AN ABSTRACT OF THE THESIS OF

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Title: Effect of High-Temperature Short-Time Pressure Blanching on Physical, Chemical and Sensory Properties of Frozen Corn

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The effect of HTST pressure blanching processing parameters, as compared to conventional steam blanching, on enzyme activity, moisture, drip loss, shear force, sensory attributes and consumer acceptability of frozen sweet corn were determined. Complete inactivation of catalase and peroxidase required HTST treatments of 60 psi and 75 psi, respectively. No lipoxygenase activity was detected in the blanched corn. Moisture content increased slightly and maximum shear force decreased in the HTST blanched corn as compared to the steam blanched samples. No differences were observed in total work of compression and shear or drip losses in frozen corn prepared by the two blanching processes. Blanch pressures of 60 psi and 75 psi resulted in corn equivalent in sensory qualities to the control steam blanched product as judged by a trained panel. The 30 psi blanch treatment was rated higher in stale/oxidized, fishy, bitter, and other undesirable descriptors. Stale/oxidized and

sweet/caramel character increased with storage time. Consumer tests resulted in no significant differences in acceptability across blanch treatments or storage time.

Effect of High-Temperature Short-Time Pressure Blanching on Physical, Chemical and Sensory Properties of Frozen Corn

by

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INTRODUCTION

As a result of the debate in the 1970s about energy usage and protection of the environment, new methods of blanching have been developed. On the basis of conventional water and steam blanchers, new blanchers have been constructed which are well insulated, compact in size, and often carefully controlled in performance (Poulsen, 1986). One such blancher is the high-temperature short-time (HTST) pressure blancher, the benefits of which include steam savings, product quality, dependable operation, and a high throughput rate (McGowan et al., 1984).

Drake and Carmichael (1986) demonstrated HTST steam blanching is able to produce high quality vegetables and imparts distinct quality parameters on frozen vegetables, when compared to water-blanching. These quality parameters are dependent on the blanching treatment (time and pressure) and are unique to the particular vegetable being processed. Energy efficiency increases to 80% with HTST blanching as compared to 60% with water blanching, making HTST blanching attractive to the vegetable processing industry. In addition, the HTST system blanches in less time, minimizing heat exposure of the product, and increasing production capacities (McGowan et al., 1984).

Blancher design influences drip loss, moisture content, total product yield and color of frozen corn (Drake and Swanson, 1986). Therefore, for wider adaptation of the more energy-efficient HTST pressure blanching process by the food industry, a need exists for more comprehensive knowledge of the effect of process treatment parameters on the long term storage quality of frozen vegetables. This study was initiated to determine the effect of HTST pressure blanching processing parameters, as compared to conventional steam blanching, on enzyme activity, moisture, drip loss, shear force, sensory attributes and consumer acceptability of frozen sweet corn.

REVIEW OF LITERATURE

Blanching

The term "blanching" was originally used to designate those heat treatment operations in the processing of foods for frozen storage which prevent deteriorative changes that occur in foods not so treated. Just as pasteurization (60 ^{o} - 85 ^{o}C) is associated with destruction of microorganisms, blanching (70 ^{o} - 105 ^{o}C) is now associated with destruction of enzyme activity. Today the procedure is used not only in frozen food processing, but also for dehydration and canning (Schwimmer, 1981). Kohman (1928) and Joslyn and Cruess (1929) were among the first to realize the importance of using heat treatments to inactivate enzymes and stabilize frozen vegetables against off-flavor and off-odor development. This has been more recently verified by the findings of Mueftuegil and Yigit (1983) and Kostaboxakis and Papanicolaou (1984).

In addition to the main purpose of blanching, prevention of enzyme action leading to discoloration, development of off-flavors, textural changes, and loss of nutritional quality during storage, there are other benefits. Proteins denature and aggregate when heated, causing coagulation and shrinkage. If this shrinkage happened during sterilization of canned products, they would appear to be underweight. Starch that could otherwise cause a cloudy appearance in the brine can be hydrolyzed. Air, which is confined to plant tissues, is expelled making a product easier to package and achieving greater package fill. Foreign materials are removed and defective parts become more visible so the product can be sorted more effectively. The microbial status is improved because vegetative cells, yeasts and molds are killed and the cooking time of the finished product is shortened (Crafts, 1944; Cain, 1950; Schwimmer, 1981; Poulsen, 1986).

Blanching has disadvantages as well. Because of the heat treatment there may be losses in textural quality. When water or steam is used for heating, leaching of vitamins, flavors, colors, carbohydrates and other water-soluble components takes place. A considerable portion of these losses occurs in the postblanch period, especially during cooling if cold water is used. The adverse environmental impact must also be considered because of the demand for large amounts of water and energy, and the output of solids-containing effluent (especially for water blanch) which can have a high biological oxygen demand. There are, therefore, tradeoffs in blanching and process optimization is critical (Holdsworth, 1968; Voirol, 1972; Schwimmer, 1981; Poulsen, 1986).

Comparison of Blanching Techniques

Blanching is accomplished using either hot water or steam. Water blanching is the oldest blanching method and up until the last fifteen years, was probably the most widely used blanching procedure in food processing. Today, use of steam blanching techniques nearly equals use of water blanching methods (Schwimmer, 1981). Both blanching methods have been improved in recent years to lower energy and water consumption and reduce pollution. One of these improved water blanchers utilizes recycling of water during blanching for product heating and cooling (Drake and Swanson, 1986; Poulsen, 1986). Water flow is counter-current to product flow, and heat absorbed by water used to cool the product is recycled to preheat or blanch the product in subsequent stages.

Steam blanching has been found to cause less nutrient loss and lower effluent volumes than water blanching (Harris and von Loesecke, 1960; Lee, 1958). However, thermal energy efficiency can be as high as 60% for water blanchers, versus 5% for ordinary steam blanchers (Bomben, 1977). The loss of energy with conventional steam blanching equipment is due to the relatively slow rate of heat penetration of food pieces in comparison with their rate of travel through the blancher. Because steam is wasted at the inlet and outlet, the heat does not have the opportunity to adequately penetrate the pieces (Schwimmer, 1981; Poulsen, 1986). Scott, et al. (1981) showed that thermal efficiency of steam blanchers could be greatly increased by reducing loss of steam to the environment. A high-temperature short-time (HTST) pressure blanching system has now been developed with an 80% calculated thermal efficiency (McGowan, et al., 1984; Drake and Carmichael, 1986).

Environmental considerations have led to development of experimental blanching procedures excluding water. The two leading methods are microwave and hot-gas (dry) blanching (Schwimmer, 1981). Microwave blanching on an experimental basis has resulted in products of inferior quality (Drake, et al. 1981; Glasscock, et al. 1982). In addition, the cost has been estimated at eight-fold more than water or steam blanching (Ralls and Mercer, 1973). In hot-gas or dry blanching, a mixture of heated air, nitrogen, carbon dioxide and water is passed over vegetable pieces as they are conveyed through a high temperature zone. The temperature of the pieces is raised by transfer of heat from the hot gas mixture until sufficient to inactivate enzymes as well as drive off occluded gases (Schwimmer, 1981). This procedure is not yet practical on a commercial scale.

