WHAT MODERN CHEMISTS HAVE DONE

for

DOMESTIC SCIENCE.

Edith Worden.

Outline.

I. Introduction.

II. Discussion,

1. Composition of Food,
2. Body Chemistry,
3. Metabolism,
4. Energy Relations.

III. Conclusion.

WHAT MODERN CHEMISTS HAVE DONE FOR DOMESTIC SCIENCE.

The woman of today who would make her home a model of all it should be in point of beauty, cleanliness, healthfulness, and opportunities for ever larger development, must be the mistress of many sciences.

If she would have her house constructed of proper materials and suitably located, and surrounded by the beauties of nature, she must know something of architecture and landscape gardening; for a pleasing interior the science of color and line harmony come into play. She must know physics and hydraulics that she may know that her house is properly plumbed, heated and ventilated.

The science of economics enables her to watch intelligently the trend of business affairs and so plan wisely her own household affairs. The science of mathematics enables her to figure out her expenses - the cost of clothing and food - and thus use the family income to the best advantage. From physiology she learns the conditions of the body in health and disease, and from chemistry, the constituents of food, the effects of cookery on it, and the particular need each constituent subserves.

Chemistry also teaches her the composition of the various cooking utensils she uses and the best way to take care of them; the mysteries of the fuel she burns and the ways of getting the greatest amount of heat from it; the effects of poisons, food adulterations and preservatives; the effects of various chemical substances used in the laundry upon her clothes; the composition of the water used for drinking and cooking; the dyeing of fabrics which are used as clothing, draperies and for fancy work.

But the would-be housekeeper owes the greatest debt to the modern chemist, who by his exact methods and painstaking labor, in physiological chemistry, and by means of various digestion experiments, etc., has worked out the principles that underlie the subject of human nutrition. It is the purpose of this discussion to show something of what he has done along this line.

Activity is the purpose of living, and hence the object of nutrition. The food consumed furnishes all the energy required for activity, whether physical, chemical or psychological, so the subject of nutrition becomes one of vital importance to the housewife.

Chemists tell us that for convenience in discussion, foods are to be divided into two large groups, organic and inorganic, the division being based on the fact that the organic foods are those which are formed in the life processes of plants and animals. The inorganic foods are water and mineral matter.

Water finds access to the body by means of drinks, liquid foods, fruit and vegetables. Perhaps the purest, most wholesome form is that in fruits. Drinking water is obtained pure when it is distilled and very nearly pure as it descends in rain, after the dust is washed from the air. Water that has percolated through the earth and appears in springs and deep wells generally holds in solution various mineral matters, some of which are not injurious, especially lime, magnesia and iron in small amounts.

Water is necessary to the body in large quantities; it holds the food material in solution, dilutes the secretions, lubricates the friction surfaces, gives fluidity to the blood, furnishes a medium in which the chemical processes may take place, enters by hydrolysis into combination with food constituents, and by evaporation, tends to equalize the body temperature, and assists in removal of waste products from the body.

Of the mineral matter, calcium salts and phosphates are used in the bony structure of the body, and chlorides in the construction of organs and preparation of digestive secretion. Iron is an important constituent of the blood and potassium salts of the muscles. Carbonates, especially that of sodium, are necessary to preserve the alkalinity of the blood.

The mineral salts reach the system largely through the proteid food stuffs. Milk is rich in the various minerals needed in the body, eggs contain sulphur, phosphorus and iron. Carbonates and phosphates of the alkalies are obtained from animal foods, and in vegetable foods are found the alkali salts of the organic acids.

The organic compounds are proteids, fats and carbohydrates. In general it may be said that fats and carbohydrates furnish energy in the form of heat and work, and the proteids go to form body tissue. However, carbohydrates are found in muscular tissue and the liver as stored food and with fats are used in the formation of fatty tissue; fats are also found in microscopic amounts in the protoplasm of muscular tissue; and proteids also serve the purpose of furnishing energy.

The proteids are found in animal tissue, milk, eggs, cereals, and leguminous plants.

Fats are of both animal and vegetable origin. Under normal conditions, the animal metabolizes and stores food as fat in characteristic form. Thus in sheep is invariably found fat known as mutton tallow, in swine that known as lard, etc. Other fats are found in some foods, especially in butter, which is an ideal fat for food, being easily digested and of agreeable taste and odor. Vegetable fats are mostly in the form of oils and are obtained from olives, peanuts and cotton seed.

Fats form an important source of energy to the body, and they are used mainly for this purpose. However, the body welcomes a slight excess of fat, the presence of which gives a rounded appearance to the muscles, and when considered with other proper factors, indicates that the body is in good healthy, working condition. Too large an excess, though, indicates faulty nutrition.

