Project title: Development of apple quality standards for slicing and optimization of sanitation procedures.

PI: Dr. Peter M.A. Toivonen

Organization: Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre, Summerland, B.C. V0H 1Z0

Co-PI(s): Drs. Pascal Delaquis, Margaret Cliff, Tom Beveridge and Leigh Moyls, AAFC, PARC, Summerland.

Cooperator(s): Dr. Jim Mattheis, USDA-ARS Tree Fruit Research Lab, Dr. Gerry Sapers, USDA-ARS, Eastern Regional Research Center.

Objectives: 2002-2003
1. To evaluate the use of low volume sprays as opposed to dips for sanitizing and applying anti-browning treatments to apple slices.
2. To continue evaluation of firmness and other internal quality measures with respect to susceptibility to secondary browning and quality in packaged slices stored at 5C.
3. To evaluate the performance of 1-MCP treated fruit for slices in comparison to non-treated air- and CA-stored fruit. Slice quality changes will be evaluated in 5EC storage. Internal quality measures will be monitored at slicing and during package storage.

Significant findings: 2000-2001
1. The respiration rates of all cultivars declined from the fall to spring. Therefore, it is recommended that package design should be based on fall respiration.
2. The minimum recommended oxygen transmission rate (mL O₂/100 in²/24 h) for a bag of 8” x 8” dimension containing 1 lb of slices is 283. A bag with this OTR maintained oxygen at safe levels in the bag when exposed to abusive handling temperatures (i.e. 41°F). Risk of off-flavor was thus minimized.
3. The major limiting factor for shelf life of slices was likely the growth of soft-rotting microbes on the slices. Predominant microbes were *Pseudomonas* spp. and *Enterobacteriaceae*. There were also low levels of yeasts and molds. No lactic acid bacteria or human pathogenic bacteria were found in any of the trials.
4. The currently recommended chlorinated wash after slicing was not an effective approach to sanitizing apple slices. Chlorine levels dropped very quickly to zero after apples slices were placed into the solution.

2001-2002
1. Soft apples (~ 23 AFS units) are more prone to secondary browning and decay than firm ones (~ 32 AFS units).
2. Slices from one apple are enough to contaminate dip solution sufficiently to increase the secondary browning significantly in a subsequently dipped apple slices.
3. In confirmation tests with cultivars from various packinghouses, no correlation between firmness and secondary browning could be found for any cultivar. Results may be confounded by the phenomenon reported in finding #2.
4. A correlation between starch content of expressed juice and secondary browning in ‘Granny Smith’ and ‘Gala’ apples was found.

5. Could not find a sanitizer that works reliably in a re-usable dip format. Need to examine a new approach to sanitizing slices. A prototype low volume spray unit is being constructed for this purpose as well as for application of anti-browning solution.

6. In general, a two-week shelf life at 5°C could be achieved on a routine basis for all cultivars except ‘Fuji’ and this appeared to be independent of firmness. A three-week shelf life at 5°C could be achieved on a routine basis only in ‘Granny Smith’. Secondary browning was the limiting factor in shelf life in all cultivars.

2002-2003

1. Spray application of sanitized water and subsequent spray application of Nature Seal (7% solution) results in significant reduction of secondary browning. The minimum volume required per pound of slices is 36 mL.

2. Allowing a 40% over spray (i.e. 50 mL/lb), it is estimated that a low volume spray would use 3.5 g of Nature Seal per pound of slices. The current recommendation for use in dip format ranges from 6-7 g per pound of slices. Therefore, spray application could reduce Nature Seal usage rate by 40-50%.

3. Addition of vanillin (the main component in vanilla extract) results in significant reductions of secondary browning. Vanillin used at 20-40 mM does not leave a significant taste or smell to the product. It does not have to be labeled since it would be considered a processing aid and it is GRAS.

4. The most consistent correlation between the incidence secondary browning in all cultivars is the starch content at the time of cutting.

5. Soluble solids content shows some relationship to secondary browning and this is likely based on the fact that sugars are a food source for microbes that cause secondary browning.

6. There is a slight, but significant increase in secondary browning in apple slices made from commercial 1-MCP treated Red Delicious apples, when compared against non-treated apples of similar firmness. Additional work, now in progress, will be reported at the Review.

