Chemicals Introduced in the Processing of Foods

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The processing of foodstuffs for dietary purposes involves chiefly physical treatment, such as the trimming, cutting, and cleaning of vegetables, the butchering of meats and the application of heat or cold to foods of either plant or animal origin. From early days, however, man has made use of available technologic aids to help in the preservation of foods. Salt, flavoring materials and spices have long been used for the purpose of enhancing the flavor of food articles. At times in the past, some of the ingredients employed for the preservation of foods, or for the improvement of their acceptability to consumers, have been found to be contrary to the public interest. While the main protection to consumers has been, and will continue to be, the reliability of food manufacturers and their awareness of possible health hazards, there have also been enacted laws to protect the public. The federal law and the laws of every state prohibit the incorporation of harmful or deleterious substances in foods.

In recent years a considerable number of new chemicals have been brought to the attention of food processors and manufacturers. In many instances, it is questionable whether existing knowledge of the metabolic processes of nutrition is sufficiently extensive to warrant scientific approval of the use of some of the ingredients which have been incorporated in foods. The question arises whether the public needs greater health protection than now is afforded. The present article is a brief account of some of the substances introduced purposely in the processing of foods, from the viewpoint of their effect on consumers, in an attempt to answer this question. Traces of substances may be introduced inadvertently during processing or during storage or the preparation of foods for consumption; but the present report is concerned only with substances which are knowingly added to foods.

The substances purposely incorporated in foods during processing are included for nutritional or functional reasons, or both. The distinction in purpose may best be explained by examples.

The chemicals added to foods to enhance their nutritive value include all the vitamins and minerals of the well recognized enrichment and fortification programs. Such are the iodization of table salt, the fortification of margarine with vitamin A, the fortification of milk and evaporated milk with vitamin D, and the enrichment of flour and bread with thiamine, riboflavin, niacin, and assimilable iron preparations. Programs have also been worked out for the nutritional improvement, by vitamin and

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mineral additions, of corn meal and corn products, rice, and prepared breakfast cereal foods. The fortification and enrichment of foods with vitamins and minerals represent programs for nutritional improvement of important foods in accordance with modern knowledge of dietary requirements for health. They have been developed by the food industry with the guidance of nutrition experts and the sympathetic cooperation of government and industry.

The iodide added to table salt has been cited as an example of a chemical substance added to a food product for nutritional reasons. Usually potassium iodide is the iodine preparation employed for this purpose. Traces of thiosulfate may be added also, in order to stabilize the iodine content of the salt; in fact, unless such a stabilizer is incorporated in the salt it is quite likely that the iodine content of the table salt will be greatly reduced on storage. Such stabilizers, then, represent substances added for functional reasons. The tricalcium phosphate added to table salt to confer "free-running" properties represents another functional ingredient.

In general, functional ingredients are those which may be incorporated in the processing of foods for definite reasons, either to facilitate manufacturing processes or to confer some property to the finished article which is of interest or importance to purchasers and users of the article.

**NUTRITIONAL EFFECTS OF SOME INGREDIENTS ADDED FOR FUNCTIONAL PURPOSES**

Improvement in the nutritive value of foods is often a happy corollary to the use of substances added primarily for their functional value. The various calcium salts afford an interesting example. For the "hot biscuit" section of the country, phosphated flour has long been available. This is flour with added monocalcium phosphate. The purpose of the calcium salt is to correct for possible excessive use of baking soda in the preparation of sour milk biscuits. Calcium monophosphate is a common acidifying salt in self-rising flour and prepared pancake mixes. Tricalcium phosphate has been shown to be a useful inhibitor of caking in powdered sugar, although for this purpose starch is more commonly employed. The nutritional value of calcium salts in baking powders which contain them has been emphasized by Melnick, Oser, and Hockberg. Calcium acid phosphate may be used in bread production as an acidifying agent to correct for high pH of the water used in baking, or as an inhibitor of rope and mold. For the latter purpose, other calcium salts, such as calcium propionate, are similarly employed. Calcium salts are used in the formulation of so-called yeast foods for commercial bakers. The use of calcium salts as firming agents in the production of canned tomatoes and canned potatoes is a recognized procedure, permitted in the standards for these products. In every instance the calcium salt not only serves a useful purpose but also increases the nutritive value of the food to the extent to which it contributes additional calcium.

