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THE ROMANCE AND ENGINEERING OF FOOD PRESERVATION[1]

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THE ELEMENTAL FOOD CYCLE

NATURE has provided a cycle for the conservation of the plant foods of this earth from one generation to another. Man in creating certain processes of civilization has defeated some of the purposes of nature by diverting constituent parts of the plants and animals from this cycle to uses for commercialized civilization.

In this diversion process these essential elements have been directed into modern sewage systems comprised of drainage streams and canals, and hence they have been deposited far from their points of origin. This diversion of the elements from the lands of their origin has slowly impoverished in strategic populated regions the animal-plant cycle established by nature. It has reduced the effective value of the essential elements where life has elected to live, and this to a critical degree especially in some regions.

It is very significant and fortunate that many of the elements to create food for living organisms are inexhaustible. As an example, carbon, oxygen, nitrogen and hydrogen are found in limitless and bountiful quantities in the air and water. From these elements starch, sugar, fats, fibers and protein are all produced. In other words, these several foods are made from unlimited constituents of air and water, transformed under the influence of the sun by the several botanical and biological processes into edible products. Chemically, each of these products originates from an inexhaustible source of supply.

On the other hand, many of the essential plant food elements that are contained in the soil are exhaustible. Potash, phosphate, calcium, magnesium, sulphur, iron,

[1] Address of the retiring vice-president and chairman of Section M (Engineering), prepared for the New York meeting of the American Association for the Advancement of Science.

copper and manganese when joined with some of the inexhaustible elements from the air and from water give us the most common organic compounds that occur in various forms in vegetables, in flesh and in bone structure. These organic compounds might be found in the form of wheat, cottonseed, corn, carrots, potatoes, bacon, mutton, beets, soybeans, etc., yet only a very small part of even these compounds are exhaustible. One hundred pounds of corn, for instance, contains only about one and one-half pounds, while a whole ton of tomatoes contains not over ten pounds of exhaustible elements. Table 1 shows the exhaustible element relationship of these and other food products.

TABLE 1

TABLE SHOWING EXHAUSTIBLE ELEMENTS NECESSARY TO PRODUCE ONE HUNDRED POUNDS OF FOOD PRODUCT

Name of product	Exhaustible elements expressed in pounds necessary to produce one hundred pounds of edible product
Apples	.5
Bananas	1.
Bacon	5.
Beef steak	1.5
Butter	4.
Chicken	1.5
Corn	1.5
Cottonseed	5.5
Milk	1.
Oats	5.
Oranges	1.
Peaches	1.
Potatoes	1.
Raspberries	1.
Soybeans	7.
Tomatoes	.5
Wheat	2.5

H. A. Morgan, formerly president of the University of Tennessee, and later chairman of the Board of the Tennessee Valley Authority, points out that since nature did not anticipate and provide for the use of her mineral elements and their resultant plant and animal compounds by man except as they should remain in the animal-plant cycle, eventually man must look forward to restoring the continuity of nature's program or he must follow the elements discharged into the rivers and take up his abode in the deltas and the flood lands. This procedure is not visionary, as is evidenced by some civilizations that have already had to adopt this method of feeding their multitudes.

In Fig. 1 is shown diagrammatically the interdependence of animal and plant life in the program of nature. Plant life is devoured or consumed by the animals, but all the constituent exhaustible elements are returned to the land either as fertilizers or as bone elements. Upon these plant foods new plant life subsists and furnishes the food for further generations of animal life. Our phosphate beds of today are the burial grounds of animal life of the eons of yesterday.

Fig. 2 indicates how man has upset the continuity of this plan by diversion of essential elements through the transportation and sewage systems of present-day civilization. Examples are multiple of man's upset of this natural sequence of fertility restoration.