Enzymes Responsible for Quality Deterioration

There are four groups of enzymes primarily responsible for the quality deterioration of un-blanched frozen vegetables: 1) lipoxygenases, lipases and proteases cause off-flavor and off-odor development; 2) pectic enzymes and cellulases cause textural changes; 3) polyphenol oxidase, chlorophylase and peroxidase (to a lesser extent) cause color changes; and 4) ascorbic acid oxidase and thiaminase cause nutritional changes. In secondary reactions, lipid hydroperoxides and hydroperoxy radicals produced by lipoxygenase cause loss of color due to chlorophyll and carotenoids. Benzoquinones and melanins, produced by polyphenol oxidase, react with the ϵ-amino group of lysine residues of proteins, thereby affecting the nutritional quality and solubility of the proteins (Schwimmer, 1981; Williams et al., 1986).

Enzyme Inactivation and Tests of Blanching Adequacy

Process optimization to avoid unnecessary energy input and product degradation because of excessive heat treatment requires measurement of enzyme activity to determine the adequacy of blanching. There has been controversy as to which enzyme is the best indicator. Catalase and peroxidase have been used because of their widespread presence in most vegetables and fruits and their ease of assay (Williams et al., 1986). Catalase was used extensively in the early years, especially for peas (Diehl, 1932; Diehl et al., 1933). Arighi and colleagues (1936) observed that catalase appeared to be inactivated at a much more rapid rate than the enzymes concerned in the production of off-flavors in peas. Mergentime (1939) and Balls (1942) suggested that peroxidase activity might serve as an index of adequacy of heating. In review of his work and that of his colleagues, Joslyn (1946, 1949) concluded that peroxidase activity paralleled the enzymes responsible for the formation of off-flavors in frozen vegetables more closely than did catalase activity. Rapid tests were developed to determine peroxidase for quality control in processing plants (Masure and Campbell, 1944). Inactivation of peroxidase is now generally used as an indicator for proper blanching of vegetables (Dietrich et al., 1955; Burnette, 1977; Lee and Hammes, 1979).

There are, however, problems associated with the use of peroxidase as the indicator of adequate blanching. Since peroxidase is generally the most heat stable enzyme in vegetables, complete inactivation may actually result in overblanching. Optimum quality may be achieved prior to complete peroxidase inactivation (Campbell, 1940; Winter, 1969; Bottcher, 1975; Delincee and Schaefer, 1975; Katsaboxakis, 1984). In addition, peroxidases of different products have different heat stabilities and there are a number of isozymes of peroxidase with quite different heat stabilities present in most vegetables. Corn has been found to contain at least two such isozymes (Naveh, et al., 1982). Problems occur because inactivation of the different peroxidases and isozymes begins at different temperatures and proceeds at different rates (Schwimmer, 1981; Vamos-Vigyazo, 1981; Williams et al., 1986). Another problem with peroxidase is that of regeneration. When all the peroxidase activity is not destroyed, the enzyme can reactivate. Reactivation itself does not contribute to quality deterioration; the problem is that quality specifications for frozen foods do not allow for it (Diehl, 1932; Balls, 1942; Schwimmer, 1944; Joslyn, 1949; Lu and Whitaker, 1974; Williams et al., 1986).

Because lipoxygenase causes off-flavor and off-odor development in vegetables, researchers have recommended lipoxygenase be used as an indicator of proper blanching (Wagenknecht, 1959; Lee, 1981; Pala, 1982; Williams et al., 1986). Williams et al. (1986) developed a rapid, easy, semi-quantitative test for lipoxygenase activity. While many vegetables and fruits have easily detectable lipoxygenase activity using this method, others such as carrots and yellow corn have no activity. In some products there may be too little lipoxygenase to detect.

Sensory Consequences of Under-blanching

The most common off-flavor developed in frozen vegetables is usually described as "hay-like," however, Joslyn (1949) pointed out that many vegetables develop their own peculiar overtones. The term "alfalfa" has been used for peas, spinach and green beans. The related terms "silage," grass" and "composted" have been used to describe the odor of spinach, asparagus and artichoke hearts. Other adjectives that have been used to describe frozen vegetable off-odors include "acrid" (squash), "fruity" (peas), and "fishy" (artichoke hearts). In addition to these odors frozen vegetables in general develop off tastes described as "sour-stale," "acid cooked" and "acid oxidized" (Schwimmer, 1981). The off-flavors which most frozen, unblanched vegetables have in common appear to be due to the transformations of lipids involving the action of lipases and lipoxygenases (Lee and Mattick, 1961; Bengtson and Bosund, 1966). Murray and colleagues (1976) investigated the volatiles of off-flavored un-blanched peas and found a complex mixture of 90-100 volatiles, all but five of which were secondary products of lipoxygenase- or other enzyme-induced degradation of unsaturated fatty acids.

Sensory Evaluation

A variety of sensory testing methods have been used over the years to determine quality and acceptability of frozen vegetable products. Dietrich et al. (1955) used sensory panels to evaluate color, flavor and skin texture of frozen peas in their study on the effect of degree of enzyme inactivation and storage temperature on quality retention. Dietrich et al. (1959) used sensory panels to evaluate color and flavor when studying the quality retention of frozen green snap beans. Wagenknecht (1959) conducted taste tests in his study on lipoxidase activity and off-flavor in underblanched frozen corn-on-the-cob. Dietrich et al. (1970) compared microwave with steam and water blanching of corn-on-the-cob and used sensory panels to rank samples in order of best natural corn flavor. In studying the chemical components of sweet corn aroma and their relative importance to overall flavor, Flora and Wiley (1974) asked panelists to rate aroma, sweetness, texture and overall flavor for fresh, frozen and canned corn samples on a preference scale. Steinbuch et al. (1979) evaluated frozen brussels sprouts for sensory characteristics (color, flavor and texture) and residual enzyme activities. Robertson, et al. (1980) compared canned and frozen intact sweet corn with cut sweet corn using hedonic rating, paired preference and duo-trio testing methods.

Williams, et al. (1986) studied the effect of enzymes on aroma development in green peas and green beans using a trained sensory panel and descriptive analysis techniques. Descriptive analysis is used in order to obtain a complete sensory description of a test product (Stone and Sidel, 1985). Cairncross and Thurston (1950) developed the flavor profile method and demonstrated it was possible to select and train individuals to describe perceptions of a product. Qualitative as well as quantitative descriptions of the individual characteristics of the total flavor complex of a product are obtained. Descriptive words for each individual flavor note are selected and their intensities measured on a scale (Dawson et al., 1963). Panelists must be thoroughly trained to understand and apply the descriptive terms in the same way (Meilgaard et al., 1987).