A recent survey of the calcium content of commercial white pan bread made throughout the United States showed that it amounted to, on the average, 401 mg. of calcium to the lb. Milk products accounted for much of this calcium, but calcium salts included for functional purposes also contributed. Tables of food composition, based on analyses of bread made some years ago, indicate much lower calcium figures.

Statistics of the Bureau of Commerce reveal that the consumption of monocalcium phosphate in 1948 amounted to more than 72 million lbs., or almost 0.5 lb. per capita. Nearly all of this calcium salt was used for food purposes. The quantity involved is sufficient to
supply at least 20 per cent of the average person's daily dietary allowance for calcium, assuming of course equitable distribution.

**ASCORBIC ACID**

Because of its chemical properties, ascorbic acid has been found to be useful in the prevention of browning in some cut fruits, notably peaches. Frozen sliced peaches, the fresh fruit color of which has been stabilized through the addition of ascorbic acid, contribute additional small amounts of vitamin C to the diet. The amount used is about 150 mg. of ascorbic acid per lb. of frozen fruit.

**SODIUM CHLORIDE AND SALT SUBSTITUTES**

Salt as an ingredient of processed foods is receiving considerable attention among physicians and dietitians because of the interest in low-sodium diets in the treatment of hypertension and other disease conditions. Sodium chloride is a dietary essential and, while low intakes are necessary for persons with certain disease conditions, increased intakes are indicated for individuals with some other diseases and for healthy persons who are subjected to environmental conditions which induce profuse sweating, with a consequent excessive loss of salt through the skin. Salt under ordinary circumstances is a condiment. Most people salt their foods to make them more palatable. It is customary to use salt both in domestic and commercial preparation of foods, the amounts being dictated primarily by considerations of flavor. To meet the needs of patients on salt-free or, as they are better termed, low-sodium diets, special preparations have been formulated such as canned, water-packed vegetables and salt-free bread.

An interesting development in connection with the use of low-sodium foods has been the formulation of salt substitutes which impart some degree of salty flavor to foods, but which contain no sodium. Potassium salts have met with some acceptance for this purpose. It is now clear that lithium chloride is unsuitable as a salt substitute.

It is unfortunate that, only after several deaths had occurred among patients using a lithium-containing salt substitute, lithium chloride was recognized as toxic under the conditions of its use in low-sodium diets. Had lithium chloride been considered as a drug, it could not have been sold for therapeutic purposes until its safety had been established by adequate experimentation under controlled conditions. As a "salt substitute," however, the new drug provisions of the Food, Drug and Cosmetic Act were not invoked.

It does not seem to be generally realized that new chemicals, intended for use in foods (unless conclusively known to be fraudulent) can be prohibited from interstate commerce only if their toxicity, or deleterious nature, if any, is demonstrated. Evidence of harmful properties must be substantial to hold up in court. The burden of proof rests on the government, in this case the Food and Drug Administration. Obviously, the time required to obtain conclusive information about some proposed ingredients may mean that considerable damage has been done before the situation is brought under control. It may be conceded that firms selling chemicals for use in foods are acting in good faith, on the basis of judgment which they as businessmen consider competent, but it is a fact well known to scientists that the results of preliminary tests may not be borne out by more extensive and intensive investigation. It should be recognized also that much more evidence will doubtless be necessary to demonstrate the harmlessness of some ingredients of foods than is needed to indicate the uses and limitations of a new drug.
CHEMICALS WHICH REQUIRE CONSIDERATION

Among the chemicals introduced in foods for functional purposes are the wetting agents, emulsifiers, stabilizers, so-called food improvers and preservatives, antioxidants for fats, and so on. Many of these substances are foreign to natural foods and little may be known about their behavior in the body. Not only may some of the substances suggested for functional reasons in food preparation be potentially hazardous in themselves, but the use of some of them also involves changes in the nature and nutritive quality of our foods which may not be recognized by consumers or even by those concerned professionally with matters of public health.

