Reliability of Nutrient Analyses and Food Tables

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FOOD tables enable dietetics to be a science as well as an art. It is necessary to know the nutrient composition of available foods and food products in order to efficiently develop a good diet, and to effectively treat malnutrition and undernutrition.

Food tables become increasingly useful, and the science of dietetics becomes more exact, as these data are applied to larger and larger population groups. It is possible to get a good idea of the dietary intakes of large population groups by conducting food consumption surveys and then calculating the nutrient intake from food tables. However, these tables are quite useless in calculating the nutrient intake of an individual or the composition of an individual meal.

If tables of food composition are the scientific basis of dietetics, how exact is that science? I could point out the inaccuracies of the methods used in food analysis and emphasize the high degree of variability in the composition of samples of the same food due to the influences of genetics, soils and stage of maturity, and to factors which destroy or inactivate nutrients as this food passes from garden to gullet. In doing so I might come to the conclusion that dietetics is by no means an exact science because food composition tables are only roughly quantitative. I need only to comment here that those who use food composition tables should be constantly aware of the fact that these tables cannot give an exact estimate of the grams or milligrams of *available* nutrients in diets. While food tables do not present data with an accuracy of atomic weight determinations, neither are they so unreliable as to be worthless.

Let us take a broad view of food tables and food analysis. Is food analysis encumbered by the traditions of a century of analysts whose purpose has been colored more by chemistry than by nutrition, more by concern for the accurate estimation of the total amounts of nutrients present in a food sample than for the amounts of nutrients available which might contribute to the nourishment of the whole animal, especially of human beings?

I would define human nutrition as "the science concerned with providing optimum amounts of all the nutrients required by all the cells to the body tissues of normal man from the beginning of fetal life until the end of a long span of years." By this definition, nutrition includes a concern for the composition (food analysis) and preparation (food science, food technology and dietetics) of the foods which enter the mouth, and for the digestion, absorption, metabolism and excretion (physiologic chemistry) of the constituents of these foods. The food analyst should be concerned not only with the quantitation of the nutrients, but also with the measurement of non-nutrients and antinutrients in foods which may interfere with the utilization of the nutrients. Traditional food tables are actually misleading if they report the milligrams of iron in a food without also reporting the amounts of oxalic acid, phytates, and so on present in this food which may interfere with iron absorption. The same may be said about thiamine and

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thiaminase, iodine and goitrogens, biotin and avidin, etc. The net availability of nutrients in foods is important. It must be remembered that most of our plant foods and a few of our animal foods contain non-nutrients and anti-nutrients which distort, sometimes very seriously, the true picture of the nutritional worth of these foods. Until now the food analyst has worked assiduously to isolate each nutrient carefully, to remove all interfering compounds and to measure precisely the number of milligrams per 100 grams. Compared to the laboratory procedure, it is likely that the gut of man cannot fully digest and extract nutrients, remove interfering substances or absorb them as completely.

Why are foods analyzed? The nutritionist will answer that it is to determine the extent to which a food will supply the forty odd nutrients required for man's nutrition. The food analyst will likely answer that it is to determine the amounts of specific nutrients in that food. He is not usually concerned with availability, only with the total amount. Therefore, the food tables which are the result of his work generally report only the total amounts of nutrients in foods. They do not report the net amounts available for man's nutrition.

MOISTURE

The moisture content of foods is one of the most important analyses made by a food chemist. It is especially important because it is the most variable constituent of foods, especially of succulent vegetables and fruits. Most people think that the moisture analysis is simple and reliable. Actually it is not.

The estimation of water in foods is based on increasing the vapor pressure by the use of heat, with or without reduced atmospheric pressure, and assuming that the loss of weight represents moisture content. When a sample stops losing weight it is assumed that all the moisture has been removed.

Although most of the moisture in foods is present in the free form and is easily removed, a significant amount is bound and difficult to extract. Few people, including many nutrition scientists, realize that moisture is retained by biological products until they reach temperatures as high as 365°c., the critical temperature of water.[1] When some organic materials, such as cereals, are heated at 105°c., which is a temperature often used in estimating the moisture content of food, as much as 40 per cent of the water may still remain in the sample. Furthermore, organic compounds in foods may decompose irreversibly during this treatment, giving off CO_2, CO, CH_4 and H_2O, and non-aqueous compounds may also be evaporated off. Thus, this method of determining moisture content is inaccurate because not all the water is measured and because not all the weight lost represents water. Why do we persist in using this primitive and crude procedure?