Acceptance testing is used to measure liking or preference for a product. Preference is measured either directly by comparison of two or more products, or indirectly by determining which product is significantly more liked in a multi-product test. Stone and Sidel (1985) recommend obtaining 25-50 responses in laboratory environment acceptance tests. A 9-point hedonic scale (Jones et al., 1955; Peryam and Haynes, 1957) is one of the most frequently used preference scaling methods. Naive subjects representative of the consuming population are used in acceptance testing (Meilgaard et al., 1987).

MATERIALS AND METHODS

Raw Materials

All samples were prepared in a frozen food processing plant, Smith Frozen Foods, Inc. (Weston, OR) using commercial frozen food processing equipment and techniques. To reduce varietal and cultural variations, grade A sweet corn (Golden Jubilee cultivar) from one field of one grower was harvested and brought to the plant on two consecutive days. Samples were taken from a commercial processing line.

Processing Methods

A high-temperature short-time blancher (Thermo-Flo® HTST) manufactured by Key Technology, Inc. (Milton-Freewater, OR) was used to prepare the HTST samples. The equipment was as described by McGowan et al. (1984) and was automatically controlled with a microprocessor. A blanching cycle involved the following operations: a batch of 900 lbs of cut corn was automatically weighed and loaded into the pressure chamber; the chamber was sealed and rotated while steam was injected; steam pressure was maintained while the chamber was rotated for a preset time; pressure was released; the corn was discharged from the blancher into a hopper and conveyed through a precooler to the freezer. Samples used in this experiment were processed at 30, 60 and 75 psi chamber pressure. Time of processing after the desired pressure was obtained in the chamber remained constant throughout these trials. Cycle time for one batch in the blancher was approximately 120 seconds for the product processed at 30 psi and increased to approximately 145 seconds at 75 psi. This increase in time was due to the longer time required to reach the desired pressure in the blancher chamber at the higher pressures. Approximately 110 seconds were required to empty the hopper. Since the corn that remained in the hopper for a longer time received a longer severe heat treatment, samples were taken 0, 45 and 90 seconds after the product had been discharged into the hopper. Samples were taken at the end of the precooler and were immediately packaged and frozen. Care was taken to replicate the processing of samples as closely as possible.

To compare the HTST blanching process to the conventional commercial blanching method, samples of corn processed (at the same location and time and from the same source) in an open-end steam blancher were also obtained. This blancher was operated at atmospheric pressure and the resident time of the product in the blancher was four minutes. Samples collected at the end of the precooler were immediately packaged and frozen. Samples of the same raw (un-blanched) corn were also collected for comparative purposes.

Packaging, Freezing and Storage of Samples

All samples (approximately 400 g) were placed in labeled polyethylene bags, heat sealed, and spread in a single layer on a freezer room (-18 °C) floor overnight. After packing into cardboard cases, the samples were immediately transported to Oregon State University and stored at -22 °C for up to one year. Due to freezer mechanical failure, the corn samples were temperature shocked twice during the storage period when the storage room temperature approached 0 °C. The corn samples remained frozen during these thermal shocks.

Enzyme Extraction

Samples of corn were removed from the freezer and thawed at room temperature (22 °C) for 10 minutes. Individual samples were used once and were not refrozen. To extract enzymes, a 50 g portion of corn was homogenized with 100 mL of cold 0.2 M phosphate buffer, pH 7.0, in a Waring blender for one minute. Homogenized corn was centrifuged in a Sorvall RC-5 centrifuge at 48,000 x g for 20 minutes at 0 °C. The cloudy supernatant was removed, avoiding the floating lipid layer, and was used for enzyme activity measurements. All homogenates and extracts were held on ice until used.

Enzyme Activity

Enzyme activities were determined for each of the blanching treatments after 0, 5 and 12 months of frozen storage. Three replications were completed for each time period. Activity determinations were made in duplicate for each replication.

Peroxidase was determined with a spectrophotometric method (Ponting and Joslyn, 1948; Rosoff and Cruess, 1949). A substrate solution of 0.05 M guaiacol and 0.02 M hydrogen peroxide in 0.2 M phosphate buffer at ph 6.0 was prepared fresh daily and held at 35 ^{o}C. A 2.95 mL aliquot of the substrate solution was pipetted into a cuvette, followed by 0.05 mL of enzyme extract and quickly mixed. Increase in absorbance at 420 ηm was determined in a Perkin-Elmer Model 550 spectrophotometer connected to a Linear Instruments laboratory chart recorder with 3.0 mL substrate as a reference. The initial velocity was calculated as ΔA/min/mL of enzyme extract.

Catalase was assayed with a modification of the spectrophometric method of Beers and Sizer (1952). A substrate solution of 0.06 M hydrogen peroxide in 0.05 M phosphate buffer at pH 7.0 was prepared fresh daily and held at 25 ^{o}C. A 2.95 mL portion of substrate was pipetted into a cuvette, 0.05 mL of enzyme extract was added and quickly mixed. Decrease in absorbance at 240 ηm was recorded with 3.0 mL substrate solution as a reference in the same recording spectophotometer system described above. Initial velocity was calculated as ΔA/min/mL of enzyme extract.

Cloudiness of the enzyme extract and low level of lipoxygenase activity prevented use of a spectrophotometric method (Surrey, 1964; Al-Obaidy and Siddiqi, 1981) for the determination of this enzyme. Therefore, a method for the determination of oxygen consumption with an oxygen electrode was developed. Two mL of freshly-prepared substrate solution, containing 1 mM sodium linoleate in 0.2 M borate buffer at pH 9.0, were pipetted into the reaction vessel of a YSI

Model 53 Biological Oxygen Monitor. After temperature equilibration at 30 ^{o}C, 1 mL of enzyme extract was added, the oxygen electrode was inserted into the reaction vessel and the rate of oxygen uptake was measured. Activity was expressed as the consumption of ηmoles oxygen/min/mL of enzyme extract.

Moisture Determination

Thawed corn was thoroughly homogenized in a Waring blender and percent moisture was determined with an Ohaus Moisture Determination Balance. The heater element was one inch above the sample surface and with a heater setting of 40, the drying time was 40 minutes. Triplicate determinations were made on each sample at 0, 5 and 12 months of frozen storage.

Total Work of Compression and Shear / Maximum Force to Shear

An Allo-Kramer Shear Press (Model S2HE with a 5,000 lb proving ring, 375 psi on the ram, a 20 second down stroke and a range of 20) was used to determine total work (Newton-meters, Nm) to compress and shear, as well as maximum force (Newtons, N) to shear a 200 g sample of corn at 12 $\pm$ 4 ^{o}C. A compensating polar planimeter (Keuffell and Esser Co.) was used to integrate the area under the curves. Triplicate determinations were made on each sample at 0, 5 and 12 months of frozen storage.

Drip Loss

Each package of corn, thawed overnight in a household refrigerator, was weighed, emptied in a tared No. 16 USA standard testing sieve, allowed to drain for three minutes and weighed. After weighing the polyethylene bag, the percent drip loss was calculated. Duplicate determinations on different samples were made at 3, 4, 6 and 8 months of frozen storage.

