

HISTORICAL DEVELOPMENT OF THE MODERN FROZEN FOOD INDUSTRY

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GENERAL HISTORY



The preservation of food by freezing has been practiced for centuries in those countries where natural freezing and storage was available, such as in the Arctic and in high mountain regions. It was not until the introduction of mechanical refrigeration that freezing preservation became widespread or extensive in volume. Even then, the growth of the industry was slow and only certain products were so preserved in large amounts. About 1880, ammonia refrigeration machines were used commercially for freezing in this country and

their use confined largely to fish products. By 1890, there was a fairly wide use of freezing with New Zealand exporting in excess of 2,000,000 carcasses of frozen mutton to England. This was also the beginning period of the frozen egg industry in this country.

Fruits were frozen in quantity in the Pacific Northwest by 1910, and by 1926 had expanded to over 40,000,000 pounds per year. The freezing of vegetables was slower in starting, probably due to problems in maintaining quality, but by the mid 1930's a very sizable quantity was

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being frozen. Since that time there has been an upward surge in volume of products and in the increase in number of items on the market. Today, almost every category of the food industry is represented in the frozen foods offered for sale. In 1960, the total quantity of product packed by the frozen food industry was in excess of 7 billion pounds. In 1961, it will be a 6½ billion dollar industry.

The frozen products first packed in quantity were for the wholesale trade and were intended for transport from the point of origin to a point where the product was not available. While quality was a factor in the marketing of these products, certain practices were employed that prompted Stevenson's (1899) comment, "the tendency to freeze fish in which decomposition has already set in, and the prosperity of the frozen fish business requires that any attempt to freeze fish already slightly tainted, should be discontinued." As the frozen food industry expanded into the retail market, the small packages of product were introduced and with this trend the development of equipment to transport, store, and market such products. This was a learning period and there is little doubt but that expansion would have been faster if the quality of the products had approached that of today.

There was a decided need for research in the areas of product varieties best for freezing, the techniques of enzyme inactivation, the maintenance of nutritional qualities of frozen products and the packaging of the products. Lack of quality, lack of know-how and certain practices in the industry often created setbacks in this beginning period. Tressler (1957) has stated in his book, "The Freezing Preservation of Foods", that "Three decades ago frozen foods were considered to be of such poor quality that many states and municipalities had enacted laws to protect the consumer from unscrupulous merchants who might attempt to sell thawed foods as fresh products. In many places, anyone retailing frozen foods was required to post a large placard 'Cold Storage Goods Sold Here' in a prominent place." Such conditions and attitudes had to be overcome before the retail industry could develop. It is to the credit of the industry that public confidence was gained through demonstrations of performance, quality, and progressive methods of handling. It was soon learned that selection of raw material was very important, that rapid handling and quality maintenance know-how were absolutely necessary, and that proper freezing techniques were required to deliver a product to the public that would be accepted and considered superior

to much of the raw products being offered. The foresight and insight of workers like Birdseye, Tressler, Diehl, Bitting, Pennington, and many others were combined in building the confidence necessary for the successful development of the industry. The U. S. Department of Agriculture took an active interest in this growing industry and, in 1931, established the U. S. Frozen Pack Laboratory in Seattle with Dr. H. C. Diehl in charge. It continued to carry out work at that location until 1941 when the activity was moved to the USDA Laboratory in Albany, California.

In the early 1930's, a conviction arose that precooked frozen foods would become products of importance. Considerable research was carried out at the Birdseye Laboratories to demonstrate the possibilities of such products. However, it was not until after World War II that such products became of great importance in the frozen food industry. True, certain products had been packed in quantity for several years, but the increase in the number of items and the volume produced in the early 1950's was phenomenal. In 1955, such items as frozen precooked potatoes exceeded 180 million pounds and poultry and meat pies 150 million pounds. By 1955, there were more than 200 different kinds of precooked foods on the market.

With the development of the precooked items it was logical that such would be combined into complete meals. The Maxson Food System, Inc. introduced the "Strato-Plates" in 1945 for airline feeding and although the idea caught on slowly at first, Vogel (1956) estimated that by 1955 frozen complete meals had exceeded 50 million pounds.

