INTRODUCTION

Blanching is a unit operation prior to freezing, canning, or drying in which fruits or vegetables are heated for the purpose of inactivating enzymes; modifying texture; preserving color, flavor, and nutritional value; and removing trapped air. Hot water and steam are the most commonly used heating media for blanching in industry, but microwave and hot gas blanching have also been studied. Different hot water and steam blanchers have been designed to improve product quality, increase yield, and facilitate processing of products with different thermal properties and geometries. More recently, energy conservation and waste reduction have driven further improvement of equipment design. Although blanching seems a simple operation, heat transfer to a conveyed bed of product and its effects on product properties are very difficult to accurately model with predictive mathematics. Processing conditions are usually set up to inactivate enzymes, but other quality parameters, such as color and texture, are commonly monitored. For a given product, typically mass flow rate is fixed, temperature is measured, and heating media flow rate is adjusted to ensure that the temperature is kept at the set point.

The objective of this article is to review blanching principles and equipment, effects of blanching on product quality, blanching indicators, and energy and waste considerations.

PRINCIPLES AND EQUIPMENT

The design of blanching systems depends on the product, the process following it, and the final use of the product. Blanching is carried out as a pretreatment for freezing, canning, and drying. In 2003, 9.8 and 13.8 million metric tons of vegetables for freezing and canning, respectively, were produced in the United States with a total farmgate value of US$1.4 billion. Studies on the effects of blanching as a pretreatment for freezing date back to the late 1920s and early 1930s, and have been reviewed. Most vegetables are blanched prior to freezing to inactivate enzymes that cause the development of off-flavors and off-colors during frozen storage. Some exceptions include onions, leeks, and peppers because they lose flavor and color on blanching. Blanching removes trapped air (e.g., in broccoli florets) and metabolic gases within vegetable cells and replaces them with water, forming a semicontinuous water phase that favors a more uniform crystal growth during freezing. Gas removal is the main benefit of blanching before canning because it allows easier can fill, reduces strain on can during heating, and reduces can corrosion. Although, in this case, enzyme inactivation also takes place, it is not relevant because any remaining activity is destroyed on retorting. Blanching facilitates peeling and dicing, and is also accompanied by microbial load reduction. Fruits are usually not blanched, or blanched under mild (low temperature) conditions prior to freezing because blanching produces undesirable texture changes. Before drying, fruits and vegetables are sometimes blanched. After blanching, vegetables are quickly chilled by spraying with cold water, or by conveying them to a flume of cold water that often serves to transport them to the next part of the process. Blowing cold dry air has also been used to take advantage of evaporative cooling, using the water adhered to the surface of the product.

Water Blanching

Water blanching is performed in hot water at temperatures ranging typically from 70°C to 100°C. However, low-temperature long-time (LTLT) blanching and combinations of LTLT with high-temperature short-time (HTST) blanching have also been studied. Water blanching usually results in a more uniform treatment, allowing processing at lower temperatures. There are water blanchers that use a screw or a chain conveyor to transport the product inside the tank, where hot water is added. Others use a rotary drum to immerse and convey the product. Water is usually heated indirectly with steam in a heat exchanger; therefore steam quality does not need to be “food-grade.” Water blanching requires longer processing times, results in increased leaching of minerals
and nutrients such as vitamins, and produces effluents with large biological oxygen demand (BOD).

**Steam Blanching**

In steam blanchers, a product is transported by a chain or belt conveyor through a chamber where “food-grade” steam at approximately 100°C is directly injected. Usually temperature in the headspace is measured and the flow rate of steam is controlled. Steam blanching is usually used for cut and small products, and requires less time than water blanching because the heat transfer coefficient of condensing steam is greater than that of hot water (refer to the articles “Convection Heat Transfer in Foods” and “Convective Heat Transfer Coefficients”). However, because of the high-temperature gradients between the surface and the center of the product, larger products or pieces of product can be “overblanch” near the surface and “underblanch” at the center. To increase heat transfer efficiency, forced convection blanchers have been designed. These blanchers are made of nested chambers that allow recirculating steam with a fan that interconnects both chambers. The fan forces the flow of steam through a packed bed of product conveyed by a mesh belt. This technology allows higher product bed depths and higher product throughput. Figure 1 shows a picture and a schematic of the cross section of a forced convection blancher. Another technology, individual quick blanching (IQB), was developed to minimize product treatment nonuniformities. In IQB, a single layer of product is conveyed through the steam chamber and each “individual” piece of product immediately enters in contact with the steam.

