Respiration and Packaging Optima for Fresh Sliced Apples.

Peter M.A. Toivonen, Tom Beveridge, Margaret Cliff, Pascal Delaquis, and Leigh Moyls.

U.S. Collaborators:

Respiration analysis, MCP effects and quality - Dr. James P. Mattheis, USDA-ARS Tree Fruit Research Laboratory, Wenatchee, WA.
Microbial analysis, safety studies - Dr. Gerald M. Sapers, USDA-ARS, Eastern Regional Research Center, Wyndmoor, PA.

Objectives:

1. To determine the respiration rates of 'NatureSeal' treated apple slices made from 'Fuji', 'Granny Smith', 'Red Delicious', 'Gala', and 'Golden Delicious' apples at harvest and after storage for several durations in air and CA storage. The influence of 1-MCP treatment of apples will also be investigated.
2. To determine the optimal packaging design to ensure consistent shelf life of sliced apples treated with 'NatureSeal'.
3. To evaluate the quality effects and spoilage microbes and/or human pathogen growth in packaged apple slices when subject to a standardized temperature abuse protocol.

Justification:

The per capita consumption of apples has been relatively flat for the last decade (Fig. 1). However per capita consumption of fruits and vegetables, as a whole, has been increasing over the past decade. Much of the increase in consumption can be attributed to development of ‘fresh-cut’ or ‘ready-to-eat’ vegetable products. As an example, carrot and and romaine lettuce consumption doubled in the 1990's (Fig. 2). These increases were largely due to the development of ‘cut-and-peel’ baby carrots and packaged salads containing romaine (e.g. Caesar salad mix). The attraction that ‘fresh-cut’ products hold for the consumer is that they are convenient and healthy fresh food items. Consumption of apples is also expected to increase if they are sold as a convenient ‘fresh-cut’ snack food. Recent marketing studies completed by the Washington Apple Commission suggest that there is a strong consumer appeal for packaged, fresh sliced apples.

The development of packaged apple slices can provide a means to add value to the apple crop and increase sales volume of apples. Smaller, misshapen, and poorly colored apples may also be used for apple slices, as long as there are no other quality defects in the fruit. A properly established apple slice program is expected to increase the profitability of apple marketing. However, successful implementation of an apple slice program will require better understanding of several factors.

The first factor to consider is the respiration rate of apple slices since this will affect the packaging films required. Apples, unlike most vegetables used for ‘fresh-cut’, will be utilized for slices immediately after harvest and also after varying durations of air and CA storage. There is limited information which indicates that respiration rates of apples changes significantly over time in air and CA storage (Bohling and Hellickson, 1993). In addition, 1-MCP may be commercially used to treat apples in the near future and it has been found to have an effect on respiration of whole apples (Fan et al., 1999). The apples will also be treated with a dip containing ascorbic acid and calcium. This dip will likely also have an effect on respiration since ascorbic acid, itself, has been found to significantly reduce respiration in ‘Fuji’ apple slices (Gil et al., 1998). Therefore the impact of storage, 1-MCP and post-cutting dip on apple slice respiration must be considered in selecting an optimal package for apple slices.

The second factor to be considered is the optimal target atmosphere for the packaged apple slices. There have been many atmospheric recommendations made for sliced apples (O'Bierne, 1990; Anese et al., 1997; Gil et al., 1998, Lu and Toivonen, 2000). However, these recommendations have been made using results from experiments where a single temperature was maintained throughout. Discussions with the 'fresh-cut' industry in California indicate that a multiple temperature abuse regime is used to evaluate the performance of packaging during shipping, distribution and retail display. The typical regime is shown in Fig. 3. There are two implications of temperature abuse for packaged apple slices. The first is that if packaging with low oxygen transmission rates are used, that off-flavors may develop (Gil et al., 1998). Also different cultivars may show different tolerances to low oxygen (Ke et al., 1991), and so several cultivars must be tested to evaluate whether the same packaging film is suitable for all of them. The second concern for temperature abuse is that it may encourage the growth of spoilage and/or human pathogens which may be resident on the apple slices. This risk must be factored into shelf life/sanitation procedure recommendations. There is evidence in the literature that package atmosphere can also affect microbial growth on apple slices (Anese et al., 1997) and so this must also be considered in the selection of the optimal packaging film.

Proposed Research:

The work will be separated into two parallel activities, to ensure the most rapid development of information for the industry. The first activity will be focused on the measurement of respiration rates of all five cultivars, immediately after harvest and after various durations in air and CA storage. Measurements will also be made on 1-MCP treated apples as well. All apple slices will be tested with the application of ‘NatureSeal’ dip treatment. The second activity will be focused on package performance studies. Packaging films of varying oxygen transmission rates will be selected, based on data values from preliminary determination of respiration rates of apple slices. These studies will initially be done for ‘Fuji’, ‘Granny Smith’, and ‘Red Delicious’ apple slices. The package performance and atmospheres will be tested under the temperature abuse regime similar to that shown in Fig. 3. Microbial analysis and sensory testing will be done. In later studies, packages will be inoculated with E. coli to evaluate risks when the slices become contaminated.