The growth of the frozen food industry in 10-year periods is shown in Table I. It will be noted that the year 1942 is included. That was the first year that "prepared" foods appeared in the statistics and only

TABLE I (ANONYMOUS, 1961a)
OUTPUT OF COMMERCIAL FROZEN FOODS (MILLION POUNDS)

Year	Fruits	Vegetables	Poultry	Meats	Seafoods	Prepared Foods *	Conc.	Total
1939	180	70	15	10	50	—	—	325
1942	275	220	70	12	70	0.5	—	647.5
1949	360	566	200	50	165	35.0	140	1,516
1959	618	1,626	1,747	300	478	700	1,096	6,565

* Potatoes are with vegetables. Fish sticks, fish portions, and breaded shrimp with seafoods.

one-half million pounds were packed in that year. Seventeen years later the figure was 700 million pounds, with a monetary value of 525 million dollars.

THE DEVELOPMENT OF MICROBIOLOGICAL INFORMATION

While the science of Microbiology was well-developed by the time the expansion of the frozen food industry began, there was comparatively little information that applied to the specific problems of the industry. The taxonomy, physiology, and fermentation reactions of bacteria were very useful tools, but such questions as longevity in frozen storage, the possibilities of public health hazards, the significance of types and of total populations were largely unanswered questions. It was only natural, therefore, that with the increase in importance of this industry there began a corresponding awareness of the importance of the study and the research in this specific field and the development of a comprehensive reservoir of information.

Public Health Considerations

With each new development and upsurge of some part of the industry there was generated interest and concern among the food microbiologists and public health workers over the safety and the sanitary quality of the products. Almost from the beginning of the frozen food expansion there was concern of the possible public health hazard from these products. Various types of food poisoning outbreaks through the use of such products seemed to be a threat. James (1932) and Fellers (1932) pointed out potential areas that should be investigated. Straka and James (1932) reported on studies of 1,200 packages of frozen peas inoculated with four strains of *Clostridium botulinum*. Toxin production was not found in samples immediately after defrosting, or after three days in the refrigerator in the defrosted state. Product defrosted and allowed to stand at room temperature for three days was badly spoiled and found to contain botulinum toxin. The same authors (1933) reported again on another inoculated pack of frozen peas with similar results. Prescott and Geer (1936) published work indicating that *Cl. botulinum* spores were markedly resistant to freezing, but that no toxin was produced in products held at refrigeration temperatures for several days after defrosting. They expressed belief that there was little or no

danger of botulinum poisoning from frozen foods that were properly handled. Such reports were reassuring and comparatively little further work was done. Saleh and Ordal (1955) reported their studies on *Cl. botulinum* in frozen chicken ala king. They found no toxin formed during the freezing and thawing of an inoculated pack of that food and none in defrosted product held at 10° C. They did find toxin, however, in products held at 30° C, and also in certain samples of uninoculated product held at that temperature. These workers reconfirmed that there was danger only in grossly mishandled products.

Wallace and Park (1933a, b) showed that certain pathogenic bacteria would survive for long periods even in acid products such as frozen fruit. McCleskey and Christopher (1941) showed that *Salmonella* sps., *Eberthella typhosa* and *Staphylococcus aureus* would survive in large numbers in frozen strawberries after eight months of storage. Buchbinder, *et al.* (1949) found that 12 of 39 samples of chicken ala king yielded staphylococci of the food poisoning type and that eight of these samples had counts of these organisms between 1,000 and 100,000 per gram, two gave counts between 200,000 and 400,000, and one a count of 2 million per gram. Of nine samples positive for enterococci, four had counts greater than 1 million. Schneider and Gunderson (1949) reported the recovery of several *Salmonella* types from frozen eviscerated chickens even after long storage. Such records as these seemed to justify the concern of the public health workers regarding the presence of a potential hazard. However, Fitzgerald (1947) had pointed out that "From the start, public health-minded food technologists worried about the implications of botulinum, staphylococcus food poisoning and pathogenic manifestations resulting from the unregulated production and use of frozen foods. As yet, such fears have not materialized in spite of the fact that one or another of these foods has been marketed commercially in ever increasing amounts from sources in every section of the country for many years." Since this was written, 14 years have passed and the observations made by Fitzgerald still hold true. To the best of our knowledge, no cases of food poisoning have been directly traced to the consumption of properly handled frozen food. However, workers have continued to point out, and rightly so, the dangers that do lurk in grossly mishandled products. Straka and Stokes (1956) pointed out the importance of understanding basic microbiological facts and the application of this knowledge to production and distribution and in enforcing