Steam blanching is more energy-efficient and produces lower BOD and hydraulic loads than water blanching. In addition, nutrient leaching is reduced compared to water blanching.

**Microwave Blanching**

Studies on radiofrequency and microwave vegetable blanching date back to the 1940s. Among the first important findings were retention of ascorbic acid and carotene, and very short processing time compared to conventional water or steam blanching. These early studies used batch ovens, making the cooling step difficult. Continuous ovens developed later overcame that issue. However, most studies on microwave blanching have been carried out using commercially available home microwave ovens. These studies are difficult to compare due to the variability in equipment performance and are difficult to extrapolate to industrial conditions. Recent studies used different products and improved instrumentation such as fiber optic temperature probes and infrared imaging to further demonstrate heat penetration and efficacy of the technology. Microwave technology has been combined with water blanching to further reduce heating time. Despite the tremendous potential of microwave blanching to improve product quality and minimize waste production, industrial implementation may take several years for several reasons:

In general, the use of microwave ovens in industry is limited. At present, high-value products are the most likely users for this technology. Once it has shown its value, it might draw the freezing and canning industry. Substitution of existing water or steam blanchers is unlikely to occur. The vegetable industry would be reluctant to replace pieces of...
equipment before full depreciation and especially if their market niche is stable.

Finally, it remains to be shown that the shorter processing times of microwave ovens will result in reduced operating costs and higher value products, thereby compensating for equipment cost.

**Gas Blanching**

Hot gas blanching using combustion of flue gases with addition of steam to increase humidity and prevent product dehydration has been studied. This type of blanching has the advantage of reducing waste production, is comparable to conventional blanching with respect to nutrient retention, but often results in product weight loss. This approach is not currently used in industry and needs further research.\(^{[2]}\)

**ENERGY AND WASTE CONSIDERATIONS**

In the freezing industry, blanching is the operation with the second largest energy consumption after freezing itself. The energy balance for a steam blancher can be written as follows:

\[
Q_H = W_P(C_P\Delta T) + Q_L
\]

\[
W_S = \frac{Q_H}{\lambda}
\]

where \(Q_H\) is the heat supplied to the blancher, \(W_P\) is the mass feed rate of the product to the blancher, \(C_P\) is the heat capacity of the product, \(\Delta T\) is the difference between the raw vegetables and the blanching temperature, and \(Q_L\) represents energy losses. \(W_S\) is the mass flow rate of steam and \(\lambda\) is the heat of vaporization of steam. In an ideal blancher, \(Q_L = 0\); assuming that \(C_P = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}\) and \(\lambda = 2330 \text{ kJ kg}^{-1}\), steam requirements would be 134 kg ton\(^{-1}\) vegetables.\(^{[8]}\) Heat losses can be estimated from the difference between the actual steam consumption and this proposed ideal estimate. Decrease in energy losses has been performed by insulating blancher walls and improving blancher seals. However, in steam blanchers, steam loss through product inlet and outlet ports is still a problem. Product retention time at a constant product feed rate (and therefore equipment size) is determined by the rate of heat transfer from the heating medium to the product. The rate of heat transfer depends on the thermal conductivity of the product, heat transfer coefficient, and temperature gradients between the heating medium and the product (refer to Eqs. 1 and 3 in the articles entitled “Heat Transfer,” “Heating and Cooling Lag Constants,” “Thermal Conductivity of Foods,” and “Convective Heat Transfer Coefficients”).

Blanchers are designed to handle a variety of products by adjusting feed rate.

