Michigan Department of Agriculture and Rural Development

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Final Performance Report

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Project Title: New Apple Varieties Optimized for Michigan's Nutraceutical Industry

PROJECT SUMMARY

Background: This project addressed the potential to exploit Michigan apple production infrastructure for production of apples as *nutraceuticals* (nutrition/pharmaceuticals) and *functional foods*. Nutraceuticals are defined as processed foods or food extracts that have a medicinal effect on human health. Functional foods are defined as normal components of the human diet that have health-beneficial effects. As the apple is already the ultimate functional food, it has high potential to be developed as a source of nutraceuticals. Anthocyanins are natural compounds that create the red color of the apple skin. These and closely related compounds called anthocyanidins are members of larger classes of chemical compounds termed flavonoids and phenolics, which are widely considered to benefit human health as antioxidants, a major focus of the multi-billion dollar nutraceutical industry. In previous work, we analyzed three naturally occurring apple cultivars for anthocyanin content and antioxidant capacity. These cultivars either accumulate abnormally high levels of anthocyanins in skin, or accumulate anthocyanins in the flesh (turning the flesh a dark red color). The three cultivars tested are known as novelties and have no current market value. However, these and similar varieties could easily be developed as a source of extractable anthocyanin. As these compounds are relatively scarce in nature, and demand for natural flavonoids far exceeds supply, their ready availability in apple would almost certainly lead to a an exceedingly profitable market for Michigan growers.

Motivation: Michigan apple growers are finding it increasingly difficult to compete nationwide for fresh market, and are also frequently at a competitive disadvantage for juice production. Specialty varieties optimized for Michigan production will be increasingly important to ensure the continued viability of the Michigan apple industry. In this project, we initiated the development of a new market for Michigan apple growers, by identifying novel apple varieties and wild species that produce high levels of valuable anthocyanin compounds in the fruit, selecting those that are optimal for Michigan cultivation, and providing growers with the resources needed to establish such varieties as rich sources of anthocyanin for juice and food additives. Such compounds are generally considered to benefit human health as antioxidants, anticancer and anti-inflammatory agents, and are in very high demand. The ready availability of these compounds in such apple varieties will provide a complementary market for Michigan apple growers that would sustain the industry over seasons that are nonprofitable for traditional (juice and fresh) markets.

PROJECT APPROACH

Activities and tasks performed: During the period of natural fruit ripening (mid-August through early November) in 2009 and 2010, we evaluated and documented both internal pattern and intensity of anthocyanins within fruit internal tissues in four major apple (*Malus*) live collections: the USDA-ARS collection in Geneva, NY, the UK National Fruit Collection in Brogdale, Kent, UK, the Canadian Clonal Genebank in Harrow, Ontario, and the Michigan State University *Malus* collection in East Lansing, MI. In all, we analyzed over 3,000 distinct domestic apples, crabapple varieties, and wild species. We classified these into groups based on similarity of anthocyanin pattern and intensity, and established genetic relationships using molecular genetics techniques and historical records. We also compiled limited yield and disease resistance data for a subset of the most potentially valuable red-fleshed apples that we identified. We extracted juice from a variety of red-fleshed apples for biochemical analysis and anthocyanin identification. Juice was subjected to analysis for acidity (pH and extractable acidity), color, sugar content, and total phenolics. This information is immediately useful to growers considering using the varieties for red juice.

Significant results, accomplishments, conclusions and recommendations: Our work revealed several aspects of red-fleshed apples that should be of interest for production and breeding. We identified many, generally unrecognized genotypes that exhibited internal pigmentation that was typically intense and broadly distributed within the flesh. Most of the most popularly planted ornamental crabapples are derived from open-pollinated progeny of 'Niedzwetzkyana', or from 'Niedzwetzkyana' x *M. baccata*. These ornamental varieties are notoriously susceptible to diseases including apple scab and fire blight (Jefferson, 1970). However, included in the parentage of other red-fleshed varieties are a diverse range of species (*M. coronaria*, *M. halliana*, and *M. sieboldii)* and interspecific hybrids [*M. x scheideckeri* (= *M. floribunda* x *M prunifolia*), *M. atrosanguinea* (= *M. halliana* x *M. toringo*), and *M. x arnoldiana* (= *M. baccata* x *M. floribunda*)]. This genetic diversity should be exploiting to create informed crosses generating new cultivars with superior qualities for industrial nutraceutical production from fruit, including disease resistance, yield, ease of mechanical harvesting, and degree of anthocyanin accumulation. We performed biochemical analysis of juice and extracted and documented anthocyanins. Some of the varieties showed high levels of anthocyanins and this will be studied further to develop nutraceutical products in the future.

