Project title: Development Of Value-Added Dried Apple Products

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Organization: Washington State University

CO-PI(s) and affiliation(s):
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- Barry Swanson, WSU Food Science and Human Nutrition
- Juming Tang, WSU Biological Systems Engineering

Cooperator(s):
- Brad Newman, Olympic Fruit
- Mark Hanrahan, Olympic Fruit

Objectives:
1. Develop and evaluate dried apple products.
2. Introduce these products to food companies.
3. Expand the demand for cull and off-grade fruit.

Significant Findings and Developments
1. High quality dried apple products were made successfully using a new dehydration technology which maintains fresh character without the use of preservatives.
2. The Boeing Company has donated patents for microwave vacuum dehydration technology (MIVAC®) to WSU. This positions WSU to commercialize the technology for production of high quality dried apple products.
3. The announcement of this donation has prompted multiple inquiries about fruit drying in Washington State. In particular, there have been inquiries from apple processors looking for ways to improve the quality and expand the demand for apples.
4. Research this year has provided methods for producing dried apple products for presentation to food companies inquiring about the technology.
5. Plans are underway to develop structure to build commercial MIVAC® systems for companies interested in commercial production of dried apple products.

Justification:
The purpose of this project is to develop new value-added apple products using new methods of dehydration that preserve fresh apple character in a dried product. Market development for this high quality dried fruit product may provide a greater demand for fruit that is not acceptable for fresh market. Apples that are sorted as culls based on physical defects like sunburn and punctures can be trimmed and cut for dehydration to produce a value-added dried apple snacks or ingredients in foods such as breakfast cereals.

With the U.S. government’s introduction of the new nutritional model of the food pyramid in conjunction with the concept of optimizing health and nutrition, consumer focus has shifted toward whole food nutrition. Minimal processing and convenience are also value-added features important to the consumer. Consumers insist on quality shelf-stable meals and snacks that are safe, nutritious, and are easily prepared or ready to eat. One example is the recent introduction of freeze-dried fruit in breakfast cereals.

* A new proposal has been submitted to continue this work.
Considering this shift in consumer preference toward healthy and convenient foods, and the responsive upturn in food company investment to reach this end, it is prudent to examine the food production system and determine how we can respond to consumer demand for value-added products and ingredients such as dried apples starting in the orchard.

Methods:

1. Process and Product Development

Conventional heated-air drying induces compositional changes in fruits. For example, apple slices turn brown and develop a leathery texture and therefore retain little resemblance to fresh apples unless they are treated with preservatives like potassium metabisulfite. These compositional changes usually occur when the fruit is nearly dry when the temperature of the fruit rises. Freeze drying is an alternative, but is expensive and the product becomes powdery and loses flavor. Microwave vacuum dehydration (MIVAC®) offers a new and unique way to dry food products.

Microwave energy heats the fruit uniformly, inducing vaporization from all parts of the product simultaneously. The result is rapid dehydration. Since vaporization takes place in a vacuum,

- the process temperature is low
- a very low final moisture content can be attained, and
- fresh color, flavor and nutritional value are preserved (Clary and Ostrom, 1995, Petrucci and Clary, 1989, Petrucci, et.al., 1993, Kohl, et.al., 2000).

The process creates a porous texture in the dried product that contributes to preservation of its original shape and size. Use of microwave in low-pressure conditions provides distinct benefits compared to field, hot air, and freeze-drying methods. Dried fruits such as strawberries exhibit a brilliant red color; bananas have a crunchy, fresh taste; grapes maintain a tangy, fresh flavor and bright color; and apple slices maintain an “airy” texture and a bright white flesh color – all accomplished without the use of added preservatives.

A batch type microwave vacuum dehydration unit has been re-located to the Food Processing Pilot Plant at WSU Pullman for testing the process and product development. This system consists of a microwave power supply, controls and a vacuum vessel for processing the apples.

Fresh cull apples were trimmed, and cut to various sizes and shapes suitable for snack foods and ingredients. The fruit was dried in the batch microwave vacuum dryer. After each test, the dried samples were evaluated for appearance and flavor.

The treatments included:
- Blanching the cut fruit in 180°F water for 3 minutes to deactivate enzymes that cause browning.
- Drying the fruit at 130, 140 and 150°F for 90 minutes.

