Quality Indicators in Blanched, Frozen, Stored Vegetables

Lipoxygenase, rather than peroxidase, is suggested as a blanching indicator

DIANE M. BARRETT AND CHOCKCHAI THEERAKULKAIT

□ VEGETABLE QUALITY: WHAT is it, how is it measured, and why is it so important? In today's marketplace, where the consumer has a choice of a tremendous cadre of food products, be they fresh, lightly processed, dried, canned, pickled, or frozen, the manufacturer strives to distinguish his or her product on the basis of quality. In the frozen vegetable industry, quality has at times been subjugated to second priority because of what may be overcompensation in the safety arena.

The purpose of this article is to discuss the quality of frozen vegetables, to emphasize the importance of effective blanching, and to give tips on how blanch time may be decreased significantly to produce higher quality products while resulting in lower energy requirements and processing water disposal costs.

The blanching process involves exposing plant tissue to some form of heat, usually steam or hot water, for a prescribed time at a specified temperature. This process is utilized in both the canning and freezing industries for slightly different reasons. As a pre-freezing operation, blanching is the primary means of inactivating undesirable enzymes present in the vegetable and reducing the microbial load, while at the same time it aids in removing tissue gases, shrinking the product, peeling, cleaning and stabilizing color. When utilized prior to canning, the blanching operation need not be sufficient to ensure enzyme inactivation and microbial load reduction because this step is followed by the more severe retort operation.

Many of the quality changes that frozen vegetables fall victim to are catalyzed by enzymes, therefore it is logical to choose an enzyme as an indicator of the adequacy of a blanching process. From about 1949 to 1975, catalase was adopted as the indicator enzyme for English green peas and a few other vegetables, while peroxidase served as the indicator enzyme for all other vegetables (Lim et al., 1989). In 1975 the U.S. Dept. of Agriculture (USDA, 1975) recommended that peroxidase (POD) inactivation was necessary to minimize deterioration of quality during frozen storage and that catalase inactivation was not a satisfactory predictor.

Which Indicator

In some commodities, measurement of peroxidase as an indicator of blanching does not make sense. Lim and co-workers (1989) point out that, with the exception of lignin formation in asparagus, there is no evidence that peroxidase is correlated to quality deterioration. By inactivating peroxidase one can assume that all other quality-affecting enzymes have been destroyed, however, use of peroxidase may also result in unneeded loss of color, flavor, texture, and nutrient quality in addition to excessive use of energy and water.

As illustrated in Table 1, there is no single key enzyme which is responsible for all of the vegetable quality changes possible during frozen storage. In many vegetables the limiting quality attribute during frozen storage is off-flavor development, which is most often catalyzed by lipoxygenase. Rather than design a process to inactivate all enzymes or the most heat-resistant one, researchers have recently concluded that the enzyme selected as an indicator should be the one directly involved with major deteriorative changes during frozen storage.

Author Barrett, a Professional Member of IFT, is Associate Cooperative Extension Specialist, Dept. of Food Science and Technol., Cruess Hall, Univ. of Calif., Davis, CA 95616-8598. Author Theerakulkait is assistant Professor, Dept. of Food Science and Technol., Kasetsart Univ., Bangkok, Thailand. Send reprint requests to author Barrett.

Table 1—**Enzymes Responsible for Quality Deterioration** *in unblanched vegetables*[a]

Quality defect	Responsible enzymes
Off-flavor development	lipoxygenase lipase protease
Textural changes	pectic enzymes cellulase
Color changes	polyphenol oxidase chlorophyllase peroxidase (lesser extent) lipoxygenase[b]
Nutritional changes	ascorbic acid oxidase thiaminase

[a]Williams et al., 1986

[b]hydroperoxides and radicals formed by lipid oxidation may destroy chlorophyll and carotenoids

Williams et al. (1986) evaluated the sensory character of blanched vegetable purees to which isolated enzymes had been added and found that lipoxygenase was the enzyme most active in aroma deterioration in English green peas and green beans. Lipoxygenase is widely distributed in vegetables and evidence is mounting to support its involvement in off-flavor development and color loss (Table 2). Off-flavors are produced as a result of lipoxygenase-catalyzed oxidation of fatty acids containing a cis, penta-1,4-diene unit (–CH–CH–CH_2–CH–CH–).

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Quality Indicators *(continued)*

The greatest hindrance to use of lipoxygenase as an indicator to date is that a rapid assay is either unavailable or not readily utilized by the frozen food industry. Lipoxygenase analysis may be carried out in the laboratory using either a spectrophotometric or a polarographic method, however both can pose difficulties and neither would be feasible in a processing facility environment. The spectrophotometric method may be not used if the reaction solution is unclear, and the polarographic method may lack sensitivity because it measures lipoxygenase activity in addition to any other reaction which utilizes O_2. A rapid assay for lipoxygenase was developed by Williams et al. (1986) based on a potassium iodide-starch method, however this assay has not been readily adapted by the frozen food industry.