Results and discussion: The first issue was to determine whether sprays were a better approach for sanitation and Nature Seal application than dip-tank application (Figure 1). Initial tests were performed to determine what concentrations and volumes of application were required to achieve successful control of cut edge browning. It was determined that a minimum of 36 mL of a 7% Nature Seal solution was required (Figure 1A). Several tests were conducted to confirm the effectiveness of spray versus dip application for control of secondary (microbial) browning and the spray was found to significantly reduce this problem. Secondary browning is the main factor limiting shelf life in apple slices in the commercial industry. So this result will provide industry with impetus to reconsider their approach to washing and application of Nature Seal. There have been 4 companies in Washington State which have enquired regarding the spray application results to date and extensive discussions with Mantrose Haeuser Co., Inc. A second concern was to evaluate whether a nature antimicrobial could be helpful to control secondary browning (Figure 2). Vanillin, a major component of vanilla extract, was initially applied after Nature Seal, but this was found to be unacceptable (Figure 2A). The vanillin was incorporated into the Nature Seal solution in subsequent trials and this was found to be effective in controlling secondary browning (Figure 2B) and the effectiveness of Nature Seal was not impaired by the addition of vanillin. This information has been shared with Mantrose-Haeuser Co., Inc. and several
Washington State apple slicing companies. Vanillin is labeled a GRAS (Generally Regarded as Safe) compound and so application in apple slices would not be problematic. Also, because the vanillin is added to the Nature Seal solution, it would be considered as a preservative for the Nature Seal solution. Hence it would labeled as a processing aid and would not require labeling on the package of slices. Taste tests show no significant odor or taste residue on the slices when used a 20-40 mM concentrations, which are effective in controlling the secondary browning. It is hoped that the use of sprays for sanitizing and Nature Seal application, along with addition of vanillin will allow a greater range of apple varieties and qualities of apples to be used. The limit to the widening of acceptable fruit firmness range needs to be determined.

Samples to complete a full storage season were collected to evaluate the potential use of physicochemical measures to predict whether an apple was acceptable for slicing or not. Firmness, in general was found not to be a good indicator (data not shown), and neither were soluble solids (Figure 3) or titratable acidity (Figure 4). However starch content of apples at the time of cutting was found to be indicative of susceptibility to secondary browning (Figure 5). However the relationship of starch to secondary browning was different early in the storage season than later in the season. In the early season (up to March), elevated starch levels were indicative of susceptibility to secondary browning in all apple cultivars. In contrast, later in the season (May to September), low levels of starch were indicative of susceptibility to secondary browning. It may be that high starch relates to relatively immature fruit in the early season and the low starch relates to fruit which have depleted respiratory reserves later in the season. In either case, the susceptibility to microbial attack might be higher than fruit which are within an optimal maturity range and also have a sufficient carbohydrate reserves to maintain respiration and basal metabolic activity. These results are encouraging and it is now likely that a test could be developed to assess for slicing quality. One option might be to develop a starch test much like the one used to determine harvest maturity since it is easier to use than the extraction method that was used in these studies. The simplified assay would involve slicing apples in half and applying a potassium iodide spray. If this was found to be workable, then color charts would have to be developed. At least one more year of work is required on this issue.

The introduction of 1-MCP to commercial use has led to many questions as to what impact this may have on slices. Commercially-treated apples were obtained this past year and several trials have been completed to date. In all current trials, apples were of similar firmness whether they were handled in the normal commercial storage or whether they were also treated with 1-MCP before storage. These tests have so far indicated that 1-MCP treated apples are more susceptible to secondary browning than non-treated apples (Figure 6). However, there are two issues outstanding and currently ongoing tests will hopefully answer them. The first is that these trials were conducted using the conventional dip-tank approach to washing and Nature Seal application. The second is that apples of similar firmness were tested in these trials, however, in the real-world situation it is probable that 1-MCP treated fruit will be generally firmer than non-treated fruit. Two trials are currently underway to evaluate these two questions and will be reported upon at the review.

In summary, over the past three years this project has determined several critical issues and provided answers to these issues in a practical way that can be implemented by the slice industry. The packaging selection issue was of first concern and it was determined that a minimum oxygen transmission rate was key, as opposed to trying to develop an optimal recommendation. Currently, the Washington apple slice industry has adopted the recommended packaging guidelines and there continue to be inquiries around this issue, especially when
companies are looking to add different package size formats and need help in determining the effect on oxygen transmission rate specification for the new package format.