Many years ago Dr. H. W. Wiley and his collaborators in the Bureau of Chemistry of the U. S. Department of Agriculture reported elaborate studies of the influence of food preservatives on digestion and health. As a result of these investigations, which still serve as models of thoroughness, and the investigations of the so-called Remsen Boards, the use as food preservatives of boric acid and borax, salicylic acid and salicylates, sulfurous acid and sulfites, benzoic acid and benzoates, and formaldehyde, were prohibited entirely or, in the case of benzoates, and sulfur dioxide and sulfites, permitted in certain foods under rigidly specified limitations.

Because of the opinion which has been expressed in some quarters, and which no doubt has a modicum of truth, that government restrictions may act as a deterrent to progress in food technology, it may not be amiss to consider the effect of the ban of the use of formaldehyde as a preservative, say, in milk. Today there is everywhere available fresh milk, pasteurized and safe to drink, as nutritious as it is palatable, which keeps sweet for many days under conditions of ordinary refrigeration in the home. To bring this about has required a great deal of investigation and work by the dairy and allied industries, but the result has been a product of which industry, health authorities, and food regulatory officials may justly be proud. How much of this program would have been possible if, in the early days of pasteurization at the close of the 19th century, small amounts of formaldehyde had been tolerated as a functional ingredient of milk?

Today we are confronted with other problems, some of which are no doubt just as difficult of solution now as were the questions posed by certain food preservatives 45 or more years ago. A few illustrations of questions recently considered by food regulatory officials may point up the problem which confronts all those interested in the maintenance of the integrity of our food supply.

MONOCHLORACETIC ACID AS A PRESERVATIVE OR STABILIZER

Monochloracetic acid, a white solid synthesized in the laboratory many years ago, first came to attention as an inhibitor of bacterial action in food products as a result of work done in Europe, for which a French patent was issued in 1933. Tests by members of the food and chemical industries showed its potential usefulness in the preparation of certain fruit juices, soft drinks, beer and wine. As little as 0.05 per cent or less of monochloracetic acid as an ingredient would permit effective pasteurization at lower temperatures, avoiding thereby discoloration or the formation of turbidity, and giving the beverage a crystal clear or sparkling appearance. Tests by competent pharmacologists, which were reported in the scientific literature, seemed to show conclusively that the monochloracetic acid in the concentrations which were commercially useful, is harmless “even in continued daily ingestion by infants.”

Later studies in other laboratories
showed that monochloracetic acid is very irritating to the gastrointestinal tract and acts to inhibit respiration of tissue cells. In the light of the other favorable reports, however, these reports of unfavorable effects may not have seemed to be conclusive; at any rate monochloracetic acid was offered for sale to the food processing industries, and it was used for its functional value in the production of beer, wine, and other products. During the war, however, large numbers of soldiers in a southern camp exhibited severe gastrointestinal distress, with nausea and vomiting. Study revealed that the condition was caused by the consumption of beverages which had been “stabilized” with monochloracetic acid. Apparently this evidence, coupled with the reports of other laboratory studies, was conclusive enough for the courts to accept. Hundreds of thousands of dollars worth of beer were ordered to be destroyed because it contained monochloracetic acid. An even greater quantity, in money value, of wine had to be destroyed, and it is said that some smaller wineries were obliged to go out of business because of the loss of an entire year’s output. Through such activity, the food processing and beverage industries have learned that monochloracetic acid is not suitable for use as an ingredient of articles offered for sale to the public. Can the conclusion be drawn that it would be better to require adequate testing of any new ingredient intended for use in food products before it is used, rather than afterward?