Significant contributions and role of project partners:
P. Schwallier managed propagation of the selected varieties, and is maintaining these and managing orchard trials. M. Nair was responsible for anthocyanin analysis of the fruit. S. van Nocker managed the evaluation and documentation, and otherwise directed the study.

GOALS AND OUTCOMES ACHIEVED
Activities completed:

- Evaluation and documentation of fruit flesh color and pattern among over 3,000 apple cultivars in Michigan, New York, England and Canada
- Literature review and compilation of data on production characteristics and disease resistance for selected cultivars
- Biochemical analysis of juice derived from a subset of red-fleshed apple cultivars
- Extraction and analysis of anthocyanins by HPLC
- Nursery propagation and test orchard establishment for ten selected cultivars
- Production of a manuscript for publication in a peer-reviewed scientific journal
- Production of an article submitted to a fruit grower's newsletter
- Reporting of results to the Michigan apple industry at a regional industry meeting

Progress made towards long-term objectives: Red-fleshed apple varieties identified in this study could easily be developed as a source of extractable anthocyanin to provide a complementary, potentially highly profitable market for Michigan growers. However, to make this idea a reality, two additional hurdles have to be overcome. First, methods for extraction and processing of the compounds need to be optimized. Second, marketing and market assessment devices must be implemented. Although these aspects were not included in this project, they would form the basis for long-term work. Also, although not proposed here, the work would also be the first step in the development of a 'super-charged' antioxidant apple as a novel functional food specialty crop fine-tuned for Michigan growers.

Actual accomplishments in relation to goals: All original objectives of the project were completed.

Data that has been gathered to date in relation to set targets: None. The project has only long-term quantitative goals, that being the establishment of industrial anthocyanin production within Michigan. This will be measured by value of the industry compared with present (zero).

BENEFICIARIES

Groups and other operations that benefited from the project:

Existing and prospective apple growers in Michigan and elsewhere can use this analysis in selection of varieties to be grown for industrial anthocyanin production. Scientists and plant breeders can use the information for selection of varieties for further optimization through breeding.

Potential economic impact of the project:

We hope to identify a low-maintenance, high profit apple crop. This is possible as many of the varieties are disease resistant, require no intensive training systems, and are amenable to mechanical harvesting and processing. Juice would be expected to command a premium price. There is also potential for red ciders. The development of a nutraceutical apple industry would provide immediate profits to growers, could expand the industry, and offers potential for Michigan's new bio-economy.

LESSONS LEARNED

This effort was greatly facilitated by maintenance and organization of large numbers of *Malus* accessions in nationally-funded germplasm collections. This trait is but one of hundreds that could contribute to the health of the apple industry. For many of these traits, these collections hold key varieties that can be used in breeding to greatly improve current varieties. The research carried out was preliminary and more work needs to be done. There are no pitfalls identified so far related to this project except that the high anthocyanin yielding plants are not yet abundant enough to afford enough fruits for processing.

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ADDITIONAL INFORMATION

- A manuscript detailing the genetics aspects of this project, titled "Genetic diversity of red-fleshed apples (Malus)", has been submitted for publication in the plant breeding journal *Euphytica*.
- Another manuscript describing the results of biochemical analysis of fruit is in preparation.
- A website is in development (*redfleshedapples.org*) that can provide a resource for producers, scientists, educators, and the general public.
- The project provided training opportunities for numerous undergraduate and high-school students in basic agriculture and genetics.