For the most part each plant and each animal uses the same elements for its existence. Sixteen ele-

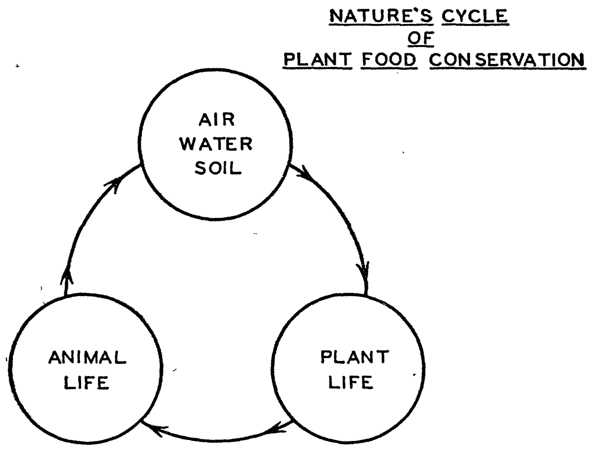

FIG. 1.

ments of the known ninety-two furnish almost the entire needs of the animal and plant life of the world. These are shown in their relation to each other in Tables 2 and 3. Of these sixteen, the three most

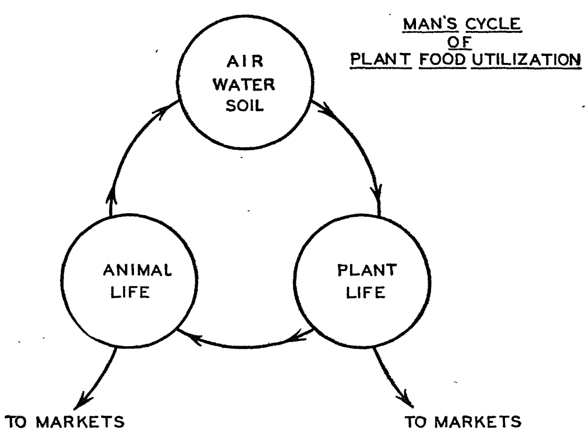

FIG. 2.

important and critical food elements are nitrogen, potassium and phosphate.

Of nitrogen there is a supply of twenty million tons over each square mile of the surface of the earth.

Of potash there is a fairly uniform supply distributed in the crust of the earth on all continents. There is no present evidence that we shall ever have a world shortage.

There are, however, real limitations of the third element, phosphate. Fortunately, nature has played a very important role in preserving for man that phosphate which he now has available. As it occurs in its natural formation most phosphate is locked up for the present and future generations through the implement of a small key of fluorine. This key modern engineering has been able to turn and thus unlock for our needs by high temperature electric or blast furnaces the phosphate products necessary to replace those that have been dissipated into sanitary sewage channels and transported to distant points of commerce.

Since the exhaustible elements of the earth are those of the soil there exists the idea that the fortunes of civilization depend in the ultimate upon the ability of the occupants of this globe to preserve the soil. This is quite true, but the breakdown can be carried to a more elemental analysis. Primarily, the ultimate fortunes of humanity depend upon the ability of the peoples on the face of the earth to conserve by careful utilization the phosphate portion of the soil for the generations yet to come.

TABLE 2

INEXHAUSTIBLE ELEMENTS FURNISHED TO THE ANIMAL-PLANT CYCLE BY AIR AND WATER AND THE EXHAUSTIBLE ELEMENTS FURNISHED BY THE SOIL

Air and water furnish the inexhaustible elements	Soil furnishes the exhaustible elements
Carbon Oxygen Hydrogen Nitrogen	Phosphate Calcium Potash Magnesium Sulphur Iron Zinc Boron Iodine Cobalt Copper Manganese

TABLE 3

FOOD COMPOUNDS PRODUCED FROM INEXHAUSTIBLE SOURCES AND THOSE PROVIDED FROM THE SOIL

Air and water furnish for plants from inexhaustible elements	Air and water furnish for animals from inexhaustible elements	Soil furnishes from exhaustible elements
Starch Sugar Fats Fibers and textiles	Fats Energy Protein Heat	Organic Compounds Bone Nature did not provide for man's diversion of these compounds from the animal-plant life cycle

More progress has been made in the research and development of phosphate extraction and processing for plant food during the past decade than had occurred before in any one hundred years. The world is beginning to recognize its dependence upon this essential element of human existence. Modern engineering is now providing the procedures and processes to conserve and utilize even the low quality and the isolated beds of the world supply of this strategic element.

FOOD HABITS OF MAN AND HIS NUTRITIONAL DEMANDS

Up to the present era, man has not been as greatly interested in the elemental food cycle and the conservation of our essential food elements as he has been in getting enough to eat each day and in being reasonably sure that he has a sufficient supply for himself and his family for his annual needs.