microbiological controls. They presented guides to prevent the development of possible hazards.

Microbial Populations

The finding of enormous numbers of microorganisms in frozen foods has always concerned the microbiologist and the sanitarian. Early workers reported finding certain types of foods with consistent high counts and almost all types of frozen products with occasional high counts. Magoon (1931) showed large numbers of microorganisms in berries. Proctor and Phillips (1947, 1948) reported counts in excess of 1 million per g in certain creamed products. Buchbinder *et al.* (1949) found large numbers in these same products. Ingram and Brooks (1952) showed counts of one to five million per g in frozen eggs, while Bauch *et al.* (1953) showed some counts as high as 7.2 million in commercial frozen whole eggs. All of these reports seemed to point to the conclusion that they were the results of selecting poor raw material, lack of attention to sanitation in processing and handling, slow freezing, and other inattentions to good food handling practices.

Role of Sanitation

Vaughn and Stadtman (1946) published work on plant sanitation and its relationship to bacterial counts. They pointed out that blanching markedly reduced bacterial populations and that high counts in vegetables were indicative of contamination and growth after the blanching process and that proper sanitation in the plant was important. Pederson (1947) studied the extent of contamination due to poor sanitation in frozen vegetables. He found that poor sanitation allowed bacteria to grow on equipment, and that, since the resulting organisms were in the active growth phase, the increase in numbers in the food was very rapid. He pointed out that the cell sap and cut tissue surfaces provided an excellent medium for growth.

Gunderson *et al.* (1947) showed that under certain conditions poultry meat could have counts of 9 million per g, and that use of such meat brought about high counts in the frozen products. Buchbinder *et al.* (1949) reported a survey in which 39 samples of chicken ala king had counts in excess of 1 million per g. Of these, 75% of the samples of one brand name and 40% of the samples of another brand name had such counts. Such a record seemed to be a reflection of the type of sanitation and handling in the plants. Proctor and Phillips (1947, 1948)

had shown similar results, but at somewhat lower bacterial counts. Buchbinder and Proctor and Phillips showed, by comparison with other types of precooked frozen products, that many types of foods had counts averaging under 50,000. Their work pointed up the areas where particular attention was required. Of 100 products studied by Proctor and Phillips, only two types of products averaged in excess of 100,000 per g. Hucker *et al.* (1952) pointed out that the cleaning of equipment, conveyor belts, and working surfaces was very important, and that subsequent growth in vegetables resulted from improperly sanitized equipment and the opportunities offered for recontamination. Huber *et al.* (1958) reported studies that were made in commercial plants operating under different philosophies of sanitation. In samples from one plant, they found plate counts on certain items in the order of 11 to 69 million organisms per g and concluded that these high counts were the inevitable result of poor sanitary practices as observed by the authors. Bacterial counts from other plants producing the same type of items showed total counts ranging from 6,800 to 54,000 per g, and demonstrated that precooked foods of low bacterial count were feasible under commercial conditions if good sanitation was practiced. The use of microbiological indexes of sanitation in food has been proposed and discussed over the years with coliform organisms and *Escherichia coli* as the leading indexes for foods. Larkin *et al.* (1955a, b, c) published a series of articles on the results of work comparing the effect of freezing storage upon various suggested index organisms. They concluded that fecal streptococci were less affected by freezing storage and survived in greater numbers over long storage than did *E. coli*.