Table 2—**Pros and Cons** *of using peroxidase and lipoxygenase as indicators*

Enzyme indicator	Pros	Cons
Peroxidase	wide distribution in vegetable tissues	correlation to quality unclear
	resistant to destruction by heat	inactivation may require overblanching
	simple and rapid quantitative test possible	regeneration is possible
		different vegetables have different thermally stable isozymes
		1-10% residual POD is thermally stable in most vegetables
Lipoxygenase	wide distribution in plants (particularly legumes and seeds)	rapid assay either unavailable or not utilized
	good evidence to support involvement in off-flavor development and color loss	interference common in the spectrophotometric assay
	heat labile	polarographic method may not be sensitive
		nonenzymatically catalyzed lipid oxidation may occur

Support for Lipoxygenase

Over the past twelve years, numerous investigators have evaluated the occurrence of lipoxygenase in vegetables and have determined its activity, sensitivity to temperature and pH, and involvement in the production of off-flavors during frozen storage. In the case of corn, green beans, and green peas, there is fairly strong evidence that off-flavor development is the limiting factor in frozen storage and lipoxygenase activity is the primary culprit. A summary of lipoxygenase-related research activities in our laboratory over the past several years is presented below.

• **Supersweet Corn.** Supersweet corn is popular as a fresh, frozen or dried product, however blanching often results in caramelization of these high sugar varieties and formation of an undesirable gray or brown product. Industrial blanch conditions were established based on the requirement for peroxidase inactivation, however off-flavor catalyzed by lipoxygenase is the greatest limitation to storage life.

Times required for lipoxygenase inactivation in kernel corn and corn-on-the-cob were determined prior to initiation of the blanching and frozen storage study. Lipoxygenase inactivation in kernel corn could be achieved in approximately 40 sec at 200°F, while inactivation in corn-on-the-cob required 6 to 9 min at 200°F. Peroxidase inactivation, on the other hand, required 60 sec at 200°F in kernel corn and 18 to 20 min at 200°F in corn-on-the-cob. With these results in mind, a study was designed where kernel corn was steam blanched (200°F) for 0, 1, 2, 3, and 4 min, and corn-on-the-cob was blanched for 0, 3, 6, 9, and 12 min. Following blanching, samples were stored at −10°F for 0, 3, 6, and 9 mo and sensory evaluation of appearance, texture, flavor, and overall desirability was carried out using a 50-member consumer panel after each storage period.

Sensory results for stored kernel corn indicated that unblanched kernels were significantly less desirable in appearance, texture, flavor, and overall desirability. There was no significant difference in any quality attribute, however, between the 1, 2, and 3 min blanch treatments after 3, 6, or 9 mo of frozen storage. In the case of the 6 and 9 mo stored kernel corn samples, the 4 min blanch treatment was significantly different from the 1, 2, and 3 min treatments. It would appear that a one min, or possibly shorter, blanch was adequate to ensure the sensory quality of frozen Supersweet kernel corn.

Corn-on-the-cob sensory results show that, although the appearance of both unblanched and 3 min blanched samples was preferable to those blanched longer, a longer blanch treatment resulted in better flavor and overall desirability after all storage times. Corn-on-the-cob samples which had been blanched for 9 and 12 min at 200°F and stored at −10°F for 3, 6, and 9 mo were preferred to samples blanched at shorter times.

Because stored kernel and cob samples blanched for times shorter than that required for peroxidase inactivation were found to be superior, one may assume that peroxidase had little to do with quality. From this study we would conclude that a one min blanch at 200°F should be adequate for Supersweet kernel corn, while a 9 min blanch would suffice for corn-on-the-cob.

• **Sweet Corn and Green Bean.** In another study, peroxidase and lipoxygenase activities in raw, blanched and stored corn and green beans were evaluated. Different varieties of each commodity were found to have significantly different initial enzyme activities and therefore require different processing times. Lipoxygenase inactivation in both corn and green beans, however, required less than half the time required for peroxidase. Times required for inactivation of peroxidase and lipoxygenase at 200°F in cut kernel Golden Jubilee corn were 1.0 min and 0.5 min, respectively. In corn-on-the-cob, inactivation of peroxidase and lipoxygenase at 212°F required 18 min and 9 min, respectively. Times required for inactivation of peroxidase and lipoxygenase at 200°F in green bean variety Oregon 91G were 2.0 min and 0.5 min, respectively.

