Development of Dehydration Processes

April 18, 2007

A National Historic Chemical Landmark

AMERICAN CHEMICAL SOCIETY

SCIENCE THAT MATTERS

“I was peeling potatoes in my sleep.”

John Sullivan, USDA chemical engineer*

potato flakes

Society, potatoes, and the Department of Agriculture

The 1950s were a decade “between” for women: between the war years that forced millions into the workplace – symbolized by Rosie the Riveter – and the rise of feminism in the 1960s. In between, in the silent 50s, television conveyed the dominant image of women as homemakers in such programs as *The Donna Reed Show* and *The Loretta Young Show*. Still, the TV image of the role of women is only half the story. Many women worked out of need; for others, rising affluence and leisure freed women from household chores. In either case, women sought labor-saving devices: machines to ease drudgery and new products to simplify life. Convenience foods – aimed at making food preparation easier and quicker – became commonplace.

The interest in convenience foods merged with a change in eating habits as rising incomes meant consumers could afford more expensive foods, such as meats and fresh leafy green vegetables. This threatened many staples of the American diet such as the potato, worsening the chronic problem of overproduction. Potatoes were hardly the only crop plagued by surpluses and lower prices for producers. As early as 1938 Congress had responded by creating four regional research laboratories within the Department of Agriculture; each was charged with finding new markets and uses for regional farm commodities.

Philadelphia was chosen as the site for the Eastern Regional Research Center (ERRC). Much of the chemical engineering work at the ERRC has focused on finding ways to convert perishable commodities into stable and convenient forms. By the 1950s a multidisciplinary team of chemists, chemical engineers, and food technologists at the ERRC zeroed in on the potato, attempting to reverse the decline in U.S. potato consumption.

* *Interview with the author, January 31, 2007*

Two cooks and a water bath

Declining potato consumption coupled with increased consumer demand for convenience foods prompted the search for ways of extending the shelf life of potatoes. Ultimately, two processes emerged for producing dehydrated mashed potatoes: granules and flakes. Granules were developed first, but while they have a long shelf life, they do not re-hydrate quickly, limiting their usefulness as a convenience food.

Initial research at the ERRC on potato flakes was conducted under Laboratory Chief Roderick K. Eskew and chemical engineers James Cording, Miles J. Willard, and John Sullivan. In studies in 1954-55, the researchers found that the structure of the potato cell could best be maintained by utilizing what came to be known as the “Philadelphia cook,” a three-step controlled cooking sequence.

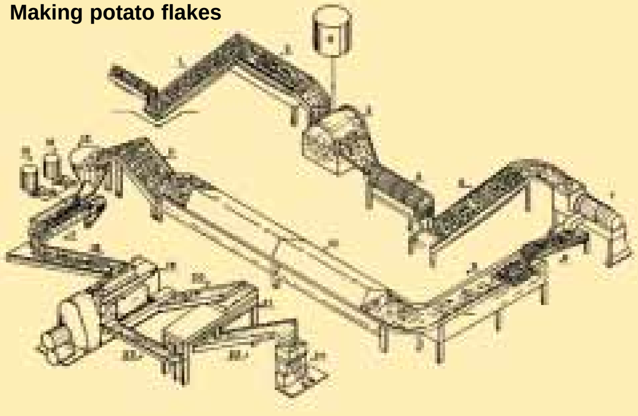
After the potatoes are peeled, trimmed, and sliced to about 5/8 inch thickness, the first cooking step begins. This is a pre-cook at a relatively low temperature – between 150° F and 165° F for about twenty minutes – to prevent the cells from softening. Because the starch gelatinizes at this point, the potatoes are not sticky when reconstituted; in fact, stopping the pre-cook at the point of gelatinization is critical for preserving cell structure.

After the pre-cook, the potatoes are then cooled to stop the cooking process and further harden the cells. (Cooks have long known that cooling cooked, starchy vegetables in cold water reduces their stickiness.) The third and final stage is the cook done in a steam cooker. Care must be taken to avoid overcooking which would result in a rupture of the cells leading to poor texture and flavor. Cooking time varies from fifteen minutes to an hour, depending on the solids content of the potato.

Pastiness caused by cell rupture can also be mitigated if the potatoes are mashed immediately following the final cooking. Experiments at the ERRC determined that additives should be incorporated into the mash before drying to improve texture and extend shelf life. One common additive is a dilute solution of sodium bisulfite to retard non-enzymatic browning; another is a monoglyceride emulsifier which also contains antioxidants and which helps prevent a pasty, rubbery texture.

The final major step in the production of instant mashed potatoes is drying. In their initial research, Cording and Willard used a tiny double-drum drier that dried the potatoes in about twenty seconds from 80% moisture to 5%. Eventually, the researchers concluded that a single-drum drier was preferable as it yielded a denser flake that was less costly to package. The processed potatoes come off the drum driers in a continuous sheet which must be broken into flakes before packaging.

Making potato flakes



The mashed potato

The potato flake process yielded a product with a stable shelf life which could be reconstituted into instant mashed potatoes with good texture, flavor, and aroma. Commercial applications of the potato flake process increased demand for potatoes. The "Philadelphia cook" enabled the production of processed potatoes from lower solids content varieties produced in the East as well as the higher solids types from the West.

