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Chemical Aspects of Updating Diet Quality

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The use of chemicals to improve the nutritional quality of foods began with the additions of iodine to salt to prevent goiter and vitamin D to milk to prevent rickets. Several hundred chemicals have been approved for use to improve the color, flavor, texture, keeping qualities, and nutritional value of food. This makes our food supply one of the most varied, palatable, convenient, and nutritionally adequate in the world. The outstanding example of the successful and economical use of chemicals to improve the nutritive value of foods is demonstrated by the enrichment of bread, flour, and other cereals. We must use chemical additives in increasing amounts and variety in order to make our food supply nutritionally adequate at the lowest cost in the face of the rapid population increase. Chemicals must be used under proper controls for safety and effectiveness. It can be anticipated that food mixtures, imitation foods, and meal substitutes in which chemicals are widely used are going to become increasingly useful and important in our food supply.

Although several hundred chemicals are used primarily to upgrade the quality and acceptability of many foods by improving their color, flavor, texture, and shelf-life, they also indirectly contribute to nutrition by making food more available, more convenient and more palatable. However, only a relatively few chemicals are used for the direct purpose of improving the nutritional value of food and this is a relatively new development in food science.

The use of various substances to prevent malnutrition, such as cod liver oil to prevent rickets, lemon juice to prevent scurvy, and fish oil concentrates to prevent vitamin A deficiency, goes back many years before synthetic nutrients became available. The use of synthetic or isolated chemical substances to improve the nutritional value of food was not possible until a number of important advances in our knowledge had occurred.

First, the nutrients had to be isolated, their chemical structure determined, and synthetic production worked out before they could be made available in sufficient quantity at a price which made the procedure commercially feasible. Even then a public awareness of their value in health had to be created, in order to make them acceptable and saleable.

The synthetic production of most of the vitamins occurred during the 1930's. At the same time, the knowledge of nutrition had to advance to a point where acceptable recommended dietary allowances for the various nutrients could be estimated in order that the proper quantity to use could be determined. The clinical diagnosis of the deficiency diseases

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and their treatment had to advance to a point where therapeutic effects and dosages could also be determined. Even today we do not have enough knowledge about the early symptoms of malnutrition to make the best use of our available synthetic nutrients.

There are many nutrients which are available from the chemical industry and which can be considered for use in foods in order to prevent malnutrition. The ones of the greatest importance are iodine for the prevention of goiter, vitamin B_{12}, iron and folacin for the prevention of anemia, vitamin D for the prevention of rickets, vitamin A for the prevention of xerophthalmia, vitamin C for the prevention of scurvy, thiamine for the prevention of beriberi, riboflavin for the prevention of ariboflavinosis, niacin for the prevention of pellagra, and fluoride in the drinking water to prevent dental caries, while vitamin B_6, calcium, magnesium, and several trace minerals are receiving increasing attention.

Recently the essential amino acids, lysine and methionine, have become available and are now under study with a view to the possibility of their widespread use in combatting protein malnutrition. The use of these chemical nutrients for the nutritional improvement of foods for health purposes has posed many problems on which nutritionists have held widely differing views. One group has held that nutritional improvement should be based on the original nutrient content of the food and that the quantity used should not exceed a high level naturally found in the unprocessed food. Others have taken the view that the quantity used should be that necessary to meet health needs and not necessarily bear any relation to the composition of the original food. The modern history of the nutritional improvement of food for health purposes began with the addition of a fish liver oil concentrate to margarine as a source of vitamin A, and the addition of iodine to salt to prevent goiter.

The addition of vitamin D to cow's milk was first achieved by feeding cod liver oil to the cow and later by feeding irradiated yeast and irradiated egosterol, and then by the direct irradiation of milk with ultraviolet light. The introduction of the international unit for vitamin D was a major factor in clearing up the confusion regarding the efficacy of various types of vitamin D. Vitamin D is now added directly to the milk. The problems of the quantity and form of vitamin D to be added to milk caused considerable discussion, and the decision to add 400 I.U. to all evaporated milk per reconstituted quart was a significant public health measure in that it provided automatic protection against rickets for about three-quarters of all the artificially fed infants in the United States. The addition of vitamin D to milk has been the major factor in the disappearance of rickets as a public health problem in this country.

Although these beginnings in the nutritional improvement of food for health purposes do not represent the addition of chemically pure nutrients, the success of these procedures laid the background for the public acceptance of the present day nutritional improvement by the use of chemical nutrients.