An entirely new approach is needed to estimate the moisture in foods. It seems better that the water be estimated *in situ*. In 1912 McNeil[2] measured the moisture in paints and soaps by estimating the amount of acetylene produced by reaction of calcium carbide with water. Shemin and Wagner[3] refined this method and used it successfully to rapidly estimate the moisture contained in grated cheese. In another approach, Fischer[4] introduced a mixture of iodine, pyridine and sulfur dioxide in methanol solution as a reagent for the titrametric determination of water in tissues. This method has been improved by many investigators.[5]

I predict that eventually a satisfactory *in situ* method for the estimation of moisture will be developed, in which essentially 100 per cent of the moisture will be measured, thus avoiding errors due to incomplete volatilization of water, evaporation of nonaqueous volatiles and decomposition of organic matter which occurs with the traditional method.

MINERALS

The traditional technic has been to prepare the ash by heating at high temperatures in a muffle furnace, then to analyze the ash for only a few elements (calcium, phosphorus and iron), usually those which tend to be deficient in dietaries. Unfortunately, a temperature which is sufficiently high to completely ash a food sample, will also drive off certain volatile elements (alkali-chlorides, potassium and sodium). Therefore, it is difficult to estimate

accurately the ash content of a food, and low values will be obtained for certain mineral elements by ash analysis rather than by direct analysis of a food sample.

Furthermore, as time goes on we are finding that more and more of the trace elements are nutritional essentials, especially as components of enzyme systems (Al, As, Ca, Co, Cu, Fe, Mg, Ni, Zn). I think that we need better and more data on the macro- and microelement content of foods. The newer methods will likely involve a wet ashing of the food, and the separation and quantitation of the component elements by chromatographic technics. In polarography and flame photometry, for instance, the quantitative estimation of each ion in a mixture is sometimes complicated by interfering ions. Chromatography, alone or in combination with other analytical technics, will permit the accurate analysis of almost any sample.[5]

AMINO ACIDS

The protein content of food is traditionally arrived at by calculation, rather than by analysis. The organic nitrogen content (not total nitrogen, by the way) is usually estimated by a modification of the moist combustion procedure, and the resulting nitrogen value is multiplied by a factor to convert the nitrogen to protein. Not all the organic nitrogen in foods, however, is protein nitrogen. While it is true that amino acids account for a major portion of the nitrogen in plant and animal tissue, a significant and variable amount is found also as pyrimidines, purines, alkaloids, creatine and creatinine. Furthermore, the factors used in converting nitrogen to protein are based on the nitrogen content of the predominating protein present in each food. Food composition tables often bear a warning that the figures given represent "crude protein values," since it has been assumed that all the nitrogen present is in the form of protein.

Why does the food analyst still estimate protein so crudely? In 1841 von Liebig[7] *assumed* that nearly all nitrogenous matter in natural foods was present as protein; he suggested that the nutritive value of a food protein could be assessed on the basis of the amount of nitrogen present.

At a much later date it was realized that the nitrogen content of different proteins varies, and that a more accurate estimate of the protein contribution of a food could be obtained by the use of nitrogen conversion factors. But it is about fifty years since it was shown that the proteins of different foods do not have the same nutritional value when fed on an equinitrogen or equiprotein basis. In other words, the nitrogen value, or the calculated protein value, does not tell the nutrition scientist what he wants to know about a food.

We now know that foods contain over sixty different amino acids and that at least eight of these are essential because the human body either does not have the capacity to synthesize them or to synthesize them sufficiently to meet its needs for growth and for the replacement of body tissues. These amino acids differ in nitrogen content. Practical methods are now available, and equipment can now be purchased, which permit an analyst to estimate the kinds and amounts of over twenty of these amino acids in a food sample in one day or less, and with considerable accuracy (±5 per cent). This recent advance in food analysis is important. Already a table has been published by the U.S.D.A.[8] which lists the amounts of eighteen amino acids in 202 food proteins. Food nitrogen analyses and calculated crude protein values in food tables will soon be antiquated. In modern nutrition science we are concerned with amino acids, not nitrogen or protein. A food should now be evaluated in terms of the amounts of specific amino acids it will supply for human nutrition.

