without the sugar.

3. When sugar was added to the ration, the protein was more economically used, 25 per cent more nitrogen, one of the elements of protein, being retained in the body, thus enabling more of the protein to be utilized for repair of muscular tissues and for growth. The value of sugar in a ration depends upon its judicious use and combination with other foods.

4. Bread made from white flour supplied the largest amount of nutrients and at the least expense of any of the foods used in these digestion experiments.

5. Milk exerted a beneficial action upon the digestibility of the foods with which it was combined, as the digestibility of these rations in which milk was present was found by experiment to be greater than the calculated digestibility.

6. Without underestimating the value and importance of the protein in a ration, it is evident that the carbohydrates, as sugar, and starch in flour and cereals, have a characteristic value, as they supply the body with more than half its total available energy.

THE DIGESTIVE ACTION OF MILK.

HARRY SNYDER.

In a former bulletin, No. 74, the influence of the enzymes or chemical ferments of milk upon the digestibility of other foods was discussed. It was found, when milk was added to a ration, that the protein was noticeably increased in digestibility, and that fresh milk rendered some of the proteids of bread toast soluble. It was suggested that in making the proteids soluble, the tryptic-like ferment naturally present in milk exerts a solvent action similar to that in the ripening of cheese, which is essentially a digestive process.

In order to determine whether the solvent power was due to other causes than enzymic action, additional work was undertaken, the results of which are given in this report. Tests were made with solvent containing traces of acids and mineral compounds similar to those found in milk, also milks containing small amounts of chloroform, and formalin were used in order to determine the influence exerted by organized ferment bodies. The plan of the experiment was similar to that of the former work. The total and water soluble nitrogen of a sample of toast were determined. Ten grams of toast were digested with 90 cc. of water and 10 cc. of fresh milk for four hours in a water bath at a temperature of 98 degrees F. The total nitrogen of the milk was determined, and also that in the filtered solution. It was shown by blank determinations that all of the nitrogen of the milk remained soluble after the four hours digestion. It was assumed that the water soluble nitrogen of the toast was entirely soluble in the milk. The excess of soluble nitrogen found after digestion was considered as being derived from the toast by the digestive action of milk. In nine separate trials in which samples of milk from different cows were used, an average of .019 of a gram of proteids was rendered soluble by the action of the milk upon the wheat proteids of the toast. The results are as follows:

TABLE XXIII. Solvent Action of Fresh Milk on Toast.

Milk used. Name of Cow.	Water Soluble Proteids in Toast Grams.	Total Proteids of Milk Grams.	Total Proteids of milk and water Soluble Proteids of Toast Grams.	Total Soluble Proteids after Digestion Grams.	Gain Grams.
Trust	.07	.306	.376	.400	.024
Swiss	.07	.325	.395	.431	.036
Shorty	.07	.319	.389	.406	.017
Reddy	.07	.269	.339	.331	.008
Klondike	.07	.356	.426	.438	.012
Euroma	.07	.331	.401	.425	.024
Cotton	.07	.281	.351	.381	.030
Alzanka	.07	.269	.339	.350	.011
Herd (mixed milk)	.07	.319	.389	.413	.024
Average					.019

While the increase in soluble protein is small, it indicates that under the conditions of the experiment fresh milk has a solvent action upon the insoluble proteids of toast. The experiments were repeated with similiar milks, twelve hours after milking. Similar results were obtained, as will be observed from the following table.

TABLE XXIV. Solvent Action of Milk (12 Hours Old) Upon Toast.