There is little doubt but that over the years, reports, such as the above, have markedly influenced the design of equipment, and the formulation of sanitation procedures in frozen food plants and pointed the way to improved sanitary quality.

Role of Processing Procedures

Obold and Hutchings (1947) reported that the holding of products after packing, or a delay in placing in the freezer, resulted in poor quality and high bacterial counts. In large containers, a slow freeze could easily result in very high counts and even a spoiled product in the core. Pederson (1947) and Vaughn and Stadtman (1946) pointed out the great reduction in microbial count that could be effected by the blanching process. Pederson observed that "Bacterial counts should not

be thought of as an indication of the quality of the food, but rather as an indication of the handling of the food between blanching and freezing." He was also of the opinion that high counts were the result of equipment contamination, followed by too-long holding before freezing. Hucker *et al.* (1952) stated that a relationship of visible sanitary condition of equipment and numbers of bacteria was not apparent. They showed extensive work on bacterial counts from various steps in processing and indicated the rise and fall in the bacterial count of the product as it moved through the plant. These data also pointed out the points of contamination.

The Quartermaster Corps became aware of the need for information upon which to base realistic requirements for the purchase of frozen food products by the Military. Cooperative work was carried out in commercial plants. Gunderson *et al.* (1947) reported on "Poultry Boning Plants Need Bacteriological Control." They showed the bacterial counts on the product at each step in the operation, and that the type of bacterial flora of eviscerated poultry containing products was similar to those found in many other frozen foods. Also, that cooking markedly reduced the bacterial count of the poultry carcass, but during the hand deboning operation the count increased rapidly, unsanitary handling and suitable temperature of the warm meat probably being the cause. Schneider and Gunderson (1949) reported on another phase of this cooperative research. They studied poultry carcasses from the dressing line through all steps to the frozen product with respect to *Salmonella* contamination. They found that washing and other steps reduced the numbers of *Salmonella*, but did not eliminate them. They also demonstrated the transfer of *Salmonella* from one point to another during the handling. The counts in the finished products were low, but freezing storage did not eliminate them.

In developing information upon which to base bacteriological requirements for the purchase of frozen meals (1958) for in-flight feeding by the Military, a crew of microbiologists was sent into the field to gather data under actual operating conditions. Rayman *et al.* (1955) and Huber *et al.* (1958) reported that the plant procedures, equipment, and the type of sanitation employed in the production of the various components of the meals was reflected in the bacterial count. One example presented by Rayman *et al.* (1955) stands out as an example of what can happen in the processing of an item such as fried potato puffs. The

cooked and mashed potatoes had a bacterial count of 10 per g, to this were added beaten eggs, rice flour, and seasoning, and the count rose to 500 per g. The potato product was then formed into balls by rolling between the hands of the worker and held for frying. Several hours elapsed before this operation and even with the product held under moderately cool conditions the bacterial count rose to 1.2 million per g. The potato puffs were then deep fat fried and had a count of only 400. When some of the fried product was cooled by placing on one of the trays that had been used to convey the raw handformed puffs to the fryer, the total count was 350,000 and the coliform count 50,000 per g. These studies demonstrated that when bacterial counts got out of line, as a rule, a survey of the plant by a sanitarian would pin-point the spot where the irregularity was occurring.

Destruction and Preservation in the Frozen State

That some bacteria could withstand cold conditions was an accepted fact, but it took many years of research to fully understand what happened in the many facets of the frozen food industry. Prescott (1932) reported on "Bacteria as affected by temperature." He showed that in foods several species were extremely psychrophilic and that some managed to grow at -7°C .