Sensory Evaluation

Sample Preparation: Drained corn from the drip loss determinations was weighed (284 g) into stainless steel saucepans, 120 mL bottled spring water added and quickly brought to a boil. The corn was stirred and covered. The heat was reduced to low for four minutes. Samples for the trained panel were served immediately in 148 ml (5 oz) clear glasses covered with tight fitting aluminum weighing dishes on trays. For the consumer panel each saucepan was placed over a second saucepan containing simmering water and the hot samples were served in plastic cups on trays as the panelists arrived. Samples for both panels were coded with three digit random numbers and the order of presenting the samples to each judge was randomized. Samples processed at each of three chamber steam pressures and from one of three time intervals in the discharge hopper plus the steam blanched control (total of four samples) were served during each sensory evaluation session. The order of presentation by time interval in the discharge hopper was randomized. Three sessions were required to obtain one set of evaluations on all the samples.

Consumer Panel: The consumer panelists were students, faculty or staff of Oregon State University who were consumers of corn and volunteered to take part in the study. Samples of corn were rated on a 9-point hedonic scale (Jones et al., 1955; Peryam and Haynes, 1957) ranging from dislike extremely (1) to like extremely (9) for four attributes: appearance, texture, flavor and overall desirability (Figure 1). Panelists were seated in individual sensory booths with white incandescent lighting. Bottled spring water and unsalted soda crackers were available. Fifty observations were obtained on samples at 3 and 9 months of frozen storage.

Trained Panel: An eight member panel of two women and six men was selected on the basis of interest and availability. Training sessions were conducted over a 1.5 month period. Initial sessions involved tasting a variety of fresh and frozen corn samples and developing a list of terms to describe the sensory characteristics of corn. After individual evaluations, group discussions ensured that all panelists were in agreement. Ten aroma, eleven flavor-by-mouth and three texture descriptors were selected for evaluation. Appropriate reference materials were selected and made available at every session to assist panelists in evaluation (Table 1).

Specific techniques for evaluation of each textural attribute using standard scales and reference materials were defined, and panelists were asked to follow these procedures throughout this study. For hardness panelists were asked to place a 13 mm (1/2 in) cube of Velveeta cheese between the molars, bite down evenly and evaluate the force required to compress the sample. This procedure was repeated with 1/2 spoonful of corn. To evaluate moistness panelists were asked to place a 13 mm (1/2 in) cube of Del Monte canned potato in the mouth and evaluate the amount of moisture released in the mouth after four chews. This procedure was repeated with 1/2 spoonful of corn. For chewiness panelists were asked to place 1/2 spoonful of corn in the mouth and count the number of chews required to reduce the sample to the state ready for swallowing.

Training was continued until results from the panel and individual panelists consistently showed statistically significant differences between samples where specific differences were purposely created and no differences where no differences were created. After the initial training and testing period, retraining sessions were conducted prior to each subsequent testing period. Ballots consisted of a nine point scale ranging from absent (1) to extreme (9) for aroma and flavor-by-mouth descriptors, a 15 cm line scale with endpoints labeled "none" and "extreme" for hardness and moistness and an absolute number for chewiness (Figure 2). Samples were evaluated around a large table under incandescent and natural room lighting. No talking was allowed. Bottled spring water was available. All samples were expectorated. Duplicate evaluations were made on different samples at 3, 4, 6 and 8 months of frozen storage. The raw unblanched sample was included at the 3 month evaluation, however, the quality had deteriorated so greatly that it was removed from the study.

Experimental Design

This experiment was conducted using a split plot design (Anderson and Bancroft, 1952; Snedecor and Cochran, 1980; O'Mahony, 1986) with blanch time (time after discharge of the corn into the hopper) as the whole plot and the blanch pressure (chamber steam pressure reached during blanching) as the split plot. Data were evaluated by Analysis of Variance (ANOVA) and least significant difference (LSD) using a Statistical Analysis Systems program SAS® (copyright 1985, SAS Institute Inc., Cary, NC). Consumer panel data for each session were analyzed separately. Special statistical procedures were used for the trained panel data because panelists and replications were treated as random effects (Anderson and Bancroft, 1952; Snedecor and Cochran, 1980). F-values based on specific equations (See Appendix) were used to test main effects and interactions. Degrees of freedom were estimated by the Satterthwaite approximation (Satterthwaite, 1946). In cases where there was a poor Satterthwaite approximation, the most conservative possible degrees of freedom approximation was utilized. For each of the descriptors where a significant panelist by pressure interaction occurred, inspection of the data was conducted by a data exploration procedure developed by Lundahl and McDaniel (1987). The procedure identifies individual panelists whose errant judgements, in conflict with those of the panel as a whole, may have caused the interaction.

Figure 1. Consumer panel ballot.

Sensory Science Laboratory
Department of Food Science & Technology
Oregon State University

Product: CORN

NAME:__________

Please write the sample number in the space following the statement which best describes your opinion of the sample. Be sure to score all samples.

FEMALE:____ MALE:____

AGE: UNDER 30   30-50   OVER 50

DATE:__________

	APPEARANCE	TEXTURE	FLAVOR	OVER-ALL DESIRABILITY
9-Like Extremely				
8-Like Very Much				
7-Like Moderately				
6-Like Slightly				
5-Neither Like nor Dislike				
4-Dislike Slightly				
3-Dislike Moderately				
2-Dislike Very Much				
1-Dislike Extremely				

COMMENTS:

THANK YOU

Figure 2. Trained sensory panel ballot.

____
Name

AROMA	Corn Intensity	Sweet/ Caramel	Starchy	Buttery	Nutty	Sulfur	Fishy	Cobby or Husk	Stale/ Oxidized	Total Off-Aroma
Extreme	____	____	____	____	____	____	____	____	____	____
Large-Extreme	____	____	____	____	____	____	____	____	____	____
Large	____	____	____	____	____	____	____	____	____	____
Moderate-Large	____	____	____	____	____	____	____	____	____	____
Moderate	____	____	____	____	____	____	____	____	____	____
Slight-Moderate	____	____	____	____	____	____	____	____	____	____
Slight	____	____	____	____	____	____	____	____	____	____
Threshold	____	____	____	____	____	____	____	____	____	____
Absent	____	____	____	____	____	____	____	____	____	____

FLAVOR-BY-MOUTH	Corn Intensity	Sweet/ Caramel	Starchy	Buttery	Nutty	Sulfur	Fishy	Cobby or Husk	Stale/ Oxidized	Bitter	Total Off-Flavor
Extreme	____	____	____	____	____	____	____	____	____	____	____
Large-Extreme	____	____	____	____	____	____	____	____	____	____	____
Large	____	____	____	____	____	____	____	____	____	____	____
Moderate-Large	____	____	____	____	____	____	____	____	____	____	____
Moderate	____	____	____	____	____	____	____	____	____	____	____
Slight-Moderate	____	____	____	____	____	____	____	____	____	____	____
Slight	____	____	____	____	____	____	____	____	____	____	____
Threshold	____	____	____	____	____	____	____	____	____	____	____
Absent	____	____	____	____	____	____	____	____	____	____	____

TEXTURE

	none	extreme
Hardness	|————————————————	————————————————|
Moistness (4 chews)	|————————————————	————————————————|

Chewiness (# chews to swallow)	____ # chews	____ # chews	____ # chews	____ # chews
	____ Code	____ Code	____ Code	____ Code

Table 1. Sensory descriptors and their reference standards for trained panel evaluation.