FATTY ACIDS

The fat content of foods can be determined by one of the following three methods: (1) extraction with a solvent, (2) acid hydrolysis followed by extraction, and (3) saponification followed by extraction. The fat content reported in most U.S. food composition tables refers to the weight of crude "fat" obtained by simple extraction with a solvent, usually ethyl ether. It should be pointed out that the ether extract of food samples contains other compounds (sterols, chlorophyll or pigments). Furthermore, the extraction of lipids is often

incomplete because some fatty acids are chemically combined with proteins and carbohydrates in cells, and are difficult to extract. During the past year we have demonstrated in our laboratories that a chloroform-methanol mixture will extract the lipids more efficiently than ethyl ether or petroleum ether, especially if the tissue is treated with acid to release bound fatty acids.

But why do we determine lipids by this inefficient solvent extraction method when more accurate results can be obtained estimating the fatty acid content of samples following acid or alkaline hydrolysis? Are we not interested primarily in these acids? Is it not these which are unusually high in calorie value?

In modern nutrition science we are interested not in lipids, but in specific fatty acids. Present knowledge of nutrition indicates that we need to know the linoleic acid and arachidonic acid content of foods. The newer knowledge indicates that we may also need to know the amounts of saturated, of monounsaturated, and of cis or trans fatty acids in a food. In the future we will want to know the amounts and kinds of branch-chained, oxidized, peroxidized, epoxidized, hydroxylated or polymerized fatty acids in prepared foods. Some natural foods contain unusual fatty acids (sterculic acid, erucic acid or hiptagenic acid) which interfere with normal metabolism; these should be quantitated.

Not long ago it was assumed that food fatty acids were of no importance in nutrition except as sources of calories, and that chain-length was of little import because all fatty acids were broken down into two-carbon fragments and burned in the metabolic fire. More recently it was realized that certain fatty acids are "essential," indicating that they have a peculiar molecular structure which places them in the class like amino acids and vitamins. We know already that chain-length determines the route and rate of digestion, absorption and metabolism of fatty acids.[9] It does appear, therefore, that the best analysis of food in the future will involve the hydrolysis of the lipid fraction, the extraction of the freed fatty acids, and the estimation of each of the component fatty acids and fatty acid derivatives by chromatography. Only then can we know the value of a food as a source of fatty acid calories and of essential fatty acids, and the extent to which these fatty acids place stresses on body metabolism.

CARBOHYDRATES

In teaching I am embarrassed to tell students that the carbohydrate content of a food is not estimated by analysis, but calculated by adding the per cent crude protein, total lipid, moisture and ash together, and subtracting the total from 100. "Carbohydrate by difference" is in the realm of pseudoscience. In addition to true carbohydrates, the calculated value includes such compounds as organic acids, pentosans, gums, fiber and other complex carbohydrates which may be metabolized poorly. Furthermore, the "carbohydrate by difference" value is subject to all the errors which occur in the analysis of food for water, nitrogen, lipid and ash content.

I think we are on the threshold of a new approach to this carbohydrate problem, when the carbohydrates will be extracted from a food sample and the individual monosaccharides, disaccharides or trisaccharides separated and quantitated by chromatographic technics. That time cannot come too soon, for we know that there are important nutritional differences between various pentoses and hexoses in relation to the routes and rates of their absorption and metabolism.

VITAMINS

I have elected to delay discussion of the analysis of foods for vitamins until the last because these analyses are less subject to criticism. Unlike all other nutrients, the vitamins were discovered and first measured by animal or microbiological assay. From the beginning analysts were concerned with developing methods which would detect the specific chemical groups in these unique molecules. I doubt that anyone ever seriously proposed that we estimate the thiamine, niacin, folic acid, biotin, vitamin B_6 or choline content of foods by analyzing for nitrogen. Vitamin analysis is generally free of the tradition which

interferes with amino acid analyses referred to earlier. While many of the vitamin methods are still quite crude, they need only refinement to make them highly accurate, and to serve the needs of nutrition science.

CONCLUSION

The newer knowledge of nutrition demands newer and more specific technics for determining the special molecular configurations which give nutrients their uniqueness. Food composition tables in the future will present increasingly more data on the kinds and amounts of specific amino acids, fatty acids, carbohydrates and minerals, just as these tables now present data on the kinds and amounts of specific vitamins. They will also contain data on the kinds and amounts of compounds present in foods which destroy nutrients or interfere with their absorption or metabolism. Nutrition science is becoming increasingly complicated and sophisticated. Food analysis, and the resulting tables of food composition which are the fruits of food analysis, must become complicated and sophisticated to serve the needs of nutrition science.

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