Ten years ago the following message was typed on a postcard and sent through the Los Angeles mail: "Propaganda is that heart disease, tuberculosis, and automobile accidents are the leading killers. Facts are that medical doctors with their drugs and poisonous vaccines are the leading killers. Donating to medical research is useless. It only adds more poisonous drugs to kill the people. The United States leads in the sick, the insane, dope and cigarette fiends, crime, alcoholics, and slums. Most meat, fowl, fish, eggs, milk products, and bread sold today are diseased with antibiotics and drugs. Such processed foods as coffee, tea, spices, condiments, salt, sugar, bread, cakes, crackers, cereals, grains, rice, colas, soft drinks, candy, alcohol, beer, and canned and frozen foods add more poisons to the human body. Most farmers use poisonous fertilizers and sprays that cause sickness and death to humans. We are a sinful nation of over-fed gluttons eating the wrong foods, drugs and vitamins. The Pure Food and Drug Act is useless." The author of that statement, if he hasn’t starved to death as a result of being afraid to eat, must be very surprised to find that now, ten years later, not everyone is dead and, in fact, many people believe that the population explosion is the major problem man must solve. Many people maintain that if we do not control population by reasonable means, its level will eventually and inevitably be controlled by war and famine. Recently, I saw the following statement, "There is a population level above which happiness, health, and even life itself cannot exist, whether we are talking about flies in a bottle, fleas on a dog’s back, or men on earth."

Misconceptions about foods

There are many misconceptions about foods and nutrition. A lot has been said and written indicating that people involved in agriculture and food processing are poisoning the American people by using chemical fertilizers, adding chemicals to foods, and selling synthetic chemical compounds as substitutes for natural foods and food constituents. Chemistry is a special area of learning that the average person doesn’t understand very well, and it seems natural for people to worry a lot more about things they do not understand. People are much more concerned about hidden hunger than they are about the rat poison in the kitchen cabinet next to the flour. No one wants to fall dead, suddenly and prematurely, for no good reason, after he has been carefully preparing for a long life by clean living.

Certainly there is nothing wrong with the word chemical. All fertilizers are chemicals. All foods are chemicals. This includes table salt, water out of the tap, milk, the wheat-germ oil one can buy at a health-food store, as well as all synthetic food constituents and additives.

Synthetic food constituents and additives are not inherently bad. It is true that the exact composition of many foods is not known but, nevertheless, any food one might mention is basically a chemical compound or a specific mixture of chemical compounds. All samples of a specific chemical compound are the same, whether made by men in laboratories or by the metabolic systems of living things. They are either utilized or not utilized by the human body, regardless of source. A specific chemical compound might be utilized by one organism and not by another. It might even inhibit the second organism. When one finds a compound that in small quantities inhibits undesired organisms but is utilized by the intended consumer—or, at least, does not harm him—then one has a potentially useful preservative.

In the absence of understanding, the word natural seems to have a psychologically soothing effect on many people. Yet, not all products used as foods are safe for consumption in the natural state; for example, raw soybeans. Some unsafe natural products can be transformed into good foods by various processing and manufacturing techniques. Chemicals are frequently used in such conversions. Other foods can be improved by chemical treatment and, when this practice is safe, it should be encouraged not discouraged.

Uses and control of food additives

There is nothing inherently foreign or harmful about adding chemicals to foods. There are hundreds of food additives in use. Even some of the additives have additives. For example, baking powder and table salt, which are additives, have calcium silicate added to them to keep them from absorbing moisture and caking. Adding chemicals to foods is a good thing so long as the chemicals added serve useful purposes and are not harmful to health. Without them many of our present foods would not be available in the convenient form and at the high quality, low price, and large quantity existing today.

Chemicals are used to assist in processing, manufacturing, storage, or distribution of foods. Chemicals are useful as preservatives, nutri-
Progress in the transformation of food processing is being accelerated in recent years, along with great problems and in products. The category of concern here is the matter of using chemicals as preservatives.

Use of food additives must be properly controlled. The Federal Food and Drug Administration is responsible for the control of additives in foods shipped interstate; the state government is responsible for the control of foods produced and consumed within the state. In California the control of additives in milk and dairy products is provided by the Bureau of Dairy Service. The guiding principle used by the Bureau of Dairy Service is that an additive is legal if it is included in the legal definition of the product. If the additive is not included in the definition of the product, its addition to the product is illegal. There is cooperation between the Bureau of Dairy Service and the Food and Drug Administration.

Control of additives in interstate commerce by the Food and Drug Administration is somewhat as follows: A list of safe food additives and tolerances is published. The current list contains about 800 chemical compounds. Chemicals not on the list must get specific approval before they can be used. A food industry or company seeking approval for an additive must state the intended use, prove that the additive is safe, and show that the intended use will be helpful. If tolerances are necessary to assure safety, it must be shown that the additive gives the intended desirable effect at the levels permitted. The chemical identity of the compound must be stated, and practical methods must be provided for determining residues of the additive. No compound that produces cancer can be used.