Descriptor	Reference Standard*
Aroma	
Corn Intensity	-----
Sweet/Caramel	Brown Sugar
Starchy	Cornstarch, 1/2 TBSP in 4 TBSP water
Buttery	Darigold butter, melted
Nutty	Cashews, roasted
Sulfur	Dimethyl sulfide, 20 μL in 100 mL water
Fishy	Starkist oil pack tuna
Cobby or Husk	Liquid from boiling cob or husk in water
Stale/Oxidized	Cornmeal mush**
Total Off-Aroma	-----
Flavor-By-Mouth	
Corn Intensity	(Above aroma standards were used as references but were not evaluated in the mouth)
Sweet/Carmel	
Starchy	
Buttery	
Nutty	
Sulfur	
Fishy	
Cobby or Husk	
Stale/Oxidized	
Bitter	
Total Off-Flavor	
Texture	
Hardness	Velveeta cheese, 13 mm (1/2 in) cube
Moistness	Del Monte canned potato, 13 mm cube
Chewiness	-----

*Served in 148 ml (5 oz) clear glasses covered with tight fitting aluminum weighing dishes on trays

**Cornmeal mush prepared as follows: Boil 2 1/2 cups water; add 1 tsp salt. Mix 1 1/4 cups cornmeal with 1 cup cold water; add slowly to boiling water. Cook 5 minutes.

RESULTS AND DISCUSSION

Enzyme Activity

Both the HTST and steam blanch processes effectively inactivated catalase and peroxidase in frozen corn (Table 2). A treatment of 60 psi was necessary to completely inactivate catalase and 75 psi was necessary to completely inactivate peroxidase. The greater resistance of peroxidase to heat inactivation was recently discussed by Schwimmer (1981). No changes occurred in catalase or peroxidase activities during frozen storage of the corn samples. Peroxidase activity has been reported to decrease during frozen storage of broccoli (Kampis et al., 1984), cauliflower and kohlrabi (Vamos-Vigyazo, 1980). Complete inactivation of peroxidase is reportedly not necessary to retard sensory deterioration during frozen storage of carrots (Baardseth and Slinde, 1983). Therefore, processing corn in the HTST blanching system at 60 psi may be adequate. Processing at lower pressures may even be adequate if a holding period after the pressure treatment is provided in the process. The corn blanched at 30 psi showed a significant reduction in catalase and peroxidase activity as time out of the blancher increased (from 0 to 90 seconds). Kinetics of heat inactivation of peroxidase in a HTST system has been studied by Adams (1978) and David and Shoemaker (1985) and has been shown to be biphasic (Adams, 1978; McLellan and Robinson, 1987).

No lipoxygenase activity was detected in the blanched samples of frozen corn. Lipoxygenase is much more heat labile than either catalase or peroxidase (Williams et al., 1986). Only trace levels of lipoxygenase were detected in the raw (un-blanched) frozen corn. The lipid layer of the enzyme extract was tested for activity as well, with no different results. The methodology was developed using fresh raw corn, and even in fresh corn the lipoxygenase activity level was low. Wagenknecht (1959) reported lipoxygenase activity in underblanched frozen corn-on-the-cob. More recently, however, yellow corn has been reported to contain no detectable lipoxygenase activity (Williams et al., 1986). Because of the extraction procedure used, only buffer soluble enzyme activity was measured, and a significant portion of plant enzymes may be bound to membranes or the cell walls. Since relative values for comparison were desired in this study, this was unimportant. However, a different extraction technique may be appropriate for determination of lipoxygenase in corn.

Moisture

Adequate blanching of corn by either the HTST or steam process generally reduced the moisture content of the frozen corn samples when compared to the raw samples (Table 2). HTST blanched samples demonstrated slightly higher (approximately 1-2%) moisture contents than the steam blanched samples. This higher moisture content would result in increased product yield with the use of the HTST process.

Since corn blanched by both processes were cooled by the same method, this increase in moisture is probably due to the limited atmospheric exposure of the corn during heating in the HTST blanching process. HTST blanching conditions were shown to influence the moisture contents of sweet peas and lima beans but not snap beans and carrots (Drake and Carmichael, 1986). Drake and Swanson (1986) observed an increase in yield due to increased moisture content when corn was blanched with a counter-flow water-blancher as compared to a steam blancher.

Physical Attributes

Total work of compressing and shearing blanched corn samples, as expressed by the shear value, revealed no significant differences between the two blanching processes (Table 2). Steam pressures used in the HTST processing of corn apparently do not significantly affect the factors related to total work of compressing and shearing. Drake and Carmichael (1986) found that HTST conditions affected shear values of snap beans, lima beans and carrots, but not sweet peas.

Maximum shear force decreased as the pressure of blanching was increased, although most of the differences are not statistically significant. As might be expected, the raw (un-blanched) sample required the greatest force to shear, which was significantly greater than all other samples. Samples blanched at 75 psi with the HTST process required significantly less force to shear than those blanched at 30 psi. This trend indicates an increased softness in the HTST processed samples as pressure is increased and suggests that the higher temperatures used in the HTST process may affect the structures of the corn which are involved with determining texture. No change was observed in the maximum shear force during the 12 month frozen storage period.

No statistically significant differences in the drip losses from the corn samples blanched with the two processes studied in this work were observed, nor were any differences observed between the samples processed at the various pressures used in the HTST process nor with frozen storage time (data not presented). Method of blanching has been noted to affect drip loss in frozen cut corn (Drake and Swanson, 1986) and conditions of HTST blanching affected drip loss of lima beans and carrots but not snap beans and sweet peas (Drake and Carmichael, 1986).

Trained Sensory Panel

Tables 3 and Table 4 contain the ANOVA factors tested and their interactions for aroma, texture and flavor-by-mouth descriptors. Time out of blancher was not a significant factor for any of the sensory descriptors rated. Blanch pressure, the other main blanching effect, was significant for seven, three, and nine of the aroma, texture and flavor-by-mouth descriptors, respectively. Table 5 contains the mean descriptor ratings for all sensory descriptors significantly affected by blanch pressure. Significant aroma and flavor-by-mouth differences occurred mainly between the 30 psi blanch treatment and the other blanch treatments. For example, 60 psi blanched corn was significantly higher than 30 psi blanched corn in buttery and sweet/caramel character, while significantly lower in off-aroma, stale/oxidized, fishy, cobby/husk, and bitter character. For all aroma and flavor-by-mouth descriptors, the 60 psi blanched samples were not significantly different from the 75 psi blanched samples. In most cases, the control, which underwent conventional steam blanching, was similar to the 60 psi treatment. The 60 psi treatment was less starchy in aroma and lower in sweet/caramel flavor-by-mouth character than the control.

