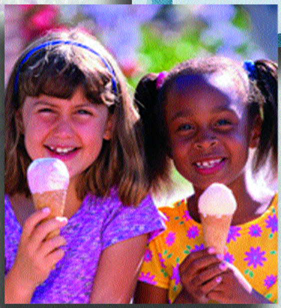
Quality and Stability of Frozen Foods
Time-Temperature Tolerance Studies and Their Significance

A National Historic Chemical Landmark

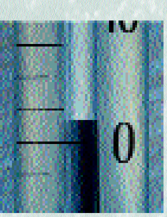


frozen food

AMERICAN CHEMICAL SOCIETY
SCIENCE THAT MATTERS

Quality and Stability of Frozen Foods Time-Temperature Tolerance Studies and Their Significance

Celebrating Chemistry
The American Chemical Society designated the study of frozen foods at the Western Regional Research Center a National Historic Chemical Landmark on December 11, 2002. For additional information see our web site: www.chemistry.org/landmarks.



"Frozen foods have a memory for adverse experiences."
– Wallace B. Van Arsdel

A Problem With Frozen Foods

During World War II a number of companies produced frozen foods, largely because food rationing and a shortage of canned goods tempted consumers to try whatever was available. By the end of the war there were 45 companies in the field, and as price controls were gradually removed by the Office of Price Administration (OPA) beginning in May 1946, the number of frozen food producers almost doubled.

Unfortunately, many packers froze almost anything that would freeze, without regard for the quality of the product that reached the consumer. Poor color and flavor, rancidity, inedible pre-cooked dinners, and even mold turned the consumer away from frozen foods as fresh and canned goods became more available. As a result, between 1946 and 1947, the production of frozen foods dropped 87 percent in a single year!

United States Agriculture Turns to Science

After this debacle the frozen food industry realized that some of its problems could benefit from careful scientific analysis. Clearly, the commercial freezing of food products is not a simple process; it was ignorance of the basic chemistry of the underlying processes that led to poor quality and the refusal of the consumer to buy frozen products.

Helmut C. Diehl, director of the Refrigeration Research Foundation, approached the United States Department of Agriculture with recommendations that it undertake a thorough investigation of the entire matter. He pledged the full financial support of the industry to this endeavor.

The project was assigned to the Western Regional Research Laboratory [now the Western Regional Research Center (WRRC)] in Albany, California, and a large staff of chemists, food technologists, and engineers was assembled. Specialized cold-storage rooms were designed and constructed. Capable of storage temperatures from –30 °F to +40 °F, these rooms could carefully duplicate the fluctuating temperatures that were the key focus of the investigation, while novel refrigeration systems could move cold air over the test foods, year after year, through many different cycles.

In close consultation with the frozen food industry, the WRRC staff worked from 1948 to 1965 to study frozen fruits, juices, vegetables, poultry, beef, precooked foods, and bakery products. The ideal scenario for the industry would be one in which the newly frozen food would forever be held in a constant low-temperature environment, generally considered at the time to be 0 °F (or lower). Much of the problem, however, lay in what happened to frozen foods between the time they left the plant and the time they were purchased by the consumer.

For practical purposes, the question was to determine what variance in the ideal temperature a product could withstand without affecting its quality. That is, according to researchers at the WRRC, "what is the tolerance of a frozen food to adverse conditions, measured in terms of time and temperature combinations?"

The newly named "time-temperature tolerance" or "T-TT" work studied changes in frozen foods as they proceeded through the distribution system, determined the deviations in the system that would still allow a satisfactory consumer product, and made recommendations for improving the distribution system itself. Once these results were available, the WRRC scientists intended to improve the selection, processing, and packaging of frozen foods so that they would better withstand adverse conditions in the distribution system. They also looked for suitable tests that could be applied to a frozen product anywhere in the distribution system to see what changes may have occurred and whether the products were still commercially acceptable when they reached the retail market. It was the beginning of a massive and arduous effort of many people over a long period of time as they attacked a complex problem using basic science and engineering.

Defining "Quality"

While it is relatively easy to measure "stability" in quantitative terms, the same is not true for "quality," which is notoriously vague and elusive. Initially, sensory panels of people trained to use sight, smell, and taste were used to provide some measure of "quality." But a new instrumentation technique was just becoming available to researchers in the early 1950s. As a method of analyzing even the trace amounts of individual chemical components in a mixture, gas chromatography (GC) quickly became the method of choice in studying aroma and flavor because

it could detect which compounds were responsible for the sensory effects, and how much of each component was present. Now that the compounds responsible for off-flavor and rancidity could be measured, the WRRC staff developed many new uses for GC in flavor and food chemistry. They were particularly successful in sampling the space above a frozen food and injecting this directly into the GC. This technique, now known as “static headspace sampling,” is still a standard in the food industry.