The carbohydrates are of vegetable origin and exist as sugar, starch and cellulose. When carbohydrate food reaches the blood, ready for work, it is in the form of dextrose or levulose, simple sugars, but the forms in which it is found, and through which it passes, are legion. The division as to class is made on the simplicity or complexity of the saccharide molecule. Thus, monosaccharides consist of the simplest molecules and are not capable of further division; disaccharides consist of molecules that may yield two molecules of a monosaccharide or one molecule of each of two monosaccharides; and polysaccharides yield disaccharides and monosaccharides.

The process known as hydrolysis here, in which water takes a part. When a molecule of a disaccharide is split up a molecule of water enters, thus:

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6$$

Of the monosaccharides, only the hexoses are of use as food. These are of the same formula, $C_6H_{12}O_6$, but differ in source and properties. Dextrose is found in ripe fruits, honey, and in blood and lymph and various tissues of the body. Levulose also occurs in many fruits that contain dextrose, it is found particularly in watermelon. Galactose is a simple sugar which is formed in the hydrolysis of lactose or milk sugar.

Three disaccharides are of importance as foods: Cane sugar, which is found abundantly distributed in nature, in cane, beets, sap of maple trees, etc., when hydrolyzed yields one molecule of dextrose and one of levulose; maltose, which does not occur in nature as such but is formed in the splitting up of the starch molecule, when hydrolyzed yields two molecules of dextrose; and lactose, which is the carbohydrate of milk, yields dextrose and galactose when hydrolyzed.

The polysaccharides are divided into three groups, starch, cellulose and gums. Starch is the form in which carbohydrates are stored in plants, in the roots, tubers, seeds and trunks, and is found widely distributed in nature. It comes on the market principally in the form of corn starch, flour, tapioca and cassava. Cellulose forms the fibrous portions of fruits and vegetables and serves a useful purpose in giving bulk to the food and enabling the waste products to be carried away more easily.

Organic acids are classed as foods because they break down into carbonates, thus helping to bring about the alkaline condition of the blood so necessary to its proper functioning. They are found in fruits and vegetables. The principal ones are tartaric acid, found in grapes; malic, in apples, pears, etc.; citric, in oranges, lemons and grape fruit; oxalic, in rhubarb and tomatoes; and benzoic in cranberries. Lactic acid, a product of the fermentation of milk, is also of importance.

With advancing civilization cooking of foods has come to be looked upon as a physiological necessity. By means of it several chemical changes are brought about in the various foods, which in the case of carbohydrates is an advantage, but with proteids it is somewhat different, as cooking generally renders them less digestible. This is offset, however, by the fact that cooked foods are more agreeable as to appearance, odor and taste than uncooked foods, which is an important psychological element in digestion.

Starch is dextrinized under the influence of dry heat, as in the crust of bread, and made more digestible, and by moist heat, as cooking in water, the resistent cell wall of the starch grain is broken down and a jelly like mass is formed which can be acted on by the digestive juices.

Cane sugar is unaffected by boiling in pure water, but in the presence of acids, as when fruits are cooked with it, it is converted into dextrose and levulose. At a high temperature some of the water is driven from the sugar molecule and a brown substance, caramel, is formed. This makes an agreeable flavoring substance when used in small quantities.

Fat is decomposed by high heat and substances are formed which have an unpleasant odor and an irritating effect on the stomach.

The proteids in meats and animal products are coagulated by heat, but if cooked at a temperature no higher than 90° Centigrade, they are not difficult of digestion. Above that, however, meat becomes tough and leathery and is less readily available to the system.

When soaked in water many of the salts and some of the proteid food material of both meat and vegetables go into solution, and by long cooking, especially in salted water, much of the nutritive material is lost unless this extract is retained and used.

The human body is made up of proteid matter similar in composition to the proteid food it consumes. It is fitted with organs which enable it to handle the food, and endowed with the power to select such as it needs for purposes of activity and to cast aside such as are no longer of use to it.

The tissues are all made up of cells varying in composition with the location and use. Physiologically speaking the living cell is made up of protoplasm, with generally a nucleus and often enclosed in a cell wall. Chemically, the cell is made up largely of proteid matter, with some fat and mineral matter.

It is in the cell that the chemical and physical changes take place than manifest themselves in the various activities of the body.

It is impossible to isolate and study a single cell alive, because the very processes undergone are fatal to its life. But there are conclusions which the chemist has been able to reach that have been of utmost importance in physiological chemistry.

The body has its bony structure, its muscle, its connective tissue, its blood that acts as carrier, and all these are nourished by the food that is consumed daily. The chemical processes of digestion are the result of enzyme action. When food is taken into the mouth and thoroughly masticated it is diluted by means of the saliva and the carbohydrates are acted upon to a slight extent by the diastatic enzyme, ptyalin, contained in the saliva. In the stomach the action ceases as soon as the contents become acid from the hydrochloric acid of the gastric juice. Here the proteids come under the influence of pepsin which converts them into the soluble form called peptones, the milk previously having been curdled by the rennen of the gastric juice. Upon passing out into the small intestine, the food comes in contact with the enzymes of the pancreatic juice, one of which, trypsin, acts further upon the proteids, but now in an alkaline medium instead of acid; one which takes up the digestion of starch again and is known as amylopsin; and steapsin, the one which splits up the ingested fats. In the small intestine the food also encounters the bile, which seems in some way to aid the juices of the pancreas in their work, and also an enzyme secreted here, invertin, which hydrolyzes cane sugar and maltose.

