Project Title: Developing an optimal postharvest system for fresh-cut apple slices with consideration of cultivar selection, physiology, pathology, and sensory quality.

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Objectives:
1. Develop a new post-cutting dip solution for apple slices that essentially prevents cut-surface browning and secondary injury-associated browning; maintains instrumental and sensory firmness, aroma, and flavor; inhibits microbial growth associated with softening, spoilage, and decay; is inexpensive to formulate; contains lower concentrations of preservatives than calcium ascorbate dipping solution; and is formulated solely from GRAS substances.

2. Evaluate the instrumental and sensory attributes of apple slices from ‘GoldRush’, ‘Granny Smith’, ‘Fuji’, ‘Golden Delicious’, and other cultivars/lines that may store well as a fresh-cut product and that may have desirable attributes for fresh-cut slices.

3. Determine instrumental quality and shelf-life differences between apple slices with and without peel, between slices packaged immediately after processing or following a time delay, and between slices prepared from prestorage heat-treated and untreated apples.

Significant findings (2002-2002)
1. Experimental wash treatments for apple slices reduced survival of five enteric human pathogens.
2. Experimental wash treatments maintain instrumental and sensory quality of apple slices.
3. Wash treatments for apple slices should not be reused on multiple batches of apple slices.
4. Apple slices from acidic apple cultivars maintain excellent quality during storage.
5. ‘GoldRush’ is a promising new cultivar for fresh-cut apple slicing.
6. High OTR film or the equivalent is required for packaging fresh-cut apple slices.

Results and Discussion (2002-2002)
Experimental wash treatments for fresh-cut apple slices reduced survival of five enteric human pathogens
Experimental wash treatments reduced survival of Salmonella serovar Typhimurium and Vibrio cholerae by >5 logs and also reduced survival of high virulence strains/substrains of Escherichia coli O157:H7, Listeria monocytogenes and Shigella flexneri by >4 logs. Experimental wash treatments used calcium isoascorbate and acetylcysteine at pH 2.0-3.0 in accordance with current industry standards of good manufacturing practice, i.e., followed FDA regulatory language for food additives. A commercial wash treatment containing the label rate of calcium ascorbate had antibacterial activity only against V. cholerae. Acidification of the commercial treatment with HCl significantly increased its antibacterial activity, but also induced off flavor development. The naturally occurring microflora on the surface of fresh-cut apple slices was transiently inhibited by the experimental and the acidified commercial wash treatments.
Experimental wash treatments maintain instrumental and sensory quality of apple slices
Experimental wash treatments described above maintained instrumental firmness, surface color, and aroma-associated volatile production and consumer sensory scores for acceptability of texture, appearance, and flavor of apple slices as well as a commercial calcium ascorbate wash treatment. Apple slices maintained satisfactory instrumental quality for at least three weeks storage at 5 °C in humidified air. Five- to six-second spray treatments were as effective as corresponding 30 second or longer dip treatments.

Wash treatments for apple slices should not be reused on multiple batches of apple slices
During dip treatment of fresh-cut apple slices, the experimental wash solutions became progressively adulterated as indicated by a decrease in conductivity, increases in soluble solids content, osmolality and pH; and they lost their antimicrobial activities. Sprays and multiple wash treatments which maintain the antimicrobial properties of wash solutions and the quality of fresh-cut fruit are being evaluated for use on fresh-cut apple slices. Not including bulk order discounts, experimental wash treatments containing calcium isoascorbate and acetylcysteine at pH 2 are estimated to be <25 % as expensive as a calcium ascorbate wash treatment. While not part of this project, a novel but highly effective wash treatment being developed to maintain quality and food safety of fresh-cut fruit is estimated to be about 5 % as expensive as calcium ascorbate wash treatments.