Chemical Reactions at Low Temperatures

Even before the T-TT work began, it was known that better frozen food quality results from blanching, the process in which vegetables are briefly heated in hot water or steam. The intent is to deactivate the enzyme peroxidase, thought to be the culprit in post-freezing degradation. T-TT studies led to a rapid, reliable, and convenient assay for peroxidase, and subsequently established the appropriate blanching parameters for individual fruits and vegetables.

As the range of foods tested in the T-TT work expanded, it became apparent that the elimination of peroxidase activity was neither necessary nor desirable during the blanching of some foods. In some cases, the index of proper blanching became the inactivation of catalase, a process that was gentler than that required for inactivation of peroxidase. In other cases, yet another enzyme, lipoxygenase, was found to be the major promoter of reduced quality. Blanching times were considerably shorter for this enzyme. Thus, what was once thought to be a single and simple blanching process was now expanded to include detailed procedures for different foods, all of which contributed to higher food quality for consumers.

Major Scientific Results from the T-TT Program

Frozen-food research had begun long before the initiation of the T-TT program, but it had been carried out by a variety of groups. This led to the fragmentation of useful information and many unanswered questions. The WRRC program was the first large-scale systematic investigation of the problems of delivering a quality product to the consumer. Among the innovative results emanating from the WRRC work were:

- Generating practical working models for a large variety of frozen foods.
- Predicting the stability and quality of the frozen food over time by using mathematical models.
- Discovering that 0 °F is the critical temperature to maintain critical stability in most frozen foods, a result that is still followed today in most household freezers.
- Recommending to the transportation industry the maximum time different foods could be warmed above 0 °F without significant deterioration.
- Identifying specific aroma compounds for a wide variety of foods.
- Establishing analytical methods for measuring “quality.”
- Establishing the stability periods for frozen foods.
- Inventing “dehydrofreezing,” wherein certain foods, such as potatoes, are partially dehydrated before freezing, resulting in financial savings because of reduced volume and weight.
- Improving the blanching process for the preparation of frozen vegetables including the Individual Quick Blanching (IQB) and the Vibrating IQB cooler.
- Discovering that for some foods, notably orange juice and onions, the addition rather than the removal of an enzyme was important for quality and stability.
- Eliminating Salmonella contamination in fresh and frozen liquid egg products.

Societal Impact of the T-TT Program

In 1950, when the T-TT studies were just underway, the frozen food industry had $500 million in sales. That number grew to $6.245 billion in 1966 and reached $68 billion in 1999. As the twentieth century ended, there were 40 million freezers and 120 million refrigerators in American homes. Over 2 million people were employed by 550 major frozen food producers, and there was a warehouse capacity of 3 billion cubic feet, with more than eight billion pounds of frozen foods in storage. One-quarter of all U.S. food exports are frozen foods, with a value of some $5 billion. The WRRC played a major part in the mobilization of scientific resources dedicated to the reproducible and safe production of high-quality, nutritious frozen foods for people everywhere to enjoy. The knowledge developed at WRRC during studies of frozen food stability and quality has since been applied to other processing and preservation techniques, to the development of value-added food products, and to food safety improvements by WRRC and other governmental, academic, and industrial research and development facilities.

National Historic Chemical Landmark

The American Chemical Society designated the Time-Temperature Tolerance research at the Western Regional Research Center a National Historic Chemical Landmark on December 11, 2002. The plaque commemorating the event reads:

After World War II, the staff of the Western Regional Research Center conducted complex and comprehensive investigations of frozen foods, focusing on how time and temperature affected their stability and quality. The discovery of the chemical changes occurring as frozen food went from the farm to the dinner table provided much of the scientific basis needed for the future success of the fledgling frozen food industry. The freezing protocols, analytical techniques, and food handling and storage recommendations from the Western Regional Research Center studies led to the superior flavor, texture, and appearance of today's frozen food.

About the National Historic Chemical Landmarks Program

The American Chemical Society, the world's largest scientific society with more than 163,000 members, has designated landmarks in the history of chemistry for more than a decade. The process begins at the local level. Members identify milestones in their cities or regions, document their importance, and nominate them for landmark designation. An international committee of chemists, chemical engineers, museum curators, and historians evaluates each nomination. For more information, please call the Office of Communications at 202-872-6274 or 800-227-5558, e-mail us at nhclp@acs.org, or visit our web site: chemistry.org/landmarks.

A nonprofit organization, the American Chemical Society publishes scientific journals and databases, convenes major research conferences, and provides educational, science policy, and career programs in chemistry. Its main offices are in Washington, DC, and Columbus, Ohio.

Acknowledgments:
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