**THIOUREA**

In 1933, there were published reports that thiourea, a substance found to be effective in 1926 for the stimulation of growth of potato shoots, would prevent the browning of cut fruits exposed to the air. This was before the effectiveness of ascorbic acid for this purpose in some products had been shown. Two American patents covering the use of thiourea for the prevention of browning of cut sections of apples, pears, and peaches were issued in 1937 and in 1943. There were published several reports from the laboratories of the corporation to whom the patents had been assigned, to show the harmlessness of thiourea. But in 1941, three investigators at Johns Hopkins University studied the effect of thiourea on the thyroid glands of experimental animals. Thiourea was found to have a depressant effect on the thyroid, inhibiting the production of thyroxin. Further studies in several laboratories amply verified this observation, and also showed beyond question that thiourea is a dangerous substance which has no place in foods. Yet in 1946, the Food and Drug Administration made several seizures of frozen peaches which contained hazardous quantities of this ingredient, about 45 p.p.m. of thiourea. When fed to adult rats, so that the quantity of thiourea consumed was about 1 mg., the animals died overnight and, on autopsy their lungs were found to be filled with a watery exudate. Relatively small doses of thiourea are poisonous to all animals to which the material has been given. The use of this substance for medicinal purposes, as in the treatment of hyperthyroidism, is outside the scope of present considerations.

Because of its therapeutic usefulness, or the usefulness of some related compounds, thiourea has received considerable study. It is now known that long continued ingestion of thiourea by experimental animals results in a high incidence of thyroid hyperplasia with the development of adenomata. The occurrence of tumors in the liver has been reported when animals have been given amounts of thiourea that may be below those necessary to cause marked hyperplasia of the thyroid.

In the food technology literature one
may find reports that thiourea is capable of stabilizing vitamin C, preventing loss of ascorbic acid in solutions, and retarding the development of rancidity in dried milk formulations such as are used in infant feeding. Thiourea has been found to prevent the development of mold in wheat of high moisture content, and the investigators who observed this effect were cautious enough to test the effect of thiourea on the germination of the wheat. In the concentrations employed they reported that the effect on wheat germination was negligible. Three reports over a period of years have demonstrated that the dipping of oranges in solutions of thiourea has a striking effect in preventing stem-end rot and decay by the blue and the green molds, but traces of thiourea remain in the rind and, in a relatively short time, appear in the juice of the oranges. The technologic details for the most efficient method of treating oranges with thiourea have been worked out and reported, but it is hardly likely that they will be put into operation. Nor is it likely that homemakers or manufacturers will follow the implied suggestions published, and later retracted, by one of the government agencies on the use of thiourea in the preparation of frozen peaches.

NITROGEN TRICHLORIDE

Nitrogen trichloride is a gas with which few students of chemistry in our schools and colleges have an opportunity to become acquainted in the laboratory, but which until recently has had intimate contact with most of the bread-stuffs which everyone eats. Introduced to American millers from Europe about twenty-five or thirty years ago as a substance for the artificial maturing of flour, nitrogen trichloride soon reached the forefront of chemical agents for the rapid improvement in baking properties of either bakery or family flour from freshly milled wheat. It was recognized by the Food and Drug Administration as a suitable bleaching (and maturing) agent for flour. It must be conceded that the evidence in support of the harmlessness of this treatment of flour had appeared to be adequate, and today there is no indication whatever of any harm to human beings from the consumption of nitrogen trichloride treated flour or its baked products.

Late in the year 1946, however, Sir Edward Mellanby reported that flour treated with nitrogen trichloride, when incorporated with milk and suitable vitamin and mineral supplements in a diet adequate for the growth of puppies, or the maintenance of older dogs, produced a pathological condition in the dogs known among veterinarians as canine hysteria, running fits, or fright disease. It is a nervous disorder that can be cured if it has not progressed too far, by changing to unbleached flour or to flour which has been treated with other recognized bleaching and maturing agents. Within a few weeks, Mellanby's report had been verified and extended as the result of several independent studies in the United States. It was found that other species of animals, the cat, rabbit, rat, monkey, and ferret, showed central nervous system disorders when fed large amounts of flour heavily treated with nitrogen trichloride. Feeding tests with human volunteers were negative, even though competent investigators looked for disturbances with all the facilities of modern medicine at their disposal.