Beard and Cleary (1932) in that same year reported the unique observation that certain microorganisms survived in greater numbers at -4°C , than at room temperature in an acid medium. Berry (1933) reported on "Destruction and survival of microorganisms in frozen pack foods." Smart (1934) reported on microorganisms surviving freezing storage and showed that although 99.3 per cent of organisms died off in strawberries after one year of storage, some 30 species of bacteria were still alive after three years. Lockheed and Jones (1936) showed that there was preferential killing of organisms during freezing storage, certain types being very sensitive to the cold while others were very resistant. They found that the micrococci and the flavobacteria were more resistant than other types in fruits and vegetables and were noticeably a greater per cent after nine months of storage. They noticed a marked drop in bacterial numbers during the first few weeks of storage, then a gradual decline. However, at the end of nine months of storage sufficient viable bacteria remained to cause spoilage upon defrosting. McFarlane (1940a, b) reported the finding that soluble solids, total

acids and yeasts and bacteria were concentrated in the core in liquids like 10% sugar solution and apple cider. He found that this redistribution took place to no marked degree when solid material was present, such as in syrup-packed raspberries and brine-packed peas. McFarlane (1942) showed that sugar protected the quality of the fruit, possibly through enzyme inhibition, but it also exerted a marked protective action against death of microorganisms. However, the highest concentration of sugar did not always give the best protection. McFarlane and Goresline (1943) reported that after frozen storage for 60 weeks at -17.8°C there was greater destruction of microorganisms in water than in any of the syrups tested. There was greater destruction in dextrose than in invert sugar. *E. coli* and yeast strains exhibited greater resistance in sucrose solutions than in invert sugar, while certain strains of yeasts showed just the reverse. McCleskey and Christopher (1941) reported that certain pathogens died at different rates in strawberries. *Eberthella typhosa* was still present in unsliced berries after 14 months at -18°C , but survived only six months in sliced berries. *Staphylococcus aureus* survived five months, while certain salmonella species lived only one month. Gunderson and Rose (1948b) found that *E. coli* and *A. aerogenes* showed a decrease in ability to initiate growth on violet red bile agar as the period of storage increased, until only 12-25% of the viable cells would grow on this medium. Also, that 20% of salmonella cells inoculated into sterile chicken chow mein survived nine months of storage at -25.5°C .

Hartsell (1949) showed that bacteria in eggs survived at lower freezing temperatures than they did at higher temperatures. Gotlib (1951) also reported on the influence of cold temperatures on the microorganisms in food. He found that during storage for 220 days at -10°C , 2.5 per cent of the bacteria survived while at -20°C the survival was 53.2 per cent. Hucker *et al.* (1952) reported what appeared to be a "base" of cold resistant flora. While many bacteria were killed by freezing, there seemed to remain certain types that were resistant. They also reported greater killing at -12.2°C . Woodburn and Strong (1960) reported on the survival of *Salmonella typhimurium*, *Staphylococcus aureus*, and *Streptococcus faecalis* in simplified food substrates. They found that the effect varied with the type of organism and that survival was greater at -30°C than at -11°C . Michener *et al.* (1960) published the results of their work on the relationship of bac-

terial populations to temperature. Elliott and Michener (1960) in an excellent review of their own work, and that of others, pointed out that death immediately after freezing and during continued storage was a function of the type of product and indicated that the more sensitive organisms died first. Also, that in certain products, such as peas and beans, after the initial kill during freezing there may be very little decrease in numbers even after a year of storage, and that the greatest survivals are at the lowest storage temperatures. Kereluk *et al.* (1961) reported upon the effect of temperature on the various types of bacteria found in frozen meat pies. Over the years such reports have indicated a species-temperature relationship and the differences in cold tolerance exhibited by different types of microorganisms. Elliott and Michener (1961d) prepared an excellent review and tabulated the reports of many workers on the lowest temperature of actual growth of microorganisms. In his excellent treatise on "Microbiological Problems of Frozen Food Products," Borgstrom (1955) stated that "The finding that low freezing temperatures of about -20°C are less harmful to microorganisms than the medium range of temperatures such as -10°C is highly important to an understanding of the microbiology of frozen food. This also implies the strange consequence that freezing is bactericidal to the greatest extent if it takes place slowly and the products are afterwards stored at a comparatively high temperature. These findings are quite contrary to the demand of modern freezing technique, which dictates a rapid freezing and subsequent storage at a low temperature." He also stated that, "Death of frozen microorganisms consequently may be ascribed to the denaturation of the protein and subsequent flocculation of the cellular proteins. This concept entirely refutes the idea that death is due to mechanical action of ice crystals."