The descriptor nutty was not significantly affected by blanching parameters, storage length or any interactions. Sulfur character was not significantly affected by blanching parameters, however some interactive effects were observed. The main components of cooked sweet corn aroma are sulfur compounds. These compounds are produced as a result of heat processing and are not present in raw corn (Shankaranarayana et al., 1982). Flora and Wiley (1974) found dimethyl sulfide to be the major component of cooked corn aroma, but found aroma to have relatively low importance in overall flavor. Blanching has been reported to affect dimethyl sulfide levels in the aroma of cooked frozen sweet corn (Dignan and Wiley, 1976).

Textural differences due to blanch pressure were also observed. The 60 and 75 psi treatments were rated significantly lower than the 30 psi treatment for number of chews. The 60 psi treatment received the highest rating for hardness, however it was not significantly different from the 30 psi treatment and the control. The 75 psi treatment was rated significantly lower in hardness than the 60 psi treatment. There was no significant difference for moisture among the pressure treated samples, although the 60 psi treatment received the highest rating, which was significantly higher than the control blanch.

A significant panelist effect (Tables 3, 4), which resulted for almost all descriptors, is not unusual and reflects panelists' usage of different portions of the intensity scale. Significant panelist by pressure effects are of concern because they might suggest panel inconsistencies. Seven aroma descriptors, one texture descriptor and eight flavor-by-mouth descriptors had a significant panelist by pressure interaction. For four of these descriptors, total off-aroma, starchy aroma, fishy flavor-by-mouth and number of chews, the significance of the pressure effect was higher ($p \leq 0.01$) than the interaction effect ($p \leq 0.05$). Because the interaction effect was low, one can rely on the validity of the pressure effect. For the other descriptors the procedure developed by Lundahl and McDaniel (1987) was used to further explore these interactions. It was found generally that one or two panelists contributed to the interaction or that the effect of the pressure treatment was greater than that of the interaction. For example, for buttery aroma panelist number eight under-reacted to the 30 psi treatment and over-reacted to all other blanch pressure levels, causing the interaction effect. When the effect is not due to only one or two panelists responding in a different manner as compared to the rest of the panel, it could be due to general confusion suggesting insufficient training and results should be interpreted cautiously.

Length of storage was a significant effect for total off-aroma, stale-oxidized and corn aroma, and for stale oxidized, sweet/caramel and corn flavor-by-mouth descriptors. Table 6 contains mean ratings for these descriptors across months of storage. The first test period was after three months of storage. By the fourth month, significant increases in total off-aroma and stale/oxidized flavor-by-mouth were found, accompanied by a decrease in corn aroma and flavor. At the sixth month, stale/oxidized aroma and sweet/caramel flavor was significantly higher than at the third month. The samples did not change significantly between the sixth and eighth months of storage.

Three descriptors showed a significant time out of blancher by storage interaction (Table 7). The interaction effect for moisture was caused by an increase in moisture rating at the fourth month for the zero seconds treatment while both the 45 and 90 second treatments showed a decrease in moisture rating. At the sixth and eighth month test periods ratings were all very similar. The significant starchy interaction may have been caused by the increase in starchy intensity for the 90 second/four month sample as compared to the decrease of the other samples. Also, from six to eight months both the zero and 90 second samples increased while the 45 second treatment decreased in starchy intensity. Because no consistent trend was observed, the panel as a whole may have been inconsistent in rating starchiness from testing period to testing period and more training may have been needed. For sulfury, the interaction was probably caused by the decrease in rating for the 90 second sample from the fourth to sixth month test periods, while for the zero and 45 second treatments the values increased. Again, no consistent trend was observed.

In general, too many descriptors were included for the trained panel to rate. While all the descriptors used are components of corn, some are not easily defined with references. A smaller subset could be used to effectively test for sensory differences in corn processed by different methods. Increased panelist screening and more intensive panel training would be appropriate to increase panel performance.

Relation of Trained Sensory Panel Analysis to Chemical and Physical Measurements

Results from the trained panel descriptive analysis (Table 5) can be related to the chemical and physical measurements (Table 2) also taken. Trained panel results suggest that to optimize sensory quality, 60 psi blanch pressure is required. Some peroxidase activity remains at this treatment level, supporting the conclusion of Baardseth and Slinde (1983) that complete inactivation is not necessary to retard sensory deterioration during frozen storage.

The 60 psi blanch treatment was rated significantly higher in moistness than the steam blanched sample, agreeing with the analytical moisture measurements. Both shear value and sensory hardness revealed no significant difference between the steam and HTST blanched samples. The sensory panel did find the 75 psi sample signficantly less hard than the 60 psi sample, which in general agrees with differences shown between the maximum shear forces for 60 psi and 75 psi. Neither analytical nor sensory changes were apparent for textural characteristics during the 12 month frozen storage period.

Consumer Panel

Evaluation of the corn by consumers was conducted after three and nine months of storage. Table 8 contains results of the ANOVA for the consumer ratings of flavor. Neither time out of blancher nor blanch pressure were statistically significant effects. Consumer mean ratings (Table 9) for three and nine months were extremely similar. The only significant effect, time out of blancher by pressure was for appearance at the three month test period. Therefore, although a trained panel could identify distinct differences between blanch treatments and across storage time, consumers generally did not rate the products different in acceptability.

CONCLUSIONS

Blanch pressures of 60 psi and 75 psi resulted in corn equivalent in sensory qualities to the control steam blanched product. Consumers did not rate any of the treatments different in acceptability. Although 75 psi were required to completely inactivate peroxidase in this study, complete peroxidase inactivaton may not be necessary to retard sensory deterioration during frozen storage. In a commercial process, lower pressures may be used if the time between the discharge of the pressure chamber and entrance to the cooler were increased. The slight increased moisture content, coupled with the reported increased energy efficiency (Drake and Carmichael, 1986) and decreased processing time (McGowan et al., 1984) would make the adaptation of the HTST blanching process appealing to commercial vegetable processors.

Table 2. Enzyme activity and physical characteristics of HTST - and steam blanched sweet corn: Means and standard errors.

