FINAL REPORT
WTFRC Project # PH-03-353

Project title: DEVELOPMENT OF VALUE-ADDED DRIED APPLE PRODUCTS

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Objectives:

1. Develop and evaluate apple products dried using MIVAC®.
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. This project has served as a platform for development of a project with a Washington state fruit processor and the Washington Technology Center to develop and commercialize the technology.

Justification:

The historical approach to the marketing processed apples is use of large-scale production facilities and dryers. This segment has been eroded by off-shore production of similar volumes of product at reduced cost. A possible solution may be repositioning the processing industry to become capable of producing smaller quantities of value-added apple products that off-shore competitors are unable to reproduce. An example of growth in demand for value-added dried fruit products is addition of freeze dried fruit to breakfast cereals. The trend of fruit in cereal continues to grow and most of the growth is using alternative methods of dehydration.

The purpose of this project is to continue to develop new value-added apple products using a new method of dehydration that preserves 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.

Funding from the Washington Tree Fruit Research Commission in 2002 and 2003 has supported development of value-added dried apple products that retain most of their fresh character including color, flavor and shape. Samples of apples dried using this new technology were distributed to fruit processors. As a result, a proposal was accepted by the Washington Technology Center to support study to determine the commercial feasibility of this new drying technology in cooperation with Washington processor.

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 and 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.

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 is loca 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 a shapes suitable for snack foods and ingredients. The fruit was
dried in the batch microwave vacuum dryer. After each te appearance and final moisture content.

The treatments included:

- Blanching the cut fruit in 180^{o}F water for 3 minutes to deactivate enzymes that cause browning.
- Drying the fruit at 130, 140 and 150^{o}F for 60 - 90 minutes.

The measurements included:

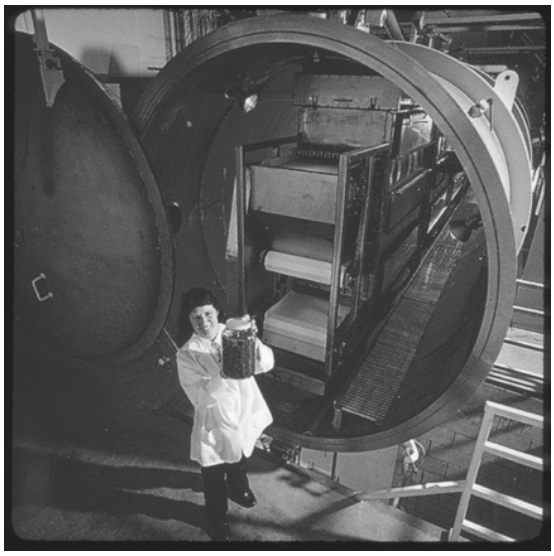
- Visual evaluation of the dried product burning and poor color.

- 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 Welchs. WTFRC funding has underwritten production of experimental samples that were distributed to these companies. As a result, a proposal was accepted by the Washington Technology Center to support study to determine the commercial feasibility of this new drying technology in cooperation with Washington processor.

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 that 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 and time. Earlier work has indicated that product temperature is the most important factor in maintaining quality in dried fruit. Therefore, several process temperatures and times were used to determine the optimum processing sequence to maximize quality.

The data collect 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, time, 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 1.64 W/gm of fresh product applied at a process temperature of 150^{o}F for 67 minutes. This treatment produced dried apple pieces that exhibited preservation of original character in a dried form at a final moisture content of 4.1% (wet basis).

2. Commercializing MIVAC® Technology

The first step was to cultivate interest on the part of fruit processors that have contacted WSU about MIVAC® technology. Funding from WTFRC for the past two years has underwritten production of dried apples for distribution to fruit processors. As a result, a project is now underway with the Washington Technology Center and a Washington state fruit processor. Phase I of this project is proof of concept for dried fruit products. Phase II will focus on development of a technology package for construction of commercial systems.

Project duration: 1 year

Budget Summary: 2003: $__**10,443**____

Item	Year 1 (2003)	Year 2 (2004)	Year 3(2005)
Salaries	7,111		
Benefits (27%)	1,920		
Wages	720		
Benefits (%)	115		
Equipment			
Supplies	100		
Travel	477		
Miscellaneous			
Total	10,443		

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

Figure 1. Model equation for prediction of final moisture content of apple pieces.

Regression Equation:
Final Moisture Content = $b_0 + b_1(x_1) + b_2(x_2) + b_3(x_3) + b_4(x_4)$

	Variable		Mean Response Coefficient
	Constant		$b_0 =$ 30.09
$x_1 =$	Microwave Power (W/gm_{fresh})	$b_1 =$	-5.11
$x_2 =$	Process Temperature (^oF)	$b_2 =$	-0.16
$x_3 =$	Dry Ratio		$b_3 =$ 1.14
$x_4 =$	Process Time (min)		$b_4 =$ -0.13
			$r^2 =$ 0.916

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

Regression Equation:
Off-grade Pieces (%) = $b_0 + b_1(x_1) + b_2(x_2) + b_3(x_3) + b_4(x_4)$

	Variable		Mean Response Coefficient
	Constant		$b_0 =$ 173.03
$x_1 =$	Microwave Power (W/gm_{fresh})	$b_1 =$	20.35
$x_2 =$	Process Temperature (^oF)	$b_2 =$	-0.61
$x_3 =$	Dry Ratio		$b_3 =$ 5.05
$x_4 =$	Process Time (min)		$b_4 =$ -1.26
			$r^2 =$ 0.908