Milk used. Name of Cow.	Water Soluble Proteids in Toast Grams.	Total Proteids of Milk Grams.	Total Proteids of milk and water Soluble Proteids of Toast Grams.	Total Soluble Proteids after Digestion Grams.	Gain Grams.
Trust	.07	.313	.383	.400	.017
Swiss	.07	.356	.426	.438	.012
Shorty	.07	.288	.358	.381	.023
Milkman's	.07	.369	.439	.469	.030
Herd	.07	.325	.395	.425	.030
Average					.022

In the case of two of the samples, digestion with the milk twelve hours old caused coagulation. This, as pointed out by Babcock & Russell, may be due to ferment action other than that caused by lactic acid producing organisms. A whey-like filtrate was obtained which contained a low per cent of acid and 52.2 per cent of the total proteids of the milk, indicating that even with the coagulation of the milk some of the proteids were changed in solubility. In the case of the eight hour digestion period, many of the samples both of fresh and old milk coagulated. An attempt was made to determine the percentage amounts of nitrogen in the form of casein, albumin, albumoses

and peptones in the samples both before and after digestion, but the preliminary work showed that while the methods used gave reasonably concordant results there was such overlapping of the different proteid groups that the methods of separation were not applicable to the determination of changes such as had occured in the samples, hence it was deemed best to class the nitrogen simply as soluble and insoluble, and to determine the amount which had been rendered soluble by the action of the milk without determining its form as albumoses or peptones.

The average solvent action of the fresh and old milk under the conditions of the experiment was .02 grams of proteids in excess of the solvent action of water, equivalent to about 1.50 per cent of the total proteids in the toast used, or about 7 per cent of the proteids in the milk. In order to determine whether this solvent action was due to the free acid of the milk, tests were made with solutions of the same degree of acidity as the milk used. In the fresh milk, the highest acidity was .05 per cent lactic acid. A solution of .05 per cent lactic acid dissolved .007 grams of protein, and weaker solutions less amounts. It is evident that the solvent action of the free lactic acid in the milk was not sufficient to account for all of the proteids rendered soluble.

The influence of chloroform and of ether upon the solvent action of milk was found to be slight. Condensers were used to prevent volatilization of the chloroform and ether.

TABLE XXV. Influence of Chloroform, Ether and Formalin on Solvent Action of Milk.

	Water Soluble Proteids in Toast	Total Proteids of Milk	Total Proteids of milk and water Soluble in Toast	Total Soluble Proteids after Digestion	Gain
	Grams.	Grams.	Grams.	Grams.	Grams.
Lactic acid .05% solution	.07	.....	.077	.077	.007
Formalin .1% solution...	.07	.338	.408	.431	.023
Chloroform 4% solution	.07	.338	.408	.433	.025
Ether 2% solution.....	.07	.338	.408	.430	.022

There was no material difference in the solvent action of either fresh or old milk to which chloroform was added, indicating that the organized ferments exerted but little, if any, influence in making soluble the proteids of the toast. Whatever action the enzymes or soluble ferments of the wheat flour may have exerted during digestion would have been apparent

in the blank determinations in which water was used and these proteids would have been included in the water soluble proteids. Alkaline salts in the proportions found in milk also failed to show any appreciable solvent action upon the insoluble proteids. There seems to be no other way in which to account for this small amount of soluble proteids except by enzymic action. In the study of individual milks, it was found that some exerted a greater solvent action than others. In one case, a negative result was obtained, and in fourteen duplicate trials, the solvent action ranged from .011 to .036 grams of protein. Most of the cows, from which the milk was obtained for these experiments were in an advanced stage of lactation; the earlier experiments reported in bulletin No. 74 were with milk given by a cow in the first period of lactation.

SUMMARY.

While the digestive action of milk upon the insoluble proteids of wheat is small, it is sufficient to render from one to three per cent of the total proteids soluble. The small amount of free acid in fresh milk has but little solvent action and alkaline salts in the proportion found in milk failed to dissolve any appreciable amount of proteids.

In the presence of chloroform and ether, agents which retard the workings of organized ferments, the solvent action of the milk was not interrupted. From all of the facts, it would appear that the solvent action of fresh milk is due largely to the tryptic-like ferment or enzyme which is a soluble ferment, and is a normal constituent of milk. These bodies enable milk to exert a slight digestive action. Under the conditions of these experiments from 1.5 to 3 per cent of the insoluble proteids of wheat, equivalent to from 4 to 12 per cent of the proteids in the milk used were rendered soluble by these agents. There is a difference in the solvent action of milk; some milks have greater digestive power than others. When milk forms a part of a ration its digestive action undoubtedly adds to its dietetic value by rendering the foods with which it is combined more digestible.