Microbiological Methods

As the various workers delved into the microbiology of frozen products they utilized the methods, techniques, and culture media that were in use in the bacteriological laboratories. Many of these methods were from the clinical laboratory and the temperatures of incubation were generally the 37°C used in the study of pathogens. It became evident that methods tailored specifically to cold storage and frozen foods were needed and from time to time such suggestions were brought forward. Pederson and Yale (1934) reported that the optimum growth tempera-

ture for the bacteria found in milk and other refrigerated foods was at 32° C, as contrasted to the 37° C so often used in total counts. Other workers have shown counts in frozen products several times higher at 32° C than at 37° C on the same sample, and in certain cases even higher counts at 20 to 25° C. Nickerson (1943) proposed a rapid method of obtaining results in vegetable freezing plants. He developed a "modified little plate method" that had a precision of the same order as the Petri plate method. The little plates were incubated about 16 hours at 25° C, then stained and counted under microscope. This provided a method for rapid estimation of the sanitary quality of products, instead of waiting out the conventional incubation period. Berry (1946) recommended the direct microscopic count as a means of assessing a true microbial quality of vegetables, since both the living and the dead cells were counted and thus reflected a truer picture of the history of the sample.

The American Public Health Association took an early interest in the microbiological methodology for foods and the Committee for the Microbiological Examination of Foods presented a report on the "Microbiological Examination of Foods—Tentative Methods for the Microbiological Examination of Frozen Foods" (1946). The work of this Committee continued with the collection of methods, their selection and revision as new methods appeared and culminated in the book "Recommended Methods for the Microbiological Examination of Foods" (1958), a chapter of which was specifically on frozen foods. It is planned that the methods specifically for frozen foods will be markedly expanded in the next revision of this book. The Association of Official Agricultural Chemists also took an interest in the developments of methods and Goresline (1948) presented a Committee report on Microbiological Methods for Frozen Fruits and Vegetables. Since the Methods of the AOAC were primarily concerned with the chemistry of agricultural products, it was agreed that the microbiological methods could best be handled by the APHA, although AOAC members continued to follow this development with interest and to contribute to the effort. Zaborowski *et al.* (1958) reported on an evaluation of microbiological methods that had been suggested for the examination of precooked frozen foods. They found considerable difference in results using different methods and culture media and, accordingly, adapted their findings to the military specification for precooked frozen meals (1958).

There are many references in the literature in which the methods used by the authors are presented. However, most of these methods are those in common bacteriological use, and in only a few cases have they been tested to determine their true adaptability to evaluation of frozen food. A very recent development, 1961, that appears to offer a great deal in this field is the grant of funds by the National Institutes of Health under which three universities will jointly study methods and culture media for the microbiological examination of frozen foods. This should provide a good base from which to work in the development of truly meaningful methods in the frozen food field.

Microbiological Standards

Reference to the subject of microbiological standards for frozen foods is frequently seen in the literature. It seems that this interest stemmed from the observations that bacterial counts of frozen products were extremely variable, or that extremely high counts were too frequently encountered. Therefore, it seemed only logical that some control was needed and that the establishment of some sort of standard would bring about an improvement in the sanitary quality of these foods. Tressler (1938) wrote on the subject of bacteria being one of the indexes of quality of frozen food. One of the early advocates of microbiological standards was Fitzgerald (1947) who proposed a maximum standard plate count of 100,000 per g and made the following statement: "The writer has felt that an industry standard of 100,000 per g, incubated on tryptone glucose extract agar for 72 hours at 30° C, might be difficult to maintain. After he saw a plant which can handle more than a million pounds daily of some products, meeting a standard of 10,000 per g, he feels firmly convinced that the industry can set the above standard for fruits, vegetables, meats, fish, and poultry, and an objective of 250,000 per g on hamburger, sausage, and similar products. Furthermore, the direct count method such as that of Breed on milk should be used as an additional standard to determine the original condition of raw material for all products processed by heat prior to freezing. A standard microscopic count of 1 million per g or ml should be considered maximum." In that same year, Burton (1947) in an editorial in Food Industries made the following observations: "In the case of foods containing sugar that, as a consequence, are never completely frozen—even at -23.3° C—close control of the number of permissible bacteria is of greater technological importance than