Blanch treatment	Storage length (mon)	Peroxidase (ΔA/min/mL)		Catalase (ΔA/min/mL)		Moisture (%)		Shear value[a] (Nm)		Max shear force (N)	
None (raw)	0	8.15	0.49	6.53	0.28	75.6	0.5	59.4	1.6	4052	44
	5	10.95	2.28	5.51	0.18	75.8	0.2	59.7	1.2	4132	4
	12	9.97	2.23	5.13	0.44	75.2	0.7	57.7	0.9	4132	13
Steam (control)	0	0.00	0.00	0.00	0.00	72.7	0.4	55.6	0.7	2949	49
	5	0.00	0.00	0.00	0.00	73.1	0.4	56.5	2.4	3269	49
	12	0.00	0.00	0.00	0.00	72.2	0.9	55.9	0.3	3122	111
30 psi[b], 0 sec[c]	0	2.71	0.25	0.72	0.03	76.0	0.6	56.0	2.0	3127	62
	5	4.08	0.24	1.34	0.13	76.3	0.3	52.2	3.6	3434	227
	12	2.75	0.17	0.93	0.03	75.8	0.2	52.0	1.5	3300	151
30 psi, 45 sec	0	1.89	0.06	0.49	0.04	75.2	0.3	56.7	3.4	3078	107
	5	1.79	0.07	0.49	0.05	75.0	0.1	53.7	0.7	3194	36
	12	1.46	0.18	0.39	0.10	75.3	0.2	55.7	1.1	3269	58
30 psi, 90 sec	0	1.41	0.15	0.28	0.09	74.4	0.5	57.2	0.6	3158	85
	5	1.38	0.13	0.10	0.06	74.9	0.1	53.3	1.8	2931	71
	12	1.09	0.09	0.31	0.02	74.8	0.3	57.7	1.9	3381	147
60 psi, 0 sec	0	0.55	0.02	0.00	0.00	76.6	1.0	51.9	4.7	2811	151
	5	0.68	0.09	0.00	0.00	75.5	0.1	59.3	2.0	3180	71
	12	0.55	0.05	0.00	0.00	73.9	0.7	55.6	0.8	3092	27
60 psi, 45 sec	0	0.00	0.00	0.00	0.00	73.2	0.7	53.8	3.1	2713	80
	5	0.00	0.00	0.00	0.00	74.5	0.0	57.1	1.4	2838	49
	12	0.00	0.00	0.00	0.00	74.5	0.2	53.2	0.7	2740	40
60 psi, 90 sec	0	0.33	0.11	0.00	0.00	73.8	0.2	55.5	1.6	2855	76
	5	0.38	0.05	0.00	0.00	74.6	0.2	56.0	2.1	2896	80
	12	0.13	0.05	0.00	0.00	73.5	0.6	54.6	2.8	2936	76
75 psi, 0 sec	0	0.00	0.00	0.00	0.00	73.5	0.2	52.8	1.0	2682	76
	5	0.13	0.08	0.00	0.00	74.0	0.1	51.0	1.4	2696	62
	12	0.00	0.00	0.00	0.00	73.3	0.2	53.6	0.8	2869	71
75 psi, 45 sec	0	0.00	0.00	0.00	0.00	72.6	0.5	54.6	2.9	2722	71
	5	0.00	0.00	0.00	0.00	73.4	0.3	53.0	1.2	2664	102
	12	0.00	0.00	0.00	0.00	73.2	0.2	52.1	1.8	2602	58
75 psi, 90 sec	0	0.00	0.00	0.00	0.00	73.8	0.5	54.5	1.9	2780	142
	5	0.00	0.00	0.00	0.00	73.4	0.1	53.7	2.9	2793	93
	12	0.00	0.00	0.00	0.00	73.3	0.2	56.0	1.0	2869	102
LSD[d] ($P < 0.05$)		0.24		0.09		1.0		6.10		258	

[a]Total work of compression and shear

[b]Pressure reached in steam chamber during blanch

[c]Time out of blancher (from discharge into discharge hopper)

[d]Least significant difference

Table 3. Analysis of variance factors from trained panel rating of corn aroma descriptors.

	DESCRIPTORS									
	Aroma Total Off-Aroma	Buttery	Nutty	Stale/ Oxidized	Fishy	Cobby/ Husk	Sulfur	Corn	Starchy	Sweet/ Caramel
Time out of Blancher (Time)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Blanch Pressure (Pressure)	**	**	NS	**	**	**	NS	NS	**	*
Time x Pressure	*	NS	NS	NS	*	*	NS	NS	NS	NS
Storage Length (Storage)	*	NS	NS	**	NS	NS	NS	*	NS	NS
Time x Storage	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pressure x Storage	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Time x Pressure x Storage	**	NS	NS	NS	NS	NS	*	NS	NS	NS
Panelist	**	**	**	NS	**	*	**	**	**	**
Panelist x Time	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Panelist x Pressure	*	**	NS	**	NS	**	**	NS	*	*

* Statistically significant at the $p < 0.05$ level.

** Statistically significant at the $p < 0.01$ level.

NS Non-significant

Table 4. Analysis of variance factors from trained panel rating of corn texture and flavor-by-mouth descriptors.

	Texture			Flavor-by-Mouth										
	# of Chews	Hardness	Moisture	Total-Off Flavor	Stale Oxidized	Starchy	Nutty	Sulfur	Cobby/ Husk	Fishy	Bitter	Buttery	Sweet Caramel	Corn
Time out of Blancher (Time)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Blanch Pressure (Pressure)	**	*	**	**	**	**	NS	NS	**	**	**	**	**	**
Time x Pressure	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	*	NS	NS	NS
Storage Length (Storage)	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	*	**
Time x Storage	NS	NS	*	NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS
Pressure x Storage	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Time x Pressure x Storage	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Panelist	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Panelist x Time	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Panelist x Pressure	*	NS	NS	**	NS	**	**	**	**	*	**	NS	**	NS

* Statistically significant at the $p < 0.05$ level.

** Statistically significant at the $p < 0.01$ level.

NS Non-significnt

Table 5. Mean descriptor ratings* of significant sensory descriptors for blanch pressures (averaged across all blanch times and storage lengths).

Attribute	Control**	30 psi	60 psi	75 psi	LSD ($P \leq 0.05$)
AROMA					
Total off-aroma	3.47[a]	4.95[b]	3.33[a]	3.18[a]	0.88
Buttery	2.64[b]	2.07[a]	2.63[b]	2.81[b]	0.27
Stale/Oxidized	2.90[a]	4.34[b]	2.72[a]	2.73[a]	0.52
Fishy	1.20[a]	1.76[b]	1.42[a]	1.40[a]	0.32
Cobby/Husk	3.31[a]	4.65[b]	3.41[a]	3.24[a]	0.28
Starchy	2.62[bc]	2.87[c]	2.33[a]	2.37[ab]	0.28
Sweet/Caramel	3.55[ab]	3.31[a]	3.66[b]	3.58[ab]	0.29
FLAVOR BY MOUTH					
Total off-flavor	3.06[a]	5.50[b]	3.26[a]	3.09[a]	0.86
Stale/Oxidized	2.72[a]	5.03[b]	2.88[a]	2.68[a]	0.83
Starchy	2.51[a]	3.20[b]	2.63[a]	2.65[a]	0.29
Cobby/Husk	2.65[a]	4.16[b]	2.83[a]	2.79[a]	0.64
Fishy	1.49[a]	2.16[b]	1.55[a]	1.40[a]	0.36
Bitter	1.73[a]	2.53[b]	1.80[a]	1.71[a]	0.42
Buttery	2.62[b]	1.82[a]	2.33[b]	2.47[b]	0.30
Sweet/Caramel	4.47[c]	3.55[a]	4.00[b]	4.08[b]	0.30
Corn	4.56[b]	3.83[a]	4.59[b]	4.59[b]	0.48
TEXTURE					
Number of Chews	14.05[ab]	14.75[b]	13.80[a]	13.51[a]	0.81
Hardness	5.65[ab]	5.41[ab]	5.97[b]	5.04[a]	0.74
Moistness	6.49[a]	7.13[ab]	7.27[b]	6.82[ab]	0.72

*Scale ranged from 1, absent to 9, extreme.