There is no historical evidence to indicate when man learned his lessons from the instinctive habits of the lower animals that inspire them to store food for the winter months. There is ample evidence that from the dawn of history his eating habits have been very profoundly affected by his ability to conserve the available edible foods over periods of scarcity.

Both in the lower animals and in man the nutritional requirements have been largely determined by instinct. Since the nutritional needs of a man do not change appreciably from one generation to the next, the process of trial and error that has extended over hundreds of years has created a large number of "do's" and "do nots" about traditionally accepted foods.

Since each plant and animal does use approximately the same chemical elements of nature in its growth, but these same plants and animals do vary considerably in quantity of any one element, those people who have been able to utilize a diversified number of plants and meats for their diet have not suffered seriously from any particular deficiency of nutritive food. Food habits, however, have had to adjust themselves to the availability of foods, and in most climates this has been very greatly affected by the facilities to preserve the foods during seasonal or famine periods.

Many of our older nations and civilizations, especially those in hot climates with frequent crop failures, developed food habits primarily centered about cereal and grain foods. These foods could be preserved by the known experiences of the clan or nation over long periods of time. The granary plan of Joseph, repeated in many of its variations in Europe and the Orient, brought about national diets composed mostly of starchy foods. Our physiologists tell us that the granary plan of Joseph left its mark on the residents of Egypt if the tooth diseases of those remains found in the crypts of Egypt is any fair basis of judgment.

For the most part the peoples of a very warm climate also are very partial to sauces and seasoning of a very high and distinctive flavor. Much of this can be traced back to the desire to counteract the taste of partially decayed meat and fish foods through the hot sauces spread thereon.

Even within continental United States in its relatively short history of two centuries the food habits have been very definitely affected by the ability of the people to store and preserve food. Within the northern areas, wheat bread, cellar-stored vegetables and snow- and ice-preserved beef and mutton were used in the winter, but the meat portion of this diet was changed in the summer to pork and chicken when the available preservation facilities for beef and mutton were not workable. On the other hand, within the southeastern states, pork and corn breads were generally accepted as an all-year-around diet. With the lack of snow and ice for preserving the beef and mutton products of the South, pork became the all-year-around meat for the southern table with a liberal introduction of chicken, which could be maintained alive until needed but was small enough to be consumed within a few hours after killing. These examples might be multiplied. A sampling of the tables of the United States prior to 1900 would have revealed that nearly every area was most provincial in its food habits. Since 1900, however, several forces have been at work making possible an effective change in these habits.

Prior to 1900 the nation lacked mobility. It was dependent upon an artery system of railroads to move goods of all kinds. Furthermore, its power systems were highly localized.

Almost simultaneously, three engineering developments changed the features of American life. Out of these three developments, historic changes were destined to bring about decentralization of American industry, new power facilities to American homes and a greater advance in the mobility of man within a quarter of a century than had been experienced from the dawn of history to the year nineteen hundred A.D. These three developments were (1) an interconnected electrical distribution system for all America; (2) mass production of the automobile and the truck, and (3) construction of a network of highways that went to virtually every farm and urban door of the nation.

The interconnected system of electrical distribution made available to most American homes facilities for processing and preserving perishables for use at any period of the year, and through the availability of the trucks and highways thousands of truck loads of fresh vegetables, dairy products, fruits and meats moved daily from one region to another. Florida, Texas and California fruits and vegetables left their semi-tropical gardens daily in winter to the ice-bound centers of the north, even into northern Canada. In the summer the same northern areas would move large tonnages of their perishables to the south.

While food preservation had been carried on within the United States for its entire history, the turn of the century marks the upward swing of many of the most essential processes for the most effective preservation of the grown perishables of the nation.

There is in each area a very definite relationship between family income and class of food consumed. In general each individual in the United States consumes one ton of food each year. If the income is high the purchases will include the more expensive available foodstuffs and *vice versa.* But in the past the locally produced foods that could be readily preserved constituted the principal poundage of human consumption because they were the cheapest. But few have suffered from lack of weight of food even during depressions, though many have found it necessary to make up their meals from low-priced starches and fats when incomes were depressed.

The Engineering of Food Preservation

For the most part there are four methods of food spoilage or deterioration: (1) odor absorption, (2) enzyme action, (3) bacterial growth and (4) oxidation.

While for the commercial market other factors such as color change, lack of freshness and shrinkage may be given great market consideration, these are closely related to the more serious deterioration factors outlined as above.