The research also very quickly determined that secondary browning, which is caused by microbial attack, was a major limiting factor on shelf life. Communications with the majority of apple slice companies have indicated that this is a common issue to the industry. Research results indicated that firmer apples were less susceptible to cross-contamination than softer apples. This information has been used by fresh cut companies in Washington State in their quality control programs. The root of the problem relates to the fact that apple slices release a high level of organic load into dip tanks, along with microbial inoculum. The consequence is that sanitation chemicals are very quickly depleted in the sanitation wash and also inoculum accumulates in the Nature Seal treatment tank. The result is that there is a high probability for cross-contamination after cutting and so alternatives had to be investigated to deal with this problem. One company has decided to acidify the Nature Seal solution and this leads to control of the microbial growth, however this also leaves a residual acid taste with the slices. In this research we explored a completely different approach of eliminating the dip-tank technology. This revolutionary change results in almost complete elimination of potential for cross-contamination and it appears that there could be a significant reduction in Nature Seal usage associated with the low volume spray. Current results are very encouraging. Another aspect is that addition of a natural (GRAS) preservative to the dip improves the control of microbially-induced secondary browning. At this time it appears very promising that conversion to spray technology and addition of vanillin will provide the same control of secondary browning as does the acidification approach. The added bonus with the spray/vanillin approach is that flavor is not compromised. Reporting and dissemination of these results should encourage the development of equipment for spray sanitation and anti-browning application. It may be possible that after Mantrose-Hauser evaluates the results with vanillin, that they may offer an option where it is incorporated into their formulation.

The one issue which still requires more work is that of minimum standards for apple that will be used for slicing. It appears that starch is the best indicator and so this assay needs at least one more year of work to confirm its usefulness and to adapt the technique to format that is easily used in industry quality control.
After 3 weeks at 5°C

Volume of Nature Seal Solution (mL/0.5kg)

Secondary Browning Index (1=none, 3=severe)

A: Spray application of Nature Seal and incidence of secondary browning. A - Effect of volume sprayed onto 1 lb of apples. B - Reduction of secondary browning in comparison to slices that were dip-treated with Nature Seal. Different letters on the histograms in graph B indicate a statistically significant difference at the P<0.01 level.

Figure 1.

After 3 weeks at 5°C

Secondary Browning Index (1=none, 3=severe)

Dip Spray

A

Nature Seal

vanillin + Nature Seal

B

Figure 2. Use of vanillin to control secondary browning. A - Reduction of secondary browning when vanillin is applied after Nature Seal. B - Reduction of secondary browning when vanillin is added to the Nature Seal solution.
Figure 3. Incidence of secondary browning and soluble solids content at cutting in apple slices throughout the storage season beginning in the fall of 2001 and ending in the fall of 2002. Bars indicate standard errors of the means.
Figure 4. Incidence of secondary browning and soluble solids content at cutting in apple slices throughout the storage season beginning in the fall of 2001 and ending in the fall of 2002. Bars indicate standard errors of the means.
Figure 5. Incidence of secondary browning and starch content at cutting in apple slices throughout the storage season beginning in the fall of 2001 and ending in the fall of 2002. Bars indicate standard errors of the means. Starch measured using the Megazyme Total Starch Kit (Wicklow, Ireland)
Budget:
Development of apple quality standards for slicing and optimization of sanitation procedures.
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Project duration: 2000-2002
Current year: 2002
Project total (3 years) $98,323:

Original budget request:

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Current year breakdown

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Figure 6. Incidence of secondary browning in apple slices made from apples stored in commercial CA versus those which were treated with 1-MCP and stored in commercial CA. Results represent levels of secondary browning after 3 weeks at 5°C.
1 Salaries for one full time technician and one part-time technician. A competition for a full-time Biologist, as originally planned, did not yield a successful candidate. However, a high level technician (Keith Walsh) was found and has provided expertise and performance equivalent to that of a Biologist. One part-time technician was also hired.

2 The original plan was to rent a commercial corer/slicer, however the logistics and expense involved was not correctly anticipated or planned for. A tabletop, restaurant-grade corer/slicer was purchased. Co-operation with packinghouses has allowed an comparison of the in-lab results at PARC with the performance of “real world” product.

3 Supplies include purchase of packaging films, microbiological supplies (media, petri plates, etc.), and gas chromatography supplies (gas tight syringes and septa for the gas chromatograph). In the last year, purchase of some apples will be required, well as starch test reagents, packaging materials, and parts and pieces for construction of the low volume spray set-up.

4 Travel costs pertain to travel to pick up apples and slice samples from Washington State packinghouses.

Note 1: The financial request reported here is half of that required to run the project, the other half was supported by Agriculture and Agri-Food Canada’s Matching Investment Initiative (MII).