Apple slices processed from acidic apple cultivars maintain excellent quality during storage
Apple slices processed from ‘GoldRush’, ‘Pink Lady’ and ‘Granny Smith’ apples maintained their individual quality characteristics of cut surface color, firmness and aroma-associated volatile production during 3 weeks storage at 5 °C better than those from slices processed from less acidic ‘Fuji’, ‘Golden Delicious’ and ‘Delicious’ fruit.

‘GoldRush’ is a promising new cultivar for fresh-cut apple slicing
Lots of ‘GoldRush’ apples collected from three orchards over two years consistently had high acid (0.8 to 1.0 % malic acid equivalents), soluble solids content (16.0 to 18.7 Brix), firmness (85 to 97 N) and aroma-associated volatile levels (~ 50 % higher than ‘Pink Lady’ and ‘Fuji’ and >4 fold higher than ‘Granny Smith’) during climacteric ripening, and maintain good eating quality after being stored for 12 months in air at 0 °C and >90 % RH, i.e., would be available year round. Consumer acceptability of texture scored highest for ‘GoldRush’ slices in year 1 and for ‘GoldRush’ and ‘Fuji’ slices in year 2. Flavor of ‘GoldRush’ slices was equally or more acceptable than ‘Fuji’ and ‘Granny Smith’ slices in different tests. During two weeks storage in air at 5 °C, volatile levels of experimentally washed ‘GoldRush’ apple slices increased while firmness and surface color values remained similar to corresponding values at the time of cutting.

High OTR film or the equivalent is required for packaging fresh-cut apple slices
The oxygen transmission rate (OTR) of several plastic films used commercially for packaging fresh-cut apple slices in 2002 was too low to maintain slices free from decay and off odor development during a three week shelf-life especially under temperature abusive conditions. Preliminary evidence suggests that a relatively high OTR (and CO₂TR) film without or with micro-perforations is more suitable than some previously used films for packaging fresh-cut apple slices. Automated techniques for continuous measurement of oxygen partial pressure within stored packages of apple slices has been established.

Other pertinent information
In an effort to better understand and minimize variance of instrumental textural data related to this project, we trained a 15-member texture panel and evaluated numerous characteristics of six instrumental methods to measure texture of apple slices. Statistical correlations between instrumental
textural data and trained sensory panel’s scores for crispness, hardness, crunchiness, toughness, coarseness, mealiness and denseness have been initiated.

**Overall Summary**
Commercialization of fresh-cut apple slices has been and continues to be hampered by the rapid oxidative browning of apple flesh, the risk of microbial development, and/or physiological deterioration during transport and storage. Browning and microbial growth can be effectively controlled by washing apple slices with acidic solutions containing antioxidants or inhibitors of polyphenol oxidase activity, but such treatments are easily adulterated and lose their antimicrobial properties if reused. Browning of apple slices also can be inhibited by packaging in low OTR packages but this leaves the fresh-cut product susceptible to decay and off odor development especially during abusive temperature storage which can occur in retail markets. Relatively inexpensive, alternative washing strategies and improved packaging that can maintain the instrumental and sensory quality and food safety of the apple slices are becoming available for commercial consideration. Ultimately, continued growth and greater consumer acceptance of fresh-cut apple slices as a safe and convenient way to eat fruit will be aided by identification of ‘GoldRush’ and other apple cultivars that can maintain excellent eating quality as a fresh-cut product and be available throughout the year.

**Budget:**
**Developing an optimal postharvest system for fresh-cut apple slices with consideration of cultivar selection, physiology, pathology, and sensory quality**
Robert Saftner
Project duration: 2002-2002
Project total – 1 year: $42,811

<table>
<thead>
<tr>
<th>Current year breakdown:</th>
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<tr>
<td>Salaries</td>
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Salary included half-year funding for a post-doctoral research associate. Equipment included ~50 % funding for a device to continuously and non-destructively measure the oxygen partial pressure in packages of apple slices. Supply funds used for purchase of fruit, chemicals and other consumable supplies.