Odor absorption has been recognized for centuries in the storage of foods. It has been most serious in the storage of dairy products such as butter, cream and ice cream. In general, the transfer of odors is a function of the temperature of storage. Butters maintained at a very low temperature are much more free of the absorption of odors than when stored warm. Probably this is brought about by two actions. When the affected product is completely frozen or crystalline, then its absorptive capacity is greatly reduced. But also, when the offending odor source is at a low temperature, the volatile odors are at a minimum. When the temperatures of both the absorbing food and the offending source of odor are high, both the absorption capacity and the odor action are intensified.

Enzyme action has been one of the most difficult of the deterioration processes to inhibit. It remains, still, as the process of which we know the least, due to the great complexity and the multiple catalytic activities of the several enzymes.

Some one has referred to enzymes as the unorganized system of ferments in contra-distinction to an organized ferment such as yeast. Another food technologist defines the enzyme as "the catalyst of living cells." Probably a more exact definition is that "an enzyme is a heat-labile catalyst elaborated by living cells yet capable of acting independently of the living processes of the cell."

Bacterial growth has been recognized as of great importance for several generations. Its prominence is evidenced by the acceptance of the study of bacteriology as a major science in courses related to health, medical service, sanitation, food preservation and water supply. Unfortunately, the public has been given sufficient misinformation about bacteria so that today to many people all bacteria are harmful. A large portion of the buying public does not realize that many of the food-preserving processes must depend upon certain bacteria for their successful operation, while other bacteria cause deterioration and decay.

Oxidation is generally most active under high temperature conditions. Often the oxidation is associated with one of the other three deterioration actions.

PROCESSES USED TO PREVENT DETERIORATING ACTIONS IN FOODS

The principal processes of food preservation are (1) drying or dehydration; (2) sterilization and canning; (3) low temperature chilling and freezing, and (4) chemical preservation including pickling, smoking, spicing and fermentation, etc.

Each of these types of food preservation has certain time limitations with the exception of freezing. The recorded discovery reported by the Smithsonian Institution[2] in recent years of mammoth flesh and other animal carcasses many thousands of years of age yet still in edible condition is mute evidence of the permanence of food preservation by sharp freezing.

Dehydration, canning and quick freezing are each of great moment at the present and will be discussed further.

PRESERVATION BY DEHYDRATION

Dried foods have been prepared for thousands of years. Either the sun or some artificial source of heat was used to evaporate the excess water. In most of these processes the water was seldom carried lower than 12 to 25 per cent. In no case is there evidence that great care was exercised to maintain controlled treatment of the product in the drying process as between humidity, enzyme action, air velocity and temperature.

Wars have most generally increased interest in the drying of foods, and in recent years dehydration has become an important part of the food programs of armies. Unfortunately, most of the demand for dehydrated foods recedes after each war period, and this recession causes the liquidation of both plants and trained personnel. Probably as a part of the permanent preparedness program of the nation the perishable food supplies areas should maintain, under the Army or Navy direction, base plants for food dehydration, these plants to operate primarily as stand-by units for war emergencies. The nation would then find it could maintain its gains in the science of food evaporation from one period of war emergency to the next.

[2] Annual Report of the Board of Regents of the Smithsonian Institution (1902–1903), p. 621.

Much argument can be exercised trying to differentiate between dried foods and dehydrated foods. In the language of the public, no line of demarcation exists between the drying and the dehydration processes. There has been an attempt on the part of food technologists to define the field of activity of food driers as that in which foods are produced down to 10 or 25 per cent. moisture without specific control of the relation of enzyme action, temperature and humidity, while dehydration is defined as a process in which scientific control is maintained as between temperature, humidity, air velocity and enzyme action to evaporate foods to moisture contents of 2 to 8 per cent.

The writer would define dehydration as "the removal of water from food products to required low values of moisture content by a process of controlled temperature, humidity, air velocity and enzyme action, and the resultant product to permit rehydration with a minimum loss of original natural color, flavor, odor and nutritive value."

There are many reasons for dehydrating products for war purposes. Principal advantages of dehydrated foods are:

(1) There is a reduction to a small fraction of the original weight.
(2) The processed product can be compressed into a small cargo package without destroying its rehydration qualities.
(3) The requirements for metal containers are reduced.
(4) They can be subjected to freezing temperatures or hot climates with considerable success.
(5) The process can be operated with a minimum of critical materials.