Apples for this proposal would be obtained from packing houses in Washington State. The apples will be transported to the Pacific Agri-Food Research Centre (PARC) in Summerland, B.C., which is ~ 4 hours north of Wenatchee. The respiration analysis will be performed using the automated respiration analysis facility at the PARC. Apples will either be treated with 1-MCP at PARC or will be obtained from Washington State already treated.

Packaging films will be obtained from various suppliers, based on specifications provided by those suppliers. Different films with a range of oxygen transmission rates will be selected. The oxygen, carbon dioxide and water transmission rates will be tested and confirmed using techniques developed by Dr. Leigh Moyls. Packaging studies will be performed using a 1 pound size format. The packages will be moved to rooms of appropriate temperatures to provide the temperature regime similar to that shown in Fig. 3. Shelf life tests will be extended beyond that suggested in Fig. 3 so as to include several additional days 45^{o}F, simulating storage in a household refrigerator. The long distance transport phase of the simulation can also be extended by several days, which would represent a a worst case scenario for shipping.

Gas composition in the packages will be measured at appropriate intervals. Accumulation of anaerobic fermentation products will also be monitored. Spoilage microbes and/or human pathogen populations on the slices will also be measured using appropriate techniques. Sensory analysis will be performed using a panel of 6-8 persons who have been trained to assess texture and flavor in apple slices. Risk for growth of E. coli will be assessed in separate experiments, using the package system which has been determined as optimal from previous tests. The research will require three years. While the first year is expected to provide good information on packaging selection, evaluation of year-to-year differences is necessary. It is essential for the sake of the industry to ensure that recommendations are sufficiently robust such that potential problems in commercial practice are minimized.

Deliverables:

Year 1

- Respiration rate information on Washington ‘Fuji’, ‘Granny Smith’, ‘Red Delicious’, ‘Gala’, and ‘Golden Delicious’ slices, treated with “NatureSeal”, at harvest and after several durations of air and CA storage. Impact of 1-MCP of whole apples on subsequent respiration rates of slices.
- Optimal target package film specifications with consideration for apple respiration rates, sensory quality and microbial quality. This will be conducted in the context of temperature abuse testing regimes.

Proposed Budget:

Line Item	Cost (CDN$)
Biologist (including 20% benefits)	$ 50, 353
Part time Technician (including 20% benefits)	$ 19, 800
Materials and Supplies	$ 10, 000
Apples	$ 1, 000
Rental of Slicer	$ 3, 000
Travel	$ 4, 000
Administrative Services (10% of total)	$ 8, 815
Total (CDN $)	$ 96, 968
Total cost, converted to US dollars	*U$ 64, 645*

Amount requested from the Washington Tree Fruit Research Commission: $ 32, 323

Note: This proposal is contingent on approval from Agriculture and Agri-Food Canada's Matching Investment Initiative.

Expertise:

Dr. Peter M.A. Toivonen - Postharvest physiology of fruits and vegetables, quality in minimally processed fruits and vegetables, anaerobic volatiles analysis.
Dr. Tom Beveridge - Modeling of respiration in fresh-cut products to determine packaging film requirements, texture measurement and analysis.
Dr. Margaret Cliff - Sensory analysis of apples and other tree fruits.
Dr. Pascal Delaquis - Microbiological quality and safety of fresh produce.
Dr. Leigh Moyls - Packaging permeability analysis (CO_2, O_2 and H_2O transmission rates), packaging design and selection.

References Cited

Anese, M., M. Manzano, and M.C. Nicoli. 1997. Quality of minimally processed apple slices using different modified atmosphere conditions. Journal of Food Quality 20: 359-370.

Bohling, H., and M.L. Hellickson. 1993. Respiration rates and mass loss of Red Delicious apples during controlled atmosphere storage. Pages 31-37. In: Volume 1, Proceedings of the 6th International Controlled Atmosphere Conference, June 15-17, 1993, Ithaca, NY.

Fan, X., S.M. Blankenship, and J.P. Mattheis. 1999. 1-Methylcyclopropene inhibits apple ripening. Journal of the American Society for Horticultural Science 124: 690-695.

Gil, M.I., J.R. Gorney, and A.A. Kader. 1998. Responses of 'Fuji' apple slices to ascorbic acid treatments and low-oxygen atmospheres. HortScience 33: 305-309.

Ke, D., L. Rodriguez-Sinobas, and A.A. Kader. 1991. Physiology and prediction of fruit tolerance to low-oxygen atmospheres. Journal of the American Society for Horticultural Science. 116: 253-260.

Kim, D.M., N.L. Smith, and C.Y. Lee. 1993. Quality of minimally precessed apple slices from selected cultivars. Journal of Food Sciene 58: 1115-1117, 1175.

Lu, C., and P.M.A. Toivonen. 2000. Effect of 1 and 100 kPa O_2 atmospheric treatments of whole 'Spartan' apples on subsequent quality and shelf life of slices stored in modified atmosphere packages. Postharvest Biology and Technology 18: 99-107.

O'Bierne, D. 1990. Some effects of modified atmosphere packaging and vacuum packaging in combination with antioxidants on quality and storage-life of ready-to-use chilled apple slices. Pages 221-229. In: P. Zeuthen, C. Eriksson, T.R. Gormley, P. Linko, and K. Paulus (eds). Processing and Quality of Foods. Vol. 3.. Elsevier, New York.