No one should think for a moment that controls are inadequate, that those in charge of controlling the use of food additives take their responsibilities lightly, or that additives are permitted in foods without good reasons. Controls are adequate, the consumer is well protected, and there are good reasons why he should be very pleased about how satisfactorily he is cared for in this regard.

Prevalence of adding chemicals to foods

Adding chemicals to foods as preservatives or for other purposes is not new, though some people seem to feel that adding chemical substances to foods is new, and that any such act is somehow deceptive. Actually, man has been adding chemical substances to foods throughout recorded history. Use of food additives has accelerated in recent years, along with great progress in the transformation of food processing and packaging to scientifically controlled operations. Chemistry has been used as a tool in solving many technical problems and in providing consumers with foods they otherwise could not have.

Addition of chemicals to milk and milk products, as preservatives or for other purposes, is neither new nor uncommon, though we are generally inclined to think of additives as applying primarily to other foods, and not much to milk and milk products. One of the first chemical substances used as a preservative undoubtedly was rennet, used in preserving milk in the form of cheese. This seems to have started accidentally, around 8,000 B.C. Butter-making dates back to very early times, and it is probable that sodium chloride was first added to butter at a very early date. Calcium propionate and sorbic acid are used in some dairy products to prevent growth of yeasts and molds. Vitamins A and D are added to much market milk as nutritional supplements. Were ascorbic acid (vitamin C) used to prevent the development of oxidized flavor in milk, it would be a preservative. Chemical coloring compounds are added to cheese, butter, and ice cream. The large amounts of sucrose and dextrose used in dairy products are chemical additives. Many chemical flavoring agents are used, especially in ice cream and chocolate milk. Stabilizers and emulsifiers are used in various dairy products, particularly in ice cream. Calcium chloride is used to assist rennet in the making of Cheddar cheese. Hydrogen peroxide and catalase are used to destroy microorganisms in some milk for cheese-making. Large quantities of alkaline chemical compounds are used to neutralize cream for butter-making.

Preservation of foods

The obvious definition of food preservation is to preserve a food, to keep it from spoiling for a period longer than it would have kept had it not been preserved. There are several commonly used methods of preserving foods. Canning, drying, freezing, and vacuum-packing are examples, as well as the addition of chemicals. The type of spoilage prevented might be a type of chemical spoilage (oxidized flavor, for example), or it might be a type that can occur only as a result of the growth and metabolic activity of microorganisms.

Defects produced by microorganisms can be prevented either by killing the microorganisms or by preventing their growth. Both methods are applied in many products. Market milk, for example, is pasteurized to kill microorganisms and subsequently refrigerated to prevent the growth of those not killed or that got in after pasteurization. In addition to the physical means of killing microorganisms or preventing their growth, certain chemical compounds are commonly used as preservatives in many perishable foods—salt in butter, aureomycin in dressed chicken, sodium or calcium propionate in bread, sodium benzoate in fruit juices, etc. Some of these compounds are natural products, some are made in the laboratory, some are

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produced by microorganisms. Aureomycin and lactic acid are examples of preservatives produced by microorganisms. Though you might not have considered lactic acid a preservative, you are aware that many potential spoilage organisms will not grow in buttermilk, because of the high concentration of lactic acid.

In a broad sense, all compounds that act on microorganisms to prevent their growth, and in most cases to kill them, are preservatives. Yet, there is a tendency to define the word preservative in a less broad sense, as meaning only those chemical compounds able to act directly on microorganisms when used in very small quantities.

**Modes of action of preservatives**

Preservatives normally act on microorganisms in one of two ways: One mode of action is, in one way or another, to influence cell permeability adversely. A bacterial cell is composed of cytoplasm and a semipermeable membrane, encased in a bag-like cell wall kept intact by covalent chemical bonds. The cell wall is comparatively thick, about 100 to 200 Angstrom units, composing about 20 to 25% of the dry weight of the cell. Its functions are to maintain cell rigidity and shape and protect the cell against changes in osmotic pressure. All food materials and waste products must pass through the cell wall, either by passive diffusion or by active transport involving stereospecific enzymes called permeases. High concentrations of compounds that influence osmotic pressure can do harm to the bacterial cell in spite of the protective influence of the cell wall. For example, a high concentration of salt or sugar can cause plasmolysis. Water passes out of the microbial cell; the cell dehydrates and becomes inactive. Some compounds (lysozyme, for example) can hydrolyze or dissolve the cell wall. Other compounds, such as the antibiotics, disrupt or interfere with cell permeability by other mechanisms.