The principal disadvantages of dehydrated foods are the change of flavor with age, the susceptibility to vermin and the ultimate perishableness of the food.

While dehydration can be carried on by cabinet, drum, spray, rotary cylinder and tunnel driers, fully 80 per cent. of the present supply comes from tunnel equipment.

At the end of World War I, the United States had about twenty dehydration plants in operation, but most of these fell into disuse before 1938. At present this country has over one hundred plants making upward of 100,000,000 pounds of dehydrated products annually. By 1944 this capacity should be quadrupled.

It is reported that Germany's curve of dehydrated plant construction would show three plants in 1900, eight hundred in 1915, eighteen hundred by the close of World War I. It is well known that hydrated and ersatz foods are very prominent articles of sustenance in Germany today and probably exceed its 1918 peak several fold.

The 1943 requirements of dehydrated foods in the United States exceed 400,000,000 pounds. Over a billion and a quarter pounds of dehydrated foods have been used in the present war by the Allied nations.

To give some physical impression of what dehydration means to the transportation systems under the present practice, eight carloads of fresh potatoes become one carload of dehydrated product and ten ships for fresh meats can be replaced by one ship for the dehydrated equivalent.

So great has been the contribution made by dehydrated products in this world conflict that never again should the democratic peoples permit their gains in accomplishment in the science of dehydration to revert to a position of subordinated emphasis. And further —if the United States has a vigilant interest in future preparedness, then sufficient productive capacity and yield should be maintained in dehydration plants as a national policy.

Preservation by Sterilization and Canning

While the preservation of food by canning dates back to the early work of Nicholas Appert in France in 1795 which brought him his first public recognition in the national competition of 1807, it did not take on the characteristics of an extensive industrial process until after the introduction of bacteriological control successfully used by H. L. Russell in 1895 for the pea canners of Wisconsin and expanded by S. C. Prescott and W. L. Underwood in 1896 in their epoch-making treatise on "Micro-organisms and Sterilizing Processes in the Canning Industries."

With these notable achievements in the control of food spoilage by the canning process, industry immediately responded, and in the early years of the twentieth century canning plants and can manufacturing flourished in both Europe and America. By the advent of the United States in the present war the canning industry within the nation represented a product output approximating a billion dollars annually with over three thousand producing companies.

While considerable improvements have been made in the laboratory control both from the bacteriological and chemical standpoint during the past forty years, the greatest impetus to the industry has been the development of new machinery to produce the cans, new mechanical engineering developments in cleaning, separating, sterilizing and packing the more than three hundred basic products now coming from the commercial canneries. Coincident with these mechanical developments have come new successes by the chemical engineers in the types of can surfaces and linings produced for the different foods to be preserved.

The excellent results now obtainable by process canning, the low cost of preserving by the canning method and the adaptability of the canning process for preserving the surplus foods in almost every region of the civilized world augur well for its future. There is every evidence that sterilized, hermetically sealed products will continue to be a very essential type of food in our daily life in America and Europe. Economically the preservation of food by canning is sound and the product produced is highly satisfactory.

Preservation by Quick Freezing

Since quick freezing is just emerging into a process that can provide foodstuffs at a price within financial reach of the majority of the people of the United States, it offers new opportunities for industrial expansion. As a new industry, quick freezing presents new problems to be met by the engineer.

Larger amounts of foods can be expected to be preserved by the freezing processes in the generations of the future. The increased facilities of transportation and the widening uses of refrigeration will make possible the preservation of foods by cold for the masses of American people. The fact that freezing is the one process that can provide preservation for an indefinite length of time and that by the new freezing processes the original flavors and colors can be retained, makes it the conservation method that will be most acceptable to the human race. The present state of the art of quick and flash freezing is now advanced to such a stage of perfection that with the release of equipment priorities after the present war, frozen foods can be made available to the purchaser at prices as low as those for hot processed and dehydrated products.

The term "quick-frozen" as applied to food is very elastic and much abused. Many cases are on record of products which have been frozen by methods that required as much as a week for complete solidification, yet they were labeled "quick-frozen." Such loose usage does not induce increased public confidence and acceptance. Too often the practice represents an attempt by some food processor to offer his cold-pack product under a classification that has the highest customer appeal in the food market. A previously proposed definition by the writer states: "Quick freezing is freezing at a rate sufficiently fast that there is no appreciable change in the physical or chemical properties of the product during the entire cycle of freezing and subsequent thawing."