The concept of the addition of synthetic nutrients to foods was so widespread and acceptable as a health measure that in 1939 the Council on Food and Nutrition of the American Medical Association published a policy statement on the addition of vitamins and minerals to food and in 1941 the Food and Nutrition Board of the National Research Council announced its policy. These statements were published jointly in 1953. There is good evidence to indicate that these policies have been beneficial and have encouraged sound nutritional practices over the past several years. The 1953 Statement of General Policy was revised in 1961 and is being revised again at the present time. The Policy states that foods that are suitable as vehicles for the distribution of added nutrients are those which have a diminished nutritive content as a result of loss in refining or processing or those that are widely and regularly consumed. The addition of other than normally occurring levels of nutrients to these foods is also approved when properly qualified judgment indicates that the addition will be advantageous to public health and when other methods of effecting the desired purpose appear to be less feasible.

The addition of vitamins and iron to white flour and bread was first proposed officially in this country in 1940 and has become one of the most important examples of the successful use of chemicals in food for health purposes. The Food and Drug Administration established a definition for "enriched bread," which set the levels of the required ingredients of thiamine, riboflavin, niacin, and iron, based on clinical evidence of the prevalence of these deficiencies in this country, estimated shortages in the intake of these nutrients in the typical American diet, and assumptions as to the extent to which flour and bread entered into the diet. The terms restoration, enrichment, and fortification have been loosely and often improperly used in referring to the addition of chemical nutrients to foods. Enrichment officially is the addition of specific amounts of selected nutrients, in accordance with the standard of identity of enriched white bread, flour, and maize meal, as defined by the U.S. Food and Drug Administration. However, the term is very loosely used beyond the legal definition and is often applied to foods that actually are fortified. Fortification means the addition of nutrients to levels which are regarded as desirable and may bear no reference to the "natural" level in the product. For example: margarine containing 15,000 units of vitamin A per pound is often referred to as "enriched" margarine. Actually, it is fortified margarine. The 15,000 units brings it up to something approximating the vitamin A content of high grade summer butter. Fruit juices of various kinds, as well as artificial mixtures which are often used as substitutes for orange juice may be "enriched" or actually "fortified" with 30 mg of ascorbic acid per serving to bring the vitamin C content up to a desirable level.

Some products, such as infant foods or products for special purposes, are frequently designed to supply a proportion of the total nutrient requirements in a single serving. These are designed according to the estimated needs of the individual rather than according to the composition of the foods used in the product. The enrichment formula for white flour and bread was designed to attain the important objective of improving the nutritive value of the diet without requiring changes in food habits, without altering the taste or appearance of the product, and using foods basic to practically every diet in this country. In addition, the product is low in cost, is readily obtainable, and the enrichment does not materially increase the price. These objectives are desirable in any plan to use chemical nutrients. It may be of interest to those who are interested in the chemical aspects of improving the nutritional quality of foods to review briefly the motivation and the steps by which the enrichment of bread and flour was brought about.

The low level of intake of thiamine, niacin, and riboflavin of a large part of the population at that time had resulted in the wide prevalence of the vitamin deficiency diseases beriberi, pellagra, ariboflavinosis, while iron deficiency anemia was widespread then, as it still is today. The medical and public

health professions were deeply concerned. The Food and Nutrition Board of the National Research Council gave it much consideration and the U.S. Department of Agriculture was actively trying to combat the problem. It was clear, however, that the situation was one which required more action. It was obviously impossible to make any rapid progress through educational methods. It was economically out of the question to distribute the necessary foods to the people who needed them most. It was impractical to get vitamin pills taken regularly by large numbers of people who needed them. Attempts to get people to eat whole grain products had been going on for years, with little success. The problem, therefore, rapidly narrowed down to the question of how to provide the newly available synthetic nutrients to the general population in the simplest and most economical way. It was reasoned that since the required nutrients were naturally present in wheat, and since the milling process reduces the level of these nutrients, the logical way to get the needed nutrients back into the diet was to add them back to the flour and get them into the one food most common on most tables, namely bread.

The average consumption of bread was calculated to be about six slices per day. It was a simple matter to determine, on the basis of the Recommended Allowances of the National Research Council, how much thiamine, niacin, riboflavin, and iron should be added to flour and bread so that six slices per day per person would bring the intake of nutrients up to the recommended allowance and thereby raise the level of these nutrients in the diet high enough to protect against deficiency disease.