**Control was conventionally steam blanched.

[abc]Letters common to means within rows signify no significant difference at $P \leq 0.05$.

Table 6. Mean descriptor ratings* of significant sensory descriptors for storage length (averaged across all blanch times and pressures).

	MONTHS OF STORAGE					
	3	4	6	8	LSD	DF(1)
AROMA						
Total Off-Aroma	3.43^{a}	3.84^{b}	4.00^{b}	3.68^{ab}	0.388	10
Stale/ Oxidized	2.61^{a}	3.04^{ab}	3.59^{c}	3.46^{bc}	0.533	10
Corn	4.54^{b}	4.08^{a}	4.26^{ab}	4.24^{ab}	0.320	4
FLAVOR-BY-MOUTH						
Stale/ Oxidized	2.89^{a}	3.29^{b}	3.50^{b}	3.63^{b}	0.390	7
Sweet/ Caramel	3.80^{a}	3.86^{ab}	4.24^{b}	4.23^{b}	0.377	6
Corn	4.53^{b}	4.07^{a}	4.50^{b}	4.47^{b}	0.253	3(2)

*Scale ranged from 1, absent to 9, extreme.

abcLetters common to means within rows signify no significant difference at $P \leq 0.05$.

(1)Degrees of freedom estimated by Satterthwaite Approximation (range between 3 and 21 DF).

(2)Due to poor Satterthwaite Approximation, most conservative possible degrees of freedom approximation was utilized.

Table 7. Mean descriptor ratings* of significant sensory descriptors for time out of blancher by storage length interaction.

DESCRIPTOR	TIME OUT OF BLANCHER (sec)	MONTHS OF STORAGE 3	4	6	8	LSD	ESTIMATED DEGREES OF FREEDOM
	0	7.29[a]	8.00[b]	6.84[a]	7.38[a]	0.596	4
Moisture	45	7.16[b]	6.17[a]	6.67[ab]	6.86[b]		
	90	7.10[b]	6.35[a]	7.23[b]	7.32[b]		
Starchy	0	2.95[b]	2.84[ab]	2.67[a]	2.80[ab]	0.212	6
Flavor-by-	45	2.89[c]	2.75[bc]	2.64[b]	2.36[a]		
Mouth	90	2.68[a]	2.97[b]	2.69[a]	2.72[a]		
Sulfury	0	2.81[a]	3.12[b]	3.53[c]	3.38[c]	0.181	6
Flavor-by-	45	3.06[a]	3.19[ab]	3.30[c]	3.11[ab]		
Mouth	90	2.87[a]	3.48[c]	3.18[b]	3.33[bc]		

*Scale ranged from 1, absent to 9, extreme for starchy and sulfury. Moisture rating was on a 15 cm line, 0 = absent to 15 = extreme.

[abc]Letters common to means within rows signify no significant difference at $P \leq 0.05$.

Table 8. Significance levels* of factors from ANOVA of consumer ratings** of stored frozen corn.

	ATTRIBUTES							
	FLAVOR		OVERALL DESIRABILITY		APPEARANCE		TEXTURE	
ANOVA FACTORS	3 mon	9 mon	3 mon	9 mon	3 mon	9 mon	3 mon	9 mon
Time out of blancher (Time)	NS	NS	NS	NS	NS	NS	NS	NS
Blanch Pressure (Pressure)	NS	NS	NS	NS	NS	NS	NS	NS
Time x Pressure	NS	NS	NS	NS	0.046	NS	NS	NS

*P levels if <0.05. NS means non-significant.

**9-point hedonic scale (9, like extremely, to 1, dislike extremely)

Table 9. Consumer panel mean ratings* from stored frozen corn blanched at different pressures.

	Month	Control	Blanch Pressure (psi) 30	60	75
Flavor	3	5.97	5.82	5.98	5.89
	9	5.84	5.89	5.89	5.87
Overall	3	5.87	5.84	5.89	5.90
	9	5.80	5.95	5.92	5.81
Appearance	3	6.69	6.49	6.73	6.51
	9	6.50	6.53	6.50	6.57
Texture	3	6.01	6.09	6.01	6.02
	9	6.31	6.06	6.25	6.21

*9-point hedonic scale (9, like extremely, to 1, dislike extremely)

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APPENDIX

Table 10. Trained panel ANOVA model and F value equations.

Source	Equation for F Value*
Panelist(PAN)	F =8(MS(PAN)/MS(REP)+7[MS(PAN*REP)])
Replication(REP)	
PAN*REP	
Time out of blancher (BLT)	F=MS(BLT)+MS(PAN*REP*BLT)/MS(PAN*BLT)+MS(REP*BLT)
PAN*BLT	F=MS(PAN*BLT)/MS(PAN*REP*BLT)
REP*BLT	
PAN*REP*BLT	
Blanch pressure(BLP)	F=MS(BLP)+MS(PAN*REP*BLT*BLP)/MS(PAN*BLT*BLP)+MS(REP*BLT*BLP)
PAN*BLP	F=MS(PAN*BLP)/MS(PAN*REP*BLP)
REP*BLP	
PAN*REP*BLP	
BLT*BLP	F=MS(BLT*BLP)+MS(PAN*REP*BLT*BLP)/MS(PAN*BLT*BLP)+MS(REP*BLT*BLP)
PAN*BLT*BLP	
REP*BLT*BLP	
PAN*REP*BLT*BLP	
Storage Length (STO)	F=MS(STO)+MS(PAN*REP*STO)/MS(PAN*STO)+MS(REP*STO)
PAN*STO	
REP*STO	
PAN*REP*STO	
BLT*STO	F=MS(BLT*STO)+MS(PAN*REP*BLT*STO)/MS(PAN*BLT*STO)+MS(REP*BLT*STO)
PAN*BLT*STO	
REP*BLT*STO	
PAN*REP*BLT*STO	
BLP*STO	F=MS(BLP*STO)+MS(PAN*REP*BLT*BLP*STO)/MS(PAN*BLT*BLP*STO)+MS(REP*BLT*BLP*STO)
PAN*BLP*STO	
REP*BLP*STO	
PAN*REP*BLP*STO	
BLT*BLP*STO	F=MS(BLT*BLP*STO)+MS(PAN*REP*BLT*BLP*STO)/MS(PAN*BLT*BLP*STO)+MS(REP*BLT*BLP*STO)
PAN*BLT*BLP*STO	
REP*BLT*BLP*STO	
PAN*REP*BLT*BLP*STO	

*Degrees of freedom estimated by Satterthwaite Approximation. In cases of poor Satterthwaite Approximation, most conservative possible degrees of freedom approximation was utilized.