More or less modification of any food may occur when it is frozen. Usually these changes are not apparent until the product has been thawed and in many cases further undesirable changes, due largely to enzyme action, may occur after defrosting is completed.

Theories on Cause of Food Damage by Slow Freezing

Several theories have been advanced to account for the effect of slow freezing. These include the cell-puncture theory, the bursting of the food cells by internal-osmotic-pressure theory, and the theory of the irreversible precipitation of colloidal constituents. Each of these will be discussed in order.

Cell-Puncture Theory. Perhaps the most widespread and persistent hypothesis is the cell-rupture theory, which holds that the cell walls are punctured by growing ice crystals, and that, upon thawing, the cell contents leak out through these minute ruptures. It is also held that, if the size of the ice crystals can be maintained less than the cell dimensions by rapid chilling, no puncturing with its consequent leakage will occur.

It should be borne in mind that foods are not composed of rigid inelastic cells. The walls are resilient and will permit considerable expansion before rupture occurs. Heat is removed from only one side of the cell so that expansion may occur on the opposite unfrozen side.

Microscopic observations have revealed that, even when freezing is exceedingly fast, the smallest ice crystals are much larger than individual cells. Many cells are contained in one crystal instead of *vice versa.* The crystal lattice both inside the cell and in the intercellular spaces is continuous. No tearing or shearing of cell walls has been observed.

Osmotic-Damage Theory. Petersen proposed that damage to foods during freezing is due to the following mechanism: "What crystallizes first in each cell is the pure water. That leaves the remainder of the juice in the cell more concentrated. The resultant increase in osmotic pressure tends to draw the water from the next adjoining unfrozen cell. The water coming into the partly unfrozen cell has a tendency to build onto the crystals between the cells when the rate of freezing is so slow that the system approaches equilibrium." It also accounts for the occurrence of collapsed cells contiguous to large ice masses in slowly frozen foods. However, this theory does not explain the damage which occurs in quick freezing when heat transfer so greatly exceeds diffusional rates at low temperatures that thermal equilibrium is attained before appreciable osmosis can occur.

Irreversible-Colloidal-Change Theory. Almost without exception perishable foods are colloidal systems in which the external or dispersing phase is an aqueous solution. This has led some investigators to the belief that alteration of the colloidal structure is responsible for changes during freezing, storage and thawing. While there are many factors which affect the stability of colloids, it is probable that only three concern the food processor.

(1) The lowering of temperature (distinct from the freezing effect) renders many colloidal dispersions unstable. Examples are the formation of gels from agar, soap and starch hydrosols. This phenomenon is often followed by syneresis, that is, shrinking of the gel and exudation of fluid.

(2) Chemical changes which occur during frozen storage are irreversible. Many of them are due to enzyme action. The rapid deterioration of frozen unblanched vegetables is well known. The "rusting" of oily fish (oxidation of the fat) is very familiar. It is probable that some of the loss of flavor from stored frozen foods may be traced to hydrolysis of esters and oxidation of unsaturated odorous components.

(3) Freezing causes concentration by removing liquid water from the external phase. More concentration, by decreasing the distance between dispersed particles, may bring about critical instability.

Freezing may also effect sufficient concentration of electrolytes to cause "salting out" of hydrophilic colloids. While such precipitation is often reversible, long storage in this state may result in an irreversible precipitate.

An Appraisal of the Theories of Freezing Damage

The freezing-damage theories might be appraised as follows:

Mechanical damage to cellular structures might be caused by ice crystals, especially for some classes of product. When this occurs, there is an internal shredding of the product, caused by growing crystals. The resultant damage is a function of the crystal size and freezing time.

Osmotic injury to cellular structure is possible but probably plays a minor role in the destruction caused by freezing. Water diffuses from unfrozen cells to the faces of growing ice crystals at a very slow rate. The action is irreversible when thawing occurs and might cause internal rupture.

Irreversible changes in the colloid system appear to be the principal cause for slow-freezing damage. Primary or secondary effects of low temperature cause irreversible precipitation of many colloids. This action is independent of cellular structure and explains the effect of freezing upon foods which do not consist of cells. The theory also accounts for the severe damage to some foods and the negligible damage to others when identical freezing technique is employed.