The measurements included:
- Evaluating the dried product for defects such as burning and poor color.
- Initial and final weight of the product to determine dry ratio.
- Calculation of specific energy (W/gm) which is the amount of microwave power used in the test.
- Final moisture content of the dried apple samples.
- Separation of off-grade product due to burning or discoloration.

The experimental data was analyzed to create a model to predict final quality in order to optimize quality of the dried apple products.

2. Commercializing MIVAC technology

The Boeing Company, owners of the original MIVAC® patents has donated the patents to WSU. This positions WSU to promote the technology in Washington State.

Announcement of the donation of the MIVAC® patents to WSU has prompted inquiries from several apple processors including Tree Top and Welch's. WTFRC funding has underwritten production of experimental samples that will be distributed to these companies. The next step is to develop a commercialization package for construction of MIVAC® units.

Results and Discussion

1. Process and Product Development

Microwave energy was applied to fresh apples that had been peeled, cut into slices and dices, and blanched in hot water for 3 minutes. The purpose of the hot water treatment is to deactivate enzymes the cause browning. No sulfites or other preservatives were used.

The prepared samples were processed in the batch MIVAC® unit at WSU based on process temperature. Earlier work has indicated that product temperature is the most important factor in maintaining quality in dried fruit. Therefore, several process temperatures were used to determine the optimum processing sequence to maximize quality.

The data collected from the experiments was analyzed using Multiple Linear Regression Analysis. This method of analysis generates a formula that predicts the response, such as final moisture content, based on process variables including process temperature, dry ratio and specific energy.

A summary of the prediction models for the test runs are shown in Figures 1 and 2. The prediction models indicated that the optimum specific energy was a mean microwave power level of 1.84 W/gm of fresh product applied at a process temperature of 140°F. This treatment produced dried apple pieces that exhibited preservation of original character in a dried form.
Figure 1. Model equations for prediction of final moisture content apple pieces.

Regression Equation: Final Moisture Content = \( b_0 + b_1(x_1) + b_2(x_2) + b_3(x_3) \)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Response Coefficient</th>
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<tbody>
<tr>
<td>Constant</td>
<td>( b_0 = 12.50 )</td>
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<tr>
<td>( x_1 ) = Process Temperature</td>
<td>( b_1 = -0.17 )</td>
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<tr>
<td>( x_2 ) = Dry Ratio</td>
<td>( b_2 = 1.46 )</td>
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<tr>
<td>( x_3 ) = Microwave Power (W/gm fresh)</td>
<td>( b_3 = 3.38 )</td>
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\( r^2 = 0.727 \)

Figure 2. Model equations for prediction of percent off-grade apple pieces.

Regression Equation: Off-grade Pieces (%) = \( b_0 + b_1(x_1) + b_2(x_2) + b_3(x_3) \)

<table>
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<th>Variable</th>
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<tr>
<td>Constant</td>
<td>( b_0 = -74.64 )</td>
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<tr>
<td>( x_1 ) = Process Temperature</td>
<td>( b_1 = 0.71 )</td>
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<tr>
<td>( x_2 ) = Dry Ratio</td>
<td>( b_2 = -4.10 )</td>
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<tr>
<td>( x_3 ) = Microwave Power (W/gm fresh)</td>
<td>( b_3 = 9.33 )</td>
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</table>

\( r^2 = 0.826 \)

The dried products have been distributed to several food companies that either produce dried apples using air dryers or companies interested in new products.

2. Commercializing MIVAC® Technology

A continuous system built at Fresno State has been relocated to Vancouver, BC for commercial operation. The new owners of the continuous MIVAC® are negotiating with WSU to license the technology for drying fruits. They are also considering the development of a project management group to oversee construction of MIVAC® units in the US. These developments offer a pathway for construction and operation of MIVAC® units for production of dried apples in Washington State.

The first step is to cultivate interest on the part of fruit processors that have contacted WSU about MIVAC® technology. Once a proof of concept is accepted, the next step is to offer a technology package for construction of commercial systems. This will be the focus of future work.
Development Of Value-Added Dried Apple Products
Carter Clary

**Proposed project duration:** 1 year

**Current year request 2003:** $11,943

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<td>Wages</td>
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<td>Travel</td>
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<td>Miscellaneous</td>
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<td><strong>Total</strong></td>
<td><strong>11,943</strong></td>
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Salaries PI @ 1month
Wages Hourly 15 hr/wk at $8/hr for 6 weeks
Supplies Fresh fruit for processing
Travel 2 trips to Yakima/Wenatchee