The object of digestion is to form substances which will be easily absorbed into the blood and lymph.

The entire change which the food undergoes after absorption until excretion is known as metabolism. It consists in building up complex compounds in which the cell takes to itself the substance brought to it by the blood and prepared for it by the chemical and mechanical processes of digestion; and a progressive tearing down again with the release of energy into very simple substances which are then excreted as such.

It is impossible to know all the steps in these two processes nor just what takes place. One theory is that the living cell binds itself to a proteid non-living molecule isomeric with it, and continuing indefinitely to do this until a large molecule is formed, which, owing to its unstable character may be easily oxidized, giving up to the body the energy which has been stored.

The synthesis of the food and cell into complex molecules is known as anabolism and the breaking up into simpler compounds as katabolism. It is the katabolic process that concerns us most, since it is by this process that we obtain the energy we need.

By means of carefully worked out methods of investigation, chemists have been able to learn what becomes of the various nutrients contained in food. Thus, carbohydrates and fats are metabolized to water and carbon dioxide, and proteids to these as well as urea, uric acid, etc.

Most of the nitrogenous products of metabolism are excreted in the urine, although some leave the body through the skin together with water. The lungs excrete water and carbon dioxide. The feces are made up of undigested residues of food, digestive juices and epithelial cells cast off in the process of digestion.

The amount of food digested is ascertained by weighing the food eaten and then the feces, the difference being looked upon as equal to the amount absorbed.

The gain or loss of proteid by the body is calculated from the difference between the total amount of nitrogen excreted and that ingested, the factor being 6 1/4, since proteid food is assumed to have 16% nitrogen.

The gain or loss of fat is estimated from the amount of carbon, after deducting the amount of carbon in the proteids. The carbon of the visible excreta is determined by ordinary analytical methods, and that of the gaseous, by means of a respiration calorimeter. By this apparatus other excreta may be determined, and also the amount of heat evolved.

Since in the formation of a molecule of carbon dioxide a molecule of oxygen is consumed, the ratio of the volume of carbon dioxide excreted to the volume of oxygen consumed is represented by the fraction $\frac{CO_2}{O_2}$ and is called the Respiratory Quotient. By means of this fraction it is possible to arrive at fairly definite conclusions in regard to the relative amounts of carbohydrates and fats oxidized.

In carbohydrates, hydrogen and oxygen are present in the proportion to form water, so that when they are oxidized the oxygen used up is only that required to form carbon dioxide from the carbon. Hence the quotient, $\frac{CO_2}{O_2}$, is equal to 1. On the other hand, with fats, some additional oxygen is required to unite with the hydrogen thus making the quotient less than 1, about 0.7. After calculating the figures obtained by means of the respiration calorimeter, if the quotient approaches 1 the material consumed must consist largely of carbohydrates, while if it falls to near 0.7 it is chiefly fat. Mixtures of fat and carbohydrates give a result between these two and an algebraic calculation can be made by which the relative amounts may be determined. The quotient for proteids is about 0.83 and if these are present in the food, the effect they would have on the volume of oxygen consumed and carbon dioxide produced must first be calculated and subtracted from the total amount, and then the figures for the fats and carbohydrates may be obtained.

The food that is eaten contains potential energy, which by the process of oxidation in the body is given up in the form of heat, chemical energy or work. Some of the food, however, does not give up all its potential energy, the metabolic products being capable of still yielding energy.

Since all forms of energy may be represented by the corresponding amount of heat, the heat of combustion of a given substance is looked upon as representative of its energy value. This value is expressed in Calories, one Calorie being the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade. The value, then, of any food is determined by its heat of combustion, and expressed in Calories.

The average composition and fuel value per pound of the common American foods have been worked out by Professor Atwater and are given in his Farmer's Bulletin, No. 142. By means of this table it is an easy matter to figure out typical meals and thus know whether or not the food principles are being given in the right proportions.

These proportions, as determined by prominent investigators, are expressed as a ratio in which the energy yielded by the protein of the food is to the energy yielded by the fat plus that of the carbohydrates as one is to (about) five. This is spoken of as the Nutritive Ratio.

Now, when the value of the different foods is known it is easily possible for the housewife to substitute cheaper foods for more expensive ones and still maintain the proper ratio.

It is not until she knows in a definite, scientific way the facts concerning the composition of the body and its food, the uses of the various food principles and the proportions in which they are needed, that the housewife can best adapt the family cookery to the needs of the household. And so I say it is to the chemist in his laboratory, who by ever improving methods and apparatus, has found out these principles and classified them, that the student of Domestic Science is most indebted for a working knowledge of the subject.