Kernel corn and green bean samples were blanched for "short" and "long" times at 200°F in order to

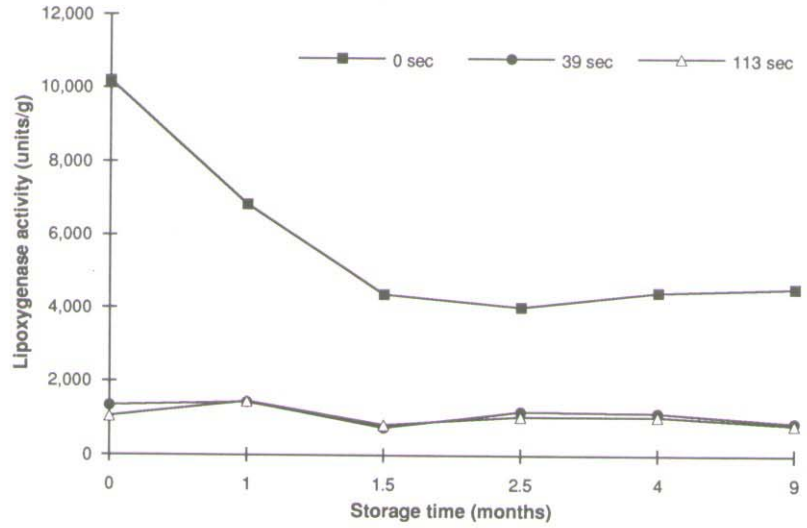
achieve lipoxygenase and peroxidase inactivation then stored at +8°F, 0°F, and −8°F for 0, 1.5, 2.5, 5 and 9 mo. Processors typically store corn at temperatures between 0 and −8°F, but temperature fluctuations are common during warehousing and distribution. Enzyme activity and color were evaluated after each storage period and sensory quality after 9 mo. Peroxidase activity was higher in all samples receiving a short blanch, but lipoxygenase activity was negligible in all short and long blanched samples.

After both blanch treatments there appeared to be a low residual level of lipoxygenase activity in corn, which may represent a thermally stable isozyme which does not affect off-flavor. This activity was found to decrease significantly with storage time (Fig. 1), and there was no significant difference in activity between short and long blanch times at any particular storage time or temperature. Peroxidase activity was significantly higher in unstored corn blanched for a short time, but in stored corn a 39-sec blanch was found to be sufficient for inactivation of both peroxidase and lipoxygenase. There was no significant difference in POD activity between the various storage times or temperatures evaluated. There were no significant differences in off-flavor or off-color between the short and long time blanched corn after 9-mo storage at +8°F, 0°F, or −8°F.

Green beans blanched at 63 and 120 sec showed no significant difference in lipoxygenase activity with storage time, however activity in samples stored at −8°F was slightly higher. There were significant differences in peroxidase activity in the short- and long-time blanched green beans, with activity in the former being higher in all cases. Peroxidase activity decreased slightly with storage time under all conditions, with green beans stored at −8°F showing the lowest rate of decline.

Sensory evaluation after 9 mo of frozen storage found no significant difference in green bean off-flavor between short and long blanch times at any storage temperature (Fig. 2). Off-color was significantly higher in green beans which were blanched for 63 sec, however, indicating that in this commodity color may be the limiting factor in frozen storage.

*Fig. 1—**Lipoxygenase Activity** in kernel corn stored at 0°F*



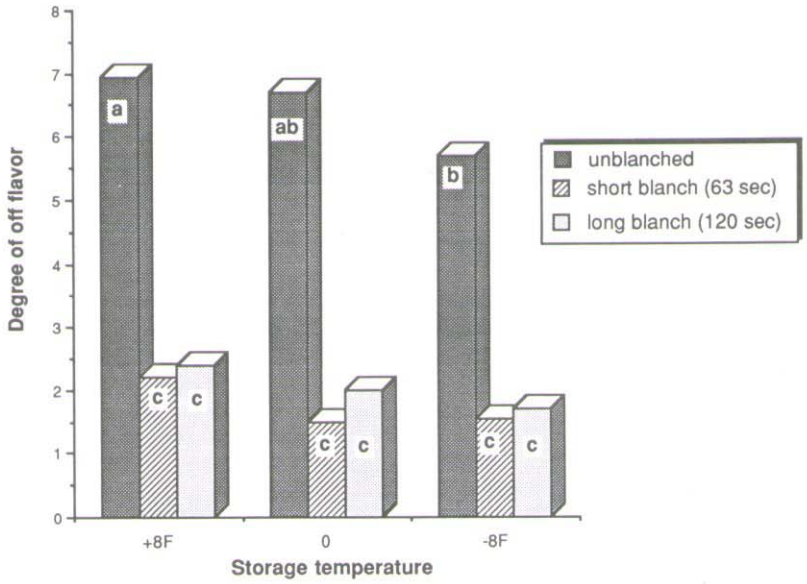


*Fig. 2—**Off-Flavor** in blanched green beans stored at −8, 0, and +8°F*

Investigations into the merits of using lipoxygenase rather than peroxidase as an appropriate blanching indicator point clearly to the former in many cases. In our laboratory we found that, in Supersweet corn, blanch times could be reduced 30–50% in kernel and cob corn. Sweet corn kernels are effectively blanched in half the time typically employed. In the case of green beans, off-flavor is eliminated by a one min blanch, but off-color prevention may require a longer time.

We strongly encourage the frozen vegetable industry to consider revision of its present use of peroxidase, and to promote research activities towards development of a rapid method of lipoxygenase determination.

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