Rapid Freezing Rates Not Essential to All Foodstuffs

Many have a mistaken idea that very rapid freezing is equally desirable for all perishable foods that require preservation by cold. The need of rapid freezing is much more pronounced for some perishables than for others. Furthermore, the colloidal composition of some products is such that even slow freezing affects the structure but slightly.

With most foods that are to be cooked as soon as defrosted, slow freezing is as satisfactory as quick freezing. In the case of meats, slow freezing may even have a tenderizing effect. Furthermore, any leakage of the meat subsequent to defrosting merely results in increased pan juices.

Vegetables with a high starch content display a much different response to the freezing treatment from leafy types that may exceed 90 per cent. of water by actual weight. Well-ripened berries and fruits with a high sugar content present a very different problem from acid and near-ripe fruit products.

Controlled supercooling and favorable colloidal action are utilized in the polyphase freezing process developed by Mr. Luis Bartlett and the author to flash-freeze foodstuffs. Unusually fast heat transfer is secured by direct contact of food with a chilled medium of high viscosity which is composed of three phases: Solid, liquid and vapor, hence the term "polyphase." A typical medium is composed of dextrose, sucrose and water. It is chilled and slowly agitated until a solid phase of finely divided ice particles has formed and is dispersed throughout the liquid. This composition is satisfactorily operated over the range -2F to -10F and is metastable at these temperatures.

Articles of food are floated in the cold medium and the slow agitation moves the articles with respect to the fluid and also to each other so the individual pieces are prevented from freezing together. Freezing is so fast that washwater or juices adhering to the food surfaces are at once frozen in place and do not dilute the polyphase medium. This film of ice is proof that diffusion of soluble constituents does not occur, solute is not transferred from the freezing medium to the food, nor does the food lose dissolved solids.

The high rate of heat transfer is due to three factors: (1) The extremely high thermal capacity of the polyphase state. (2) Increase in the thermal conductivity of the fluid film by the suspended ice particles. (3) Almost complete elimination of food supercooling by the "seeding" effect.

The polyphase medium removes heat approximately twice as fast as a liquid medium under identical operating conditions. Polyphase media, composed of water and sugars, may be operated in the metastable state at temperatures as low as -10F, while syrups employed in food freezing are seldom operated below $+3$F. Thus it is possible by employing the polyphase media to chill foods in a fraction of the time required by liquid media under ordinary operating conditions.

An important advantage of heat-transfer fluids which can be operated at subzero temperatures is that freezing is completed in one operation and no heat is removed in the storage room. By eliminating this period of exceedingly slow cooling, less irreversible damage to the colloidal structure occurs. Furthermore a more immediately practical result is that the food does not freeze into a solid mass in the container. Each piece retains its individual character so that it may be removed without disturbing the remainder and repackaging in smaller packages is easily accomplished.

Summation: The engineering profession of the world can be expected to give more attention to the animal-plant food cycles in the years ahead and to determine new methods of preserving for complete utilization the critical and exhaustible supplies of plant foods for the generations yet to live. Coincidentally with this obligation which the engineer must assume, there is the romantic but very real task ahead of applying the same intensive interest in the ultimate preservation of foods as the agriculturists have displayed in producing them.

The food preservation arts and sciences have now progressed forward far enough that the engineering profession can well assure the world that diets can henceforth be determined on the basis of what is good for man. With the coordination of our implements of electrical power, internal-combustion engine, propelled transportation, excellent network of roadways and mechanical inventions, and with the competent support of the food technologists, the bacteriologists and the chemists, the engineering profession should be able to assure the multitudes that the world's ability to preserve is now prepared to equal the world's capacity to produce food. When complete coordination is effected, and production, preservation and distribution become daily realities, then the profession will have reached new heights in engineering, achievement, statesmanship and service.

PUBLIC HEALTH IN THE U.S.S.R.[1]

By Dr. C.-E. A. WINSLOW
YALE UNIVERSITY

DURING a period of rapid demolition and rebuilding of Yale University a student was showing his father about the campus and the father said, "What is that building?"

[1] Address at the Science Panel of the Congress Celebrating the Tenth Anniversary of American-Soviet Relations, New York, November 9, 1943. The complete proceedings of the Science Congress including the Medical Session will be published at a later date by the National Council of American-Soviet Friendship.