Having met the requirements that enrichment was an excellent public health idea and economically feasible, with the endorsement of the American Medical Association and the Food and Nutrition Board of the National Research Council, the next step was to determine how to get the job done and here a principle was adopted which is as necessary today as it was then. This was to secure the cooperation of science, industry, and government in a mutually agreed upon program. This was accomplished by consultation with the people who were to be responsible for carrying out the program. The proposal was placed before a meeting of the official organizations of the millers and bakers and members of the medical profession, as well as nutritionists, government officials and scientists. The proposal received immediate and wholehearted endorsement. An important factor was the determination that the proposed additives would not change the product in form, appearance, or flavor, and that it was economically feasible without any material increase in the price of the final product. The U.S. Food and Drug Administration then set the legal standards for enriched flour and bread with minimal and maximal levels of nutrients which could be included. The "enrichment" policy was enforced during World War II through the promulgation of War Food Order #1, which terminated at the end of the war. Since that time the continued use of these products has been due to the enactment of state laws in 29 states, as well as Puerto Rico, which require that commercial white bread and flour be enriched according to the Food and Drug Administration standards. Following the introduction of enrichment, beriberi, ariboflavinosis, and pellagra disappeared as public health problems in this country. This has led to some controversy as to the role played by enrichment in eliminating these diseases. This is a question that can never be completely and positively answered since it was impractical to set up an experiment to prove its value.

The white bread and flour enrichment program was carried forward without any direct experimental evidence that the enrichment would be successful or effective. It seemed clear enough that since it had been demonstrated that thiamine would prevent and cure beriberi any food to which thiamine would be added would help prevent the disease. The same reasoning was followed in adding niacin to prevent pellagra and riboflavin to prevent ariboflavinosis. However, questions arose and have continued to arise for more than 25 years as to whether the enrichment program was effective and people still seem to want direct proof, which is practically impossible to obtain. In any procedure of this kind affecting the general population, it is exceedingly difficult to design a study that can ethically be carried out to prove that the product is effective. If it is done on a confined selected group of individuals, the study is immediately criticized on the basis that the conditions do not apply to the general public. If a large scale study is made of the general public, such as the population of the United States over 25 years, one is faced with the situation that many other things occurred at the same time and the effects of the enrichment program cannot be separated from those of nutrition education, food availability, food prices, income, etc. Even when the U.S. Department of Agriculture shows by its family dietary studies that the vitamins present in enriched bread and flour make a substantial contribution toward making a deficient diet reach recommended allowances, the argument is made that these data do not apply to individuals.

It is, therefore, extremely difficult to make a clear cut appraisal of a health measure of this kind designed to be for the public health benefit of the population of the entire United States. It was not felt that an experiment was necessary in the face of the logic of the situation. The statistics indicate that the result was beneficial and that the deficiency diseases due to inadequate intake of the three B vitamins (thiamine, niacin, and riboflavin) have disappeared as public health problems. They were widely prevalent in the United States when the measure was instituted. The number of cases of niacin deficiency were numbered in the hundreds of thousands. There were 1836 recorded deaths from pellagra in 1941 when enrichment was introduced, even though niacin had been available as a treatment for pellagra for about 5 years. In the 10 years following the introduction of the enrichment program, the number of deaths dropped to 262. In 1966 there were only 21 recorded deaths from pellagra in the entire United States. Clinical riboflavin deficiency and beriberi heart disease are now rarities. Studies of chronic alcoholics in Chicago and Boston in 1941 showed many cases of pellagra and beriberi. Five years later, studies of these same groups failed to find the disease. There was little doubt in the minds of those making the study that the disappearance of the disease in this group was due to the enrichment program.

A large field study showing the beneficial effects of adding thiamine to rice was carried out in the Philippines by Dr. Salcedo and his associates. Among a population of 63,000 people on the Bataan Peninsula, there were 167 deaths from beriberi in the years 1947–48. Following the introduction of enriched rice, the deaths from beriberi declined until there were only 49 deaths in the years 1949–50 and not a single death during the fourth quarter of the year. Thus, in a population severely deficient, such as on Bataan, the effects of enrichment are more easily seen, although this study still does not conclusively prove that the effects were due to the rice enrichment program.

I doubt very much that it is ever going to be possible to set up an experiment that will conclusively prove the benefits of the addition of any synthetic nutrient to a food as applied to a large population. Other events always take place at the same time, such as changes in the economic situation, changes in food intake that are not controllable experimentally, the occurrence of epidemics, and other factors that cannot be anticipated or controlled.

