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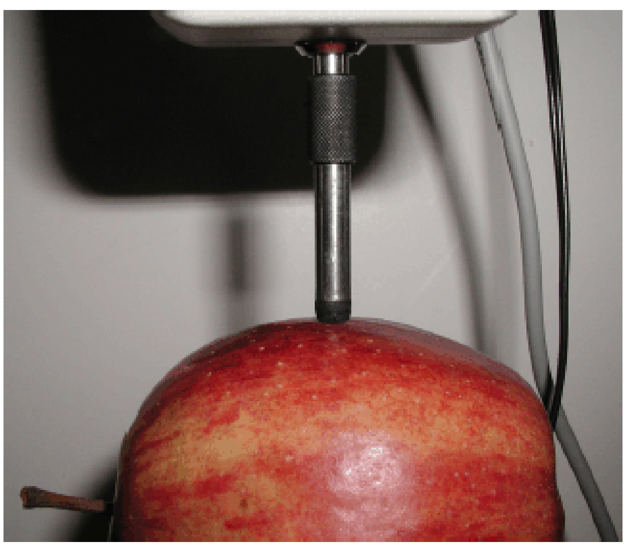
**Introduction:** Two projects were completed this past year. One project was to develop a prototype non-destructive firmness tester for apple. Working with the USDA Ag. Engineering group and the Biosystems and Ag. Engineering Department at MSU, a prototype was developed that accurately assesses fruit textural properties while bringing about minimal damage to the fruit. An on-line unit should be able to accurately identify and cull soft apple fruit and avoid their use in fresh-cut fruit preparations. A second project was to evaluate the impact of non-target materials on the sorption of 1-MCP, which might be included in packaged produce or used to treat produce in packages. We found that cellulose-containing materials were not inert and could remove a significant portion of the 1-MCP.

## Activities

### Objective 1: Develop, evaluate, and standardize subjective and objective quality evaluation methods in intact and fresh-cut fruits and vegetables.

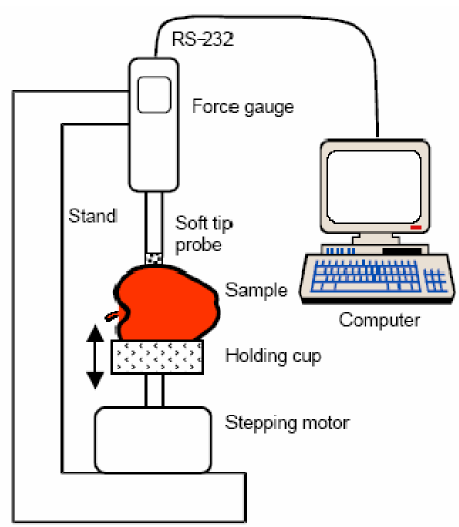


Development of a bioyield tester for intact apple (Tipper, Lu, Beaudry, Srivastava). Firmness is an important quality attribute for intact and fresh-cut apple fruit and directly influences consumer purchase decisions. Currently, several fruit growing states in the United States require that fresh apples meet a specific firmness standard before they can be shipped to the market. The Magness-Taylor (MT) fruit firmness tester is the standard device used by the industry to measure fruit firmness. MT firmness measurements involve the penetration of a round steel probe (11 mm in diameter for apples) into fruit flesh to a specified depth (normally 9 mm). The maximum force recorded is considered to be a measure of fruit firmness. The penetration process takes place in the form of compression, shearing, and tension, which is difficult to quantify. The technique is destructive and prone to operational error. Many nondestructive or minimally destructive devices or methods have been developed for measuring fruit firmness. Most nondestructive mechanical methods measure elastic properties, such as elastic modulus, as an index of fruit firmness.

The concept of using bioyield force as an indicator of fruit firmness goes beyond elastic deformation but has not resulted in a complete rupture of fruit tissue. According to Hertz contact theory, when a rigid probe is compressed against a fruit, the stress distribution is not uniform within the contact area and stress concentration occurs. This non-uniform stress distribution causes the tissue within the contact region to fail gradually, making it more difficult to detect the bioyield point from the force-deformation curve. We studied several sizes of rigid probes with different tip designs, i.e., the elasticity and thickness of the tip material. A soft rubber tip allows for large elastic deformation, producing a uniform stress distribution within the contact area. This uniform stress distribution should improve the detection of the bioyield point because the fruit tissue within the contact region tends to fail simultaneously, creating a sudden drop in force that is easy to detect. Experiments of Ababneh (2002) confirmed that a soft tip probe usually produced a smooth force-deformation curve with a sharp bioyield point, whereas with a rigid probe, the force-deformation curve was less smooth, characterized with a series of micro failure taking place over a range of deformation and the bioyield point was less evident and sometimes could not be identified. A correlation of 0.83 between bioyield force and MT firmness was obtained for the pooled data of four apple varieties.

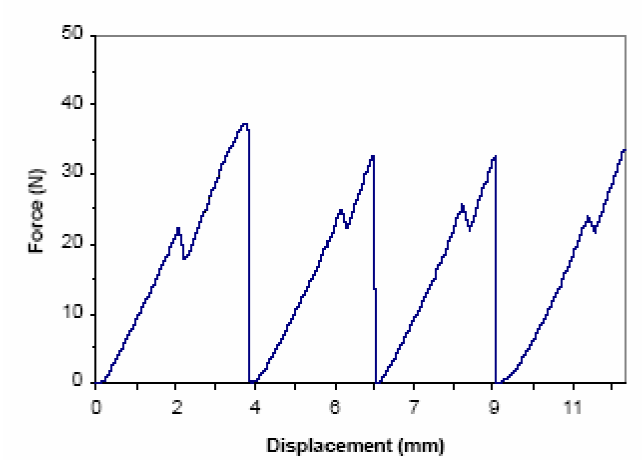
The objective of this research was to further evaluate the bioyield probe designed by Ababneh by coupling it to a portable digital force gauge for measuring the firmness of apple fruit with the ultimate goal of developing a portable bioyield tester for laboratory and field uses. Specific objectives were to:

1. Determine correlations between MT firmness and bioyield force for two cultivars of apples;
2. Compare the changes of bioyield force and MT firmness over time under different postharvest storage conditions/treatments; and
3. Evaluate the variability of bioyield force and MT firmness measurements within individual apple fruit. In this article, unless otherwise specified, the term 'bioyield force' is referred to the force to cause bioyield by the soft tip probe, designated as Fbyst, which is different from the bioyield force for