in the case of foods like vegetables that are more completely frozen. A plate count of 10,000 per g or cc appears to be the maximum permissible. At the present moment nobody seems to be quite certain why there must be definite limitations on bacterial counts, but the public health aspect of such a matter is seemingly of minor importance compared to the deterioration of quality that is evident when the numbers of bacteria get out of hand. No evidence is available to prove that quality deterioration is the result of bacterial growth or metabolism, but there is pretty general agreement among food technologists that deterioration is definitely associated with high bacterial counts."

Tressler and Pederson (1951) wrote on a "Sound basis for frozen food standards". They set forth the quality control factors which should be considered in setting up measurements of quality, but did not propose definite numbers. Hucker *et al.* (1952) reported no pronounced relation found between numbers of bacteria and the quality of stored frozen food. Dr. G. S. Wilson (1955) of Great Britain presented the following comment: "—it is far more important to lay down a strict code for the preparation or processing of food and see that it is carried out properly than to rely on bacteriological sampling of the finished product". He stated further, "Samples are essential and a simple reliable technique for examining samples is essential, but sampling can be no more than a check on the efficiency of the processing; and it is the high quality of the processing maintained day by day that is required to ensure the safety of many of our foods". Dack (1956) discussed the "Evaluation of microbiological standards for foods" and pointed out the necessity of being realistic in establishing standards. He believed that the best standards would be those self imposed by industry for in-plant operations.

With the coming of the 1960's, the subject of standards brought forth several meetings and considerable discussion. A conference was held on "Microbiological Standards for Foods" (1960a) sponsored by the National Research Council at which several phases of the subject were discussed. Robertson (1960) presented material on the "Precooked frozen foods and the new handling code". A conference was held at the Western Utilization and Research Laboratory of the USDA on Frozen Food Quality (1960b) at which microbiological standards were discussed.

Elliott and Michener (1961d) presented an excellent review of

"Microbiological standards and handling codes for chilled and frozen foods." Slocum (1961) discussed "Setting microbiological limits for frozen precooked foods" and Gunderson (1961) made a bacteriological survey of products appearing on the market. After extensive discussions the Association of Food and Drug Officials of the United States (AFDOUS) (1961c) came to the conclusion that, "In the absence of adequate information for the establishment of bacterial limits for frozen foods, the Committee recommends that this question be referred to a subcommittee of microbiologists, to be appointed by the Chairman, to develop definitive recommendations on this subject. Under a broad charter this subcommittee would be concerned with further simplification and development of uniform methods of analysis and the interpretation of the microbiological findings obtained."

SUMMARY

The foregoing review of the route that the frozen food industry has traveled has been, in part, to lead us to the reason why we are assembled at this symposium. An attempt has been made to point up where we stand in the fields of technical know-how and scientific attainment in explaining the mechanisms of quality deterioration and the behavior of microorganisms under freezing storage conditions. In the confines of the type of review necessary for this occasion, it was only possible to touch on some of the highlights that the literature reveals and to mention only a relatively few of the personalities that have been involved in the development of a 6½ billion dollar industry; one that has markedly influenced our way of daily living. It is regretted that the coverage could not have been more complete.

It is evident that over the years many problems within the industry have been solved and ways have been found to smooth out many difficulties. While some of the reports of this history may be viewed with some chagrin, it is pleasing to also review many of the accomplishments. The know-how accumulated over the years makes it possible to produce frozen food products of good sanitary and product quality. It seems evident that ways and means must be sought to engender the desire to make full use of this knowledge by everyone in the industry. Those involved have learned how to produce foods of high quality, and, thanks to the outstanding long-term work of the USDA group at Albany, California, and the work of many others, know the mechanisms and the

deteriorative factors that reduce product quality that must be guarded against in frozen storage and in handling. All concerned can be justly proud of the accomplishments of the last 40 years.