Blanching produces approximately 40% of total plant effluent BOD in vegetable processing. Each vegetable produces different amounts of wastes because different products have different compositions, shapes, and surface areas. In addition, organic matter diffuses at different rates depending on the product. For example, leaching is faster in cut product through the cut sections than in wholesome products such as peas or lima beans where a membrane acts as a diffusion barrier. To reduce BOD and hydraulic waste loads, in many cases, water blanchers have been substituted by steam blanchers. When water blanching is required, it has been recommended to recirculate water streams to saturate them, thus preventing further leaching of organic matter, resulting in an overall decrease in BOD and a potential increase in nutrient retention. Microwave blanching may play an important role in further reducing BOD load, but as mentioned above, this technology has not reached industrial applications for blanching and its energy efficiency relative to conventional blanching needs to be demonstrated.

**EFFECTS ON FOOD QUALITY AND BLANCHING INDICATORS**

Flavor, texture, and color are quality parameters that are typically assessed for fresh products, immediately after blanching and after a given storage time. These studies allow determining the efficacy of the process in retaining or improving food quality and depend on each process. As discussed above, food quality is greatly affected by the type and extent of blanching. Mathematical equations describing the effects of thermal treatments on the quality of foods are presented in the articles “Decimal Reduction Times,” “Activation Energy in Thermal Process Calculations,” and “Thermal Resistance Constant and \(Q_{10}\)” in this encyclopedia. A summary of the quality parameters, commonly used to evaluate the effects of blanching is presented below.

**Flavor**

Blanching indirectly and directly affects the flavor of many products by inactivation of enzymes responsible for off-flavor development. The most notable is lipoxygenase (LOX) in several vegetables.\(^{[9,10]}\) Sometimes
Blanching increases flavor retention, and sometimes it removes undesirable bitter flavors from the product. Headspace volatiles assayed mostly by gas chromatography have been correlated to flavor attributes defined in sensory panels.

**Texture**

Blanching can result in undesirable softening of vegetable tissues. However, calcium can be added to reduce the softening.[11] A combination of low-temperature blanching and calcium addition has also been shown to be effective in firming canned vegetables.[4] The latter is due to the activity of pectin methyl esterase that produces pectin with a reduced degree of methylation that readily interacts with calcium. Texture assessment of the effects of blanching includes sensory characterization of firmness, crispness, and crunchiness, and instrumental measurements such as cutting energy and maximum shear force (refer to an article entitled “Food Texture”).

**Color**

Blanching can have both direct and indirect effects on color. The former is exemplified by the destruction of pigments, such as chlorophyll, by heat. A good example of an indirect effect is in potato processing, in which the reducing sugar content can be adjusted via water blanching, affecting color development during later, more intensive heating steps where the Maillard reaction takes place.[12] Color assessment in the food industry is commonly performed visually by comparison to standards. Instrumental methods based on reflectance (e.g., Hunter colorimeter) are also frequently used.

**Nutritional Value**

Generally, blanching produces a decrease in the nutritional value of foods. Nutrients leach out from the product especially during water blanching. In addition, vitamins are degraded by heat. Vitamin C (ascorbic acid) is, by far, the most commonly assayed nutrient in blanching probably because its high solubility and heat susceptibility make it a conservative indicator of nutrient retention. Vitamins B1 and B2, carotenes, and dietary fibers have also been assayed.

**Quality Indicators**

Peroxidase and catalase are the most commonly assayed enzymes for blanching before freezing because they are more resistant to heat than most enzymes, and there are simple rapid assays to measure their activity. However, for many vegetables such as corn, peas, and green beans, LOX, a less heat-resistant enzyme, was found to be the enzyme responsible for the development of off-flavors.[9,10,13] Although food processors are aware of this, it is only recently that some rapid methods to measure LOX activity have been developed.[14,15]

**CONCLUSION**

Blanching is an old and well-established practice in the food industry. Early technological improvements focused on increasing product quality. Later, process efficiency in terms of product throughput, energy efficiency, and waste effluent reduction has been the main concern. Targeting the right enzyme indicator would reduce blanching time and tackle all these priorities: improving product quality (increasing retention of nutrients and other freshlike quality attributes), reducing energy consumption, and reducing waste production. However, implementation of this requires modification of existing equipment to allow either faster product conveying or shorter pieces of equipment. Furthermore, food processors and their customers have been using long-established United States Department of Agriculture guidelines that suggest the use of catalase or peroxidase as indicators. Therefore there is still room for improvement of an apparently simple technology.

**REFERENCES**