In the United States, where there is such a wide variation in diet, and where the number of people severely affected is relatively small, the effects of adding synthetic nutrients to foods are more difficult to follow and would require special studies of low income groups where malnutrition is more prevalent. Even then, the results would very likely be inconclusive because of the difficulty in controlling the total diet, in preventing other changes from occurring at the same time, and making the necessary clinical and biochemical evaluations. My point in all this is that the public health value of the addition of synthetic nutrients to foods has been amply demonstrated with the vitamins, although it has never been proven. The vitamin deficiency diseases have very largely ceased to exist as public health problems where synthetic nutrients have been added to foods, although one is unable to offer conclusive proof of the direct effects of the procedures. It seems unreasonable and unnecessary to ask for direct proof of this, having demonstrated that the deficiency will produce lesions in experimental animals. Having demonstrated that administration of vitamins will cure these lesions, in both animal and man, it seems that one could logically assume that increasing the intake of the nutrient will be of benefit to a population deficient in the vitamin concerned. However, many people differ from this viewpoint and it is one which has already arisen, in connection with the use of synthetic amino acids to improve protein quality. Here the problem is even more difficult than in the case of the addition of vitamins because of the problem of the balance between amino acids, the relation to the amount of nonspecific nitrogen, and the difficulty of determining what would be the amount necessary to pervent a deficiency. With the vitamins, since they are so specific, and the deficiency diseases so clearly marked, the problem is much simpler than dealing with one as intricate as the relation between proteins, calories, and amino acid balance. It would seem to me that the goal should be an effort to approach an ideal protein in composition.

The question today is whether to add lysine to white flour and bread or possibly to add methionine to other products. We already see the same questions, doubts, and uncertainties arising in the minds of scientists that we saw years ago when the question of the advisability of adding vitamins to foods arose. What level of the amino acid should we add? Will the addition create an imbalance that will be harmful? Will there be toxic effects if too much is added? Should the mixture be adjusted to meet human needs, or, what would be an amount that would make a theoretically good protein? Some scientists will ask for experimental proof that the addition is effective before it is done. Others will say that it is too expensive and a waste of money, and that the same effect could be obtained by education or by making natural high quality protein available. To my mind, many of these questions do not need an answer and to some it is impossible to reply. It has been amply demonstrated in experimental animals that if the nutrients are complete, except for lysine, the animal will not grow properly until lysine is added. It would appear that given a population on a diet of low protein quality in which lysine is one of the limiting amino acids, nothing but benefit could be obtained from the addition of this nontoxic material to a commonly eaten food containing protein of low biological value in which lysine is an important limiting amino acid. To try to set up a human experiment to prove this advantage would not only be unnecessary but is nearly impossible because of the difficulty of controlling the entire diet and the inability to maintain adequate controls. Ethically, one cannot withhold lysine from a food supply to human beings when animal experiments indicate that the result can only be deleterious. It is also evident that if a diet is deficient in several nutrients, as is the usual case in human diets, the provision of only one of these such as lysine is going to have little measurable effect on growth, although it may be making a worthwhile improvement in the nutriture of the individual. It would seem practically impossible to find a population existing on a diet deficient only in lysine.

Now let us turn for a moment to another aspect of the problem of the chemical improvement of foods, namely that of acceptability by the public. In today's atmosphere of consumerism, it appears that people are reading labels more closely than ever, not only to learn the ingredients in the product, but also many seem to want to reject a product that has a number of chemicals listed on the label, simply because of an attitude of mind that is biased against chemical additives of all kinds. However, I am also of the impression that there are many mothers and housewives who are more conscious of nutrition than ever before and who read labels in order to try to estimate nutritional value and to purchase a food supply that constitutes good nutrition at a satisfactory price.

A trend is also taking place whereby people seem to be turning away from our present processed food supply which in safety and quality exceeds anything ever seen anywhere before, and leaning toward the old fad of "natural" foods and foods with no chemical additives. This trend is apparently being fanned by the fear created by the widespread reports of mercury in foods and the withdrawal of large amounts of tuna and swordfish, although no case of toxic effects has been found from the normal use of these foods in the United States. The fear generated over the withdrawal of the cyclamates, although no important toxic effects were ever seen in man, and the fear of carcinogenic substances in foods, although to the best of my knowledge no case of human cancer has ever been traced to eating a food in this country, is really unjustified. This type of publicity has tended to create a feeling of fear and distrust in our food supply which is totally unwarranted. If this trend continues to grow, it must result in an increased cost of food, decreased availability, and a deterioration in quality and possibly nutritional value.