Instant potato flakes were introduced commercially in 1957 and became an "instant" success; by 1960 six processors had turned more than four million bushels of potatoes into flakes. In the 1960s, consumption increased as flakes were used not only in mashed potatoes, but also in coatings, ingredients, and fabricated foods.

Miles Willard, who had been instrumental in the research conducted at the ERRC, went into the private sector where he developed a new class of potato chip-like snack foods using reconstituted potato flakes. Called "crisps," these products included Pringles®; the market for these chips exceeded $1.4 billion in 2000. In 2003 more than 2.4 billion pounds of potatoes were turned into dehydrated potato flakes in the United States. The United States Potato Board estimates that 10% of the U.S. potato crop is used in dehydration processes, with half of that number turned into potato flakes (compared to 30% for granules and 20% for potato pieces).

Processed potato flakes have been used as rations by the U.S. military and are a key component of international food aid programs because of their long shelf life. Millions of pounds of potato flakes are purchased by the USDA annually for use in the National School Lunch Program and other domestic child nutrition and food assistance projects.

Milea and co-workers at the USDA, circa 1955

Explosion-puffing process

By the mid-1970s research on the potato flake process was over and the commercial applications of the process were assured. This enabled researchers at the ERRC – among them, Eskew, Cording, Sullivan, and Nelson Eisenstadt – to shift their attention to developing new methods for drying fruits and vegetables. The two most commonly employed methods – hot-air drying and freeze drying – had limitations. Dehydrating pieces of fruit or vegetable by hot air is slow, as is the re-hydration process. The flavor of the re-hydrated pieces often is poor because of long exposure to high temperatures during drying. Freeze-dried products re-hydrate quickly and their quality is superior to the hot-air dried products, but the drying time is even slower and thus more expensive.

A third process – developed at the ERRC – incorporates explosion puffing in the dehydration process. Cording had observed that air-dried pieces of fruits and vegetables collapsed so he hypothesized that if the pieces were puffed up, this would open the inside in a honeycomb effect, making drying easier and quicker. The resulting product is similar in quality to the freeze-dried version, but the re-hydration times are even faster. The explosion-puffing process yields low-moisture – less than four percent – fruit and vegetable pieces, producing a rapidly reconstituted, high quality, and inexpensive product.

Initially fruit or vegetable pieces are hot-air dried to a moisture content between 15% and 35%, a level at which the pieces attain a degree of rigidity. The partially-dried pieces are then fed into the "puffing gun." The initial experiments were carried out in a small gun heated by an external gas flame. The vegetable or fruit pieces were heated while the gun rotated at a speed sufficient to tumble the pieces. Chamber pressure in the gun resulted from steam released by the heating of water in the pieces. In the small gun the time required to obtain the requisite pressure varied from seven to fifteen minutes at which point the product exploded from the gun with a loud bang. The vegetable or fruit pieces expanded – "puffed" – during the explosion.

Soon, the process was scaled up to get reasonable cost estimates. A large commercial cereal-puffing gun was acquired to test commercial-type feed rates on large batches. The new gun produced vegetable and fruit pieces of superior color and flavor, but it was too labor intensive for commercial use. To lower processing costs, a Continuous Explosion Puffing System (CEPS) was built by Cording, Wolfgang Heiland, and R.G. Mercado. This device separated the two major functions: heating and explosion puffing. The heating is done in the main chamber by dispersing superheated steam. The explosion puffing takes place when the discharge piston is released. This reduces the pressure in the discharge chamber from that in the heating chamber to atmospheric levels. The resulting explosion produced a better product with reduced labor costs.

CEPS was initially developed to produce dried potatoes and carrots, but was later applied to apples, blueberries, pears, celery, beets, sweet potatoes, turnips, rutabagas, onions, peppers, mushrooms, and other commodities. Puffed carrots work well in quick-cooking dehydrated soup mixes where rapid re-hydration occurs and they have been marketed by companies world-wide. Puffed potatoes are marketed as ingredients in meals for campers and for emergency rations.

National Historic Chemical Landmark

The American Chemical Society designated the research on food dehydration processes at the Eastern Regional Research Center as a National Historic Chemical Landmark in a ceremony in Wyndmoor, Pennsylvania, on April 18, 2007. The plaque commemorating the event reads:

Chemists, chemical engineers, and food technologists at the Eastern Regional Research Center developed innovative dehydration technologies, most notably the potato flake process and explosion puffing. These technologies created opportunities for the development of novel, high-quality convenience foods and food ingredients for domestic and global markets. Instant mashed potatoes and formulated potato crisps, both made from potato flakes, are among the most popular and recognizable food products ever created. These food dehydration technologies increased U.S. potato production and utilization, provided key products for food aid programs, and made a lasting and significant impact on the ways in which foods are processed worldwide.

About the National Historic Chemical Landmarks Program

The American Chemical Society, the world's largest scientific society with more than 160,000 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: www.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:

Written by Judah Ginsberg

Photos supplied by the Eastern Regional Research Center; Photo Illustration: Paul Pierlott.

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American Chemical Society
Office of Communications
National Historic Chemical Landmarks Program
1155 Sixteenth Street, NW
Washington, DC 20036
202-872-6274
800-227-5558
www.chemistry.org/landmarks