There is need, however, to spread the knowledge and information that is available so that those who do not produce high quality products, or mishandle the products of others, will know how to do a better job. Material such as the series of articles on, "Bacteriology of frozen food processors" (1961b), the series published by Elliott and Michener (1961a, b, c) on the, "Microbiology of frozen food" and the "Review of the microbiology of frozen food" by Elliott and Michener (1960) should be very helpful in setting the know-how of producing and maintaining quality products before those who need it most. The various food industry groups would do well to see that every member gets this type of information in an understandable and usable form and a way must be found to engender a desire to use it.

The literature reveals that high bacterial counts, or widely fluctuating counts, are the marks of certain production plants, while consistently low counts are the earmarks of others. It is safe to assume that such counts are a direct reflection of the type of quality and sanitary controls exercised in the production of the products. While it is true that a certain amount of poor quality products continue to appear on the market, it has been demonstrated that such products are the result of carelessness, unsanitary procedures, and often the use of shortcuts. The fact that high quality products can be and are being produced indicates that the means are available if people can just be induced to make use of them. The situation is reminiscent of the farmer who resisted the invitation to attend meetings on improved farming methods by saying that he saw no reason to attend, since he was presently farming only half as good as he knew how. Perhaps competition within the industry and pressures from without will serve to correct such a situation.

It is time to turn now to the things about which there is little knowledge, or those areas that are seen only darkly in the glass and to take stock of data that may point the way to new and better accomplishments. Although many bacterial surveys have been made, comparatively little is known about the true microbiology of the solid state, and perhaps that part that may not be truly solid. There is need to know more of the enzyme systems of microorganisms and of possible roles in the deterioration of quality and of ways of really determining quality by rapid

objective means. The literature seems vague on these subjects, but today there is gathered a group of experts from various disciplines of science that will undoubtedly shed considerable light on the subject and prepare the way for the research of the future.

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DISCUSSION PERIOD

DR. H. E. GORESLINE

NICKERSON—I think the idea that slow freezing and low temperature storage are more destructive to bacteria than fast freezing and high temperature

storage or fast freezing and low temperature storage is controversial. Mazur's work with *Brucella*, for instance, would seem to indicate this. The idea that destruction of bacteria at temperatures below freezing is due to protein denaturation is also controversial.

GORESLINE—I agree that as you go to the literature, one finds various articles that give rise to controversy in this area. With regard to survival at different temperatures, there are many articles in the literature that show that destruction is greater above freezing than it is at, say, -20° . Some of the controversy arises from differences in the manner in which the experiments were carried out. Many of the articles refer to a given temperature, but I'm certain that the researchers at the Western Regional Laboratory and some of those in industry realize that there are fluctuations in temperature of several degrees in even very good storage rooms. Nothing is said about this in the literature. Papers give a temperature of -10° or -20° and one can only assume that it remained absolutely constant. I think the reason for the destruction of bacteria is very controversial. There are those who have believed over many years that ice crystals actually penetrate the cells and kill them. Others have proven that they do not by making extremely small ice crystals. MacFarland and I used to put on earmuffs and stand in the freezer rooms while we supercooled tubes down to where they crystallized when you just touched them with a pencil. There didn't seem to be any difference in the killing rate whether the tubes had ice crystals in them or not. On that particular point, there is a great deal to be said, and I think that is one of the things this kind of a meeting ought to bring out.

CONNELLY—In heat sterilization, the medium itself is quite important. In acid medium, killing is a little more rapid. Does the substrate or medium enter into the rate of destruction in freezing?

GORESLINE—This is a very important factor in freezing storage in an acid medium such as certain fruits. I'm not sure, however, about the exact role of the medium in the actual freezing process itself. If there is anyone in the audience who has done work on the protection offered by the lyophilization of food, I would like to know about it. I mention that in case someone might be here who has been doing work in that area that I don't know about. I don't know whether or not the freeze dehydration process for food protects bacteria in the same way as the lyophilization process used in the laboratory for preserving microorganisms.