It seems to me that one can only take the view that we must do everything we can to make our food supply nutritionally adequate at the lowest possible cost. In order to do this we must use synthetic nutrients of all kinds on the basis of demonstrated safety and effectiveness. If there is a demonstrated need and it is economically feasible under suitable regulations, I can see no objection to improving the nutritive value of any food that is known to be nutritionally defective, by the use of mixtures of processed foods and the addition of chemical additives as needed. The necessity for such products is already evident in developing countries where malnutrition is a serious health problem aggravated by rapid growth of the population. It is heartening to a public health man to see the vast effort that the chemical and food industries are already making. Many low cost high protein vitamin and mineral fortified preparations are under development. New pasta products are being introduced, and many beverages are receiv-

ing a great deal of attention. The use of enriched flour is being broadened to cakes, pancake mixes, and other products. Snack foods are being nutritionally improved and the meat analogs prepared from textured protein offer great possibilities.

In closing, there is one thought that I would particularly like to leave with you. Much effort has been spent in the past trying to produce and market a single food product that is adequate in all nutrients, and our science fiction writers dream of the day when we can get all of our nutrition from a pill. Although such things are technical possibilities and may be useful in emergencies or special situations, they are unrealistic when it comes to the population of this country. We eat meals of combinations of foods and I think we are all going to continue to do so for the foreseeable future. We should create foods which make tasty, satisfying, and nutritionally adequate meals.

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Nutrification: A Concept for Assuring Nutritional Quality by Primary Intervention in Feeding Systems

Paul A. Lachance

Malnutrition can and does exist in highly technological societies. Assuring adequate nutrition on the basis of a balanced intake of commodity foods is impractical because an increasing percentage of the American dietary is derived from preprepared convenience foods with varying nutritional value. Restoration, fortification, and enrichment as classically defined are evidently insufficient in practice to assure a community-wide, fail-safe, balanced nutriture. Nutrification—meaning to make completely nutritious—of selected foods would foster adequate nutrition community-wide in spite of man's diet habits and would thwart malnourishment. Meal replacements as well as any food which provides 7% or more calories as utilizable protein should be considered for proportionate nutrification with the NAS/NRC Recommended Dietary Allowance (RDA) nutrients. This approach, based on protein, would be consistent with nutritional biochemistry principles, existing information on diet habits, and food technology capabilities, as well as leverage for monitoring purposes.

Nutrification is a term meaning "to make *completely* nutritious" and has been proposed to describe the addition of a *proportion* of all necessary vitamins and minerals to food, particularly fabricated food. The objective of nutrification would be to foster nutrition or thwart community malnourishment (Lachance, 1970). A new term is needed, particularly in the case of formulated, fabricated, or engineered foods because such products may have ingredients which have already undergone restoration, enrichment, or fortification or conceivably all three.

We have arrived at a stage in the evolution of nutrition, food technology, marketing, federal guidelines and regulations, and consumer awareness wherein we must simplify and/or broaden our definitions in order to make technical knowledge on the one hand and responsibility to the consumer on the other more compatible.

We must recognize that man is a social being with both instincts and habits, who in the Western world is evolving in an increasingly sophisticated and systematized technological culture, controlled to a significant degree by economics (Lachance, 1971b).

Man has no inborn physiological or instructive urges to keep him on the safe side of malnutrition. He has food tastes (Clark, 1966) and food fashions (Leininger, 1970; Jerome, 1970) but these cannot be relied upon as a sound guide to nutrition, least of all in a technically sophisticated community such as our own.

However, modern man can alter the methods of food processing and food distribution as though the composition of his daily diet was of no greater biochemical importance to him than the style of his clothes or his automobile.

At least 90% of the food consumed in the Western technologically developed nations has benefited in some manner from food technology before the food is purchased by the ultimate consumer (Kertesz, 1966). Further, the effect of science and technology on dietary customs in the West is proving a potent force in the change of food habits, even where older cultures still persist (Pyke, 1968).

The 1965 USDA dietary survey of household diets (ARS, 1968; Leverton, 1971) revealed a 10% increase since 1955 (a 10-yr period) in the percentage of the population purchasing (and supposedly consuming) a poor quality diet (providing nutrients assuring less than $^2/_3$ of the RDA). This inferior input to nutrition is generally supported by the results of the National Nutrition Survey (Schaeffer 1970) and other nutrition studies (Davies *et al.*, 1969; Smith and Unglaub, 1972).

Bivens (1967) utilized the USDA household dietary survey to demonstrate the increase in the consumption of convenience foods over the same 10-yr period. It is my contention (Lachance, 1971a) that the dramatic increase in the consumption of highly palatable and socially acceptable snack type convenience foods, which provide for the most part only energy, has had a dilution effect upon the quality of the input of nutrients from conventional "basic four" type foods, thus decreasing the overall quality of the dietary.

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