The other mode of action of preservatives is to interfere with one or more of the numerous essential enzymatic reactions that must go on if the microbial cell is to live and multiply. Chances are that the same reaction interfered with is also essential in the metabolism of people; but a man is very much larger than a microbial cell, and the quantity of a preservative required to affect his health is very much greater than that required to affect the health of a microbial cell. This fact is very important in chemo-therapy, the use of chemicals (medicines) to control diseases. Another matter of great importance in regard to consumer safety is the action of the protective mechanisms of the body. Sorbic acid, for example, interferes with oxidative phosphorylation, an essential enzymatic reaction in the metabolism of both man and microorganisms. Yet, sorbic acid can be used as a food preservative because it is decomposed in the body before it does the consumer any harm.

Another preservative, hydrogen peroxide, is rapidly split into water and oxygen in the body.

**Use of preservatives in milk**

Chemical preservatives have been used in the preservation of some milk products for a very long time, but there has not been much use of them in fresh milk. The general attitude in most countries has been that fresh milk is a basic food and that its preservation should be secured through improved methods of production, processing, and distribution, rather than through addition of preservatives. Against this thought there is the philosophy that preservatives are permitted in some other basic foods; that intelligent use of preservatives would undoubtedly result in greater use of milk in countries where methods of production, processing, and distribution are not well-developed, especially in countries with warm climate and few household refrigerators; that permitting intelligent use of preservatives would not prevent the establishment of stringent sanitary requirements and the use of adequate sanitary measures in production, processing and distribution.

In view of the good that might come from their use in underdeveloped warm countries, several preservatives have been studied as possible substitutes for pasteurization, and as possible means of keeping milk sweet until it can be pasteurized. Hydrogen peroxide is the preservative that has received most attention. After hydrogen peroxide is added to the milk and permitted to act, catalase is added to inactivate the residual hydrogen peroxide. This treatment apparently works quite well as a means of retarding the souring of unrefrigerated milk, but it is questioned as a substitute for pasteurization, because experiments indicate that certain pathogenic microorganisms, especially *Mycobacterium tuberculosis*, may be able to survive comparatively severe hydrogen peroxide—catalase treatments. Consequently, authorities on the subject recommend that milk treated by hydrogen peroxide to delay souring should subsequently receive an effective heat treatment to ensure the destruction of pathogens, before it is distributed to the consumer, except in cases where it is used to manufacture products that could and would have been made from raw milk without the hydrogen peroxide treatment.

About two years ago some dairy industry people in California decided that the dairy industry should know more about the possibility of using preservatives in milk and fresh milk products under our conditions—not as means of keeping milk sweet until pasteurized or as substitutes for pasteurization or good sanitation. They were aware of the fact that preservatives are permitted in many foods and wanted to know if some of them might have value as a means of prolonging the shelf life of pasteurized milk and fresh milk products made from pasteurized milk. They proposed to the California
Dairy Council that a broad project be undertaken aimed at trying to find ways of improving the shelf life of milk and milk products, including use of preservatives. They gave the following reasons in the project proposal:

(1) There is a tendency for consumers to reduce the frequency with which they make purchases of dairy products. Retail deliveries generally are made every other day, but in some cases are made only once a week. Consumers expect dairy products to keep with little or no deterioration.

Restaurants, for example, usually let cream or half-and-half remain on the tables without refrigeration for many hours or until used. Whipping cream is often stored longer than recommended. These practices jeopardize the quality of such products.

(2) The dairy industry is duty-bound to process and distribute products economically. It is understood, of course, that economies that impair the quality of products are false economies. Less frequent deliveries are a means of utilizing economies, that is, if the shelf life of the product delivered is satisfactory.

(3) Reducing or eliminating returned merchandise would result in considerable or significant economies to the dairy industry, and enable them to pass on some of the savings to the consumer.

(4) Fungistats are currently used in certain food products, and consumers have become accustomed to their use in these cases. Approval to use preservatives in certain dairy products has been sought, with permission granted in a few instances. In such cases the objective is the extension of shelf life.

(5) Even though it is legally not possible to use preservatives in milk and related products, it is felt that the field should be explored as a basis for deciding whether such practices should be recommended in specific cases. It is not desirable to use preservatives as a substitute for good sanitary practices, or as a substitute for acceptable processing methods. But it is felt that an exploration of the uses of preservatives might be profitable for all concerned.

Differences in sensitivity of microorganisms to preservatives

The specified intention of the study of preservatives included in the project was that it should deal with the retardation or prevention of microbiological problems. It was not a sure bet that preservatives would be found useful in pasteurized milk and fresh milk products, though several preservatives are commonly used in some perishable foods. One reason is that pasteurized milk and fresh milk products are ready for consumption when they are sold. The consumer normally does not give them a treatment that can be depended on to get rid of or destroy a preservative. Take aureomycin in fish or poultry meat, for example. Aureomycin is permitted in these foods only because they are normally cooked more than enough to destroy the added aureomycin.