There has been no nitrogen-trichloride-treated flour permitted on the market since August 7, 1949, and even before that time the use of this agent had diminished to nearly the vanishing point. Its disappearance resulted from the voluntary action of American millers who, in effect, asked for the elimination of nitrogen trichloride from the standards for bleached flour and the substitution of chlorine dioxide as a suitable bleaching and maturing agent. Ex-
periments showed no deleterious effects from the feeding of flour treated with this latter agent. As a result of such evidence presented at a public hearing, the Food and Drug Administration revised the standard for bleached flour.

The subject of bleaching of flour has had a long history, but the work done as a result of the nitrogen trichloride incident emphasized the relative paucity of knowledge as to the mechanism of the action of artificial maturing agents on flour. There are a number of countries where chemical bleaching or maturing of flour has been prohibited for one reason or another, and the physical characteristics of the bread in these countries are different from those of ordinary American white pan bread. Perhaps the fact that artificial bleaching and maturing agents and oxidizing agents have been recognized in the United States is an example of how progress, say along the lines of improving baking quality of flour by the application of heat, has been retarded. This is a subject that could well be explored thoroughly by the milling and baking industries. The per capita consumption of wheat flour has declined considerably from what it was before the use of bleaching and maturing agents came to be common in the milling industry, and oxidizing agents (which have much the same functional value as the maturing agents) came to be used in the baking industry. There have been many conjectures about the possible causes of this phenomenon of declining consumption. There is no more proof of the validity of any of these suppositions than there is that the effects produced by chemical treatment of the flour or dough may be responsible, in some degree at least.

MINERAL OIL

Mineral oil is not absorbed, except possibly in minute traces, from the digestive tract, and it has no food value. It is used medicinally as a mild cathartic. In foods, it has been used for fraudulent purposes, as a substitute for food oils or fats without label declaration, or it has been incorporated in salad oils and dressings, and in mayonnaise, with labeling of the products as foods of particular usefulness in dietary caloric or fat restriction. The sale of foods containing mineral oil is considered illegal, even if the label declares the presence of mineral oil, because the courts have held such preparations to be deleterious. There is ample reason to support this stand, for the ingestion of mineral oil with other foods, as is inevitable when mineral oil is incorporated in such foods, results in the excretion of excessive amounts of some of the fat-soluble vitamins, which are soluble in the mineral oil and carried with it out of the body. The food factors capable of being lost in this manner are carotene, vitamin D (with a consequent disturbance of the metabolism of calcium and phosphorus), vitamin K, and no doubt other substances of importance.

During World War II days, and afterward when the supply of fats was short, there may have been a temptation to substitute mineral oil for food oils. Violations of the prohibition against the use of mineral oil in food have been recorded in instances involving popcorn, salad oils and dressings, mayonnaise, and a few other food products.

OTHER INGREDIENTS AGAINST WHICH REGULATORY ACTION HAS BEEN TAKEN

An examination of the notices of judgment published lately shows several other instances where an alert Food and Drug Administration has brought action in the interest of public health. Saccharin, a product with an interesting history, has been found as a substitute for part of the sugar in soft drink beverages and other foods. Fluorides have been found in beer, where they have been
included for preservative properties. Quaternary ammonium compounds have been found in a few other foods, in which it appears either as a contaminant from the use of this material in sanitizing apparatus or as an added preservative. Surely all would agree that action to prevent such abuses is highly commendable. With a limited number of federal food inspectors, however, one wonders how many other instances are not recognized, and one wonders also how well abuses which do not involve products sold in interstate commerce are taken care of.

INGREDIENTS OF DOUBTFUL SIGNIFICANCE

There are a number of chemicals being offered for sale to food manufacturers, about the safety to health of which little is known. Parahydroxybenzoic acid, first used in Europe, is being offered to food manufacturers as a preservative in place of benzoic acid. There is a patent covering a process for the treatment of flour with diluted nitric acid; an orange colored product is obtained as one would expect in recalling the xanthoproteic reaction as a test for proteins. When dried and mixed with ordinary flour to the extent of 2 per cent, and with the addition of a little soya flour and lecithin, the resulting preparation has been offered for sale to bakers. The function of this preparation is to convey a deep yellow color, similar to that produced by egg yolks, so that a bun or sweet roll has a better consumer acceptance, at least as far as appearance of the article is concerned. The effects on human beings of eating products containing this nitric-acid treated flour are unknown.

The trade journals of the food processing industries almost regularly contain announcements of new chemicals which reputedly have a functional value in certain processed foods. Advertising literature, samples, and demonstrations may help convince a businessman that a particular chemical has merit. If the processed food under consideration is not one of the relatively few for which definitions and standards of identity have been established by the Food and Drug Administration, then the businessman is in a position to take a considered risk and use the ingredient. The competency of the manufacturer and the wisdom of his scientific advisers may afford just about all the protection the consumer receives in some instances. If used the chances are excellent that consumers and health officers will be unaware of the nature of the new ingredient.

EMULSIFYING AGENTS IN BREAD AND OTHER FOODS

Beginning November 30, 1948, the Federal Security Administration reopened a public hearing for the purpose of receiving information which would enable the Administrator to develop a definition and standard of identity of bread and bread-like buns and rolls. This hearing was concluded on September 20, 1949. Although there were some recesses during the course of this reopened hearing, the taking of testimony covered more than 100 days, and the transcript of the record covers thousands of pages. This would seem like a great deal of testimony about the ingredients of a food item such as bread, but much of the record is devoted to testimony about certain chemicals which were unknown in the baking industry prior to 1946 or 1947.

Among the proposed ingredients for inclusion in the standard are the surface active agents sometimes designated as "bread softeners." One of these compounds, or mixtures of substances, which conveys to the finished baked loaf properties which some bakers have testified they liked, is polyoxyethylene monostearate. This is not a pure chemical compound, but a mixture of substances produced in the polymerization of ethyl-
ene oxide, or of ethylene glycol, depending on the method of manufacture, followed by esterification with a fatty acid, which may be commercial stearic acid. It is conceded by the manufacturers that only about 40 per cent of the molecule (the fatty acid portion) has possible food value; the polyoxyethylene portion is excreted partly by way of the intestines and partly by way of the kidneys. It is not established that none of the polymerized oxyethylene moiety remains in the tissues of the body. Evidence of the possible toxicity of this substance is conflicting. It has been recommended for use by bread bakers to the extent of \( \frac{1}{2} \) lb. to each 100 lbs. of flour; more has been used, and less has been suggested. It has been found that this material precipitates the amyllose fraction of wheat starch, leaving an excess of the amylopectin fraction in the bread. The bread has an unusual softness when removed from the oven, probably because of the alteration of its structure. There is evidence that such bread stales at the same rate as bread which does not contain the softener, but it remains measurably softer to squeezing throughout the normal shelf-life of the bread.

The so-called emulsifiers or surface active agents are being used, it is reported, in commercial cake as well as in some prepared cake mixes, in salad dressings and mayonnaise, in ice cream, and in many other products. The first commercial product in the cake field seems to have been developed during World War II as a substitute for eggs, which were in short supply. Eggs, in addition to their nutritive value, have a functional value in cake batters; the lecithin of the egg yolk is a fairly efficient emulsifying agent because it is soluble in fats and in water.

Apart from the question of possible harmful or deleterious effects of some of these substances, there is a nutritional question involved in their use. Should the inclusion of the newer emulsifying or surface active agents in foods encourage or permit the replacement of appreciable amounts of ingredients such as milk, butter, eggs and shortening in processed foods, there is the possibility that the nature and nutritive quality of our dietary may be significantly altered without the knowledge of consumers or the awareness of persons interested in public health.

**CONCLUSIONS**

The use of chemicals in the processing or formulation of many foods is increasing. In many instances the use of certain substances as ingredients of processed foods raises grave questions of the effect of their use on the nutritive quality of our diet, and on the health of consumers. While the present Food, Drug and Cosmetic Act affords considerable protection, to manufacturers as well as to the public, there is insufficient protection offered in the case of products for which definitions and standards of identity have not been promulgated. A considerable improvement would be provided if the Federal Food, Drug and Cosmetic Act were amended to require the same unbiased consideration, and approval prior to their use, of new substances intended for foods as the present law now extends to new drugs.