Another reason is that preservatives are generally not universally effective. A particular preservative might be very effective against fungi and quite ineffective against bacteria. Earlier, I mentioned that the list of food additives accepted as safe contains approximately 800 chemical compounds. Of this large number of compounds, only 15 have appreciable antimicrobial activity when used in small quantities. Further, 12 of the 15 are primarily antifungal compounds. Eleven of this 12 are propionic acid, sorbic acid, benzoic acid, and various salts and esters of these acids. Another ester, diethyl ester of pyrocarnic acid (DEPC), completes the dozen. These acids and their derivatives are noted primarily for their activities against fungi, because fungi can grow at low pH values, whereas most bacteria cannot grow, or grow very poorly, at pH values below 5.0. At pH values approaching neutrality, where control of bacteria is very important, these acids and many of their derivatives are unable to pass through cell walls readily and are not very destructive.

Three accepted safe compounds remain on the list: (1) borax, permitted only in export meat; (2) potassium bisulfite, not permitted in foods recognized as sources of vitamin B. (thiamine), but used primarily to prevent browning in foods (though it is also used as an antimicrobial agent in wine-making and bottled dry wines); and (3) chlortetracycline (aureomycin), permitted at the rate of not more than 7 ppm in fish and poultry, only because they will later be cooked sufficiently to destroy the aureomycin. Applications have been submitted for use of two compounds active against aerobic bacteria, neomycin and tylosin, but these compounds are active primarily against gram-positive bacteria.

Whether the bacteria normally important in the spoilage of a product are gram-positive or gram-negative is important in selecting preservatives. Bacterial cell walls are very complex in composition, and the fact that some bacteria take the gram stain while others do not is a reflection of the difference in cell-wall composition. The cell walls of gram-positive bacteria are much simpler in chemical composition than those of gram-negative bacteria. At least partly as a result of the greater simplicity of the cell walls of gram-positive bacteria, some preservatives are quite effective against them in small concentrations, but ineffective against gram-negative bacteria. In fact, it is very difficult to find potential preservatives effective in small quantities against gram-negative bacteria, particularly at pH values near neutrality.

It is the gram-negative bacteria that are of greatest concern in efforts to improve the shelf life of milk and fresh milk products. The gram-
negative bacteria of greatest importance in limiting the shelf life of pasteurized milk and fresh milk products are pseudo-photosynthetic. Many belong to the genus *Pseudomonas*, and some to the genus *Alcaligenes*. A well-known representative species of the genus *Pseudomonas* is *P. fragi*, the organism that commonly produces fruity odor in milk, Cottage cheese, half-and-half, and a variety of dairy products. In addition to being difficult to inhibit with preservatives, these microorganisms are among those most difficult to kill with chlorine and other sanitizing agents. They often manage to get into pasteurized milk and pasteurized milk products in very small numbers. Potable water used for rinsing clean equipment is a common source of this contamination. They are able to grow slowly at refrigeration temperatures, and only a few per quart can become sufficiently numerous to cause spoilage after five to seven days, particularly if the refrigeration temperature is a little high.

**Importance of differences in composition of foods**

Milk and products made from milk are different from each other and different from other foods in regard to preservation. To find a preservative useful against certain microorganisms in one food cannot be taken as proof that the same preservative will be found active against the same microorganisms in a different food. Thus, it should not be assumed that a preservative found useful in one dairy product will be found useful in other dairy products. For example, we found that lysozyme and EDTA (ethylenediaminetetraacetic acid) will inhibit *P. fragi* in lactose broth but not in skim milk or cream. The inhibitory action of lysozyme and EDTA against the organism in lactose broth can be prevented by addition of milk ash. This shows that low concentrations of lysozyme and EDTA most likely fail to inhibit *P. fragi* in skim milk because they are rendered inactive or ineffective by the large amounts of divalent metal ions, such as calcium and magnesium, in the skim milk. For the same reason, the inhibitory action of aureomycin is greatly decreased in skim milk and cream. Sorbic acid will not inhibit *P. fragi* in lactose broth at pH 6.5 or in skim milk, but we have found the same compound to do a good job of inhibiting the organism in Cottage cheese at pH 5.2. This is undoubtedly because sorbic acid is able to pass through cell walls much more readily at low pH.

Our studies are incomplete. We have found that most of the accepted food preservatives are of little value in fresh milk, but such negative information is valuable. On the other hand, if there are helpful preservatives that can be used safely to increase the shelf life of pasteurized milk and fresh milk products, we hope we can find them, because this information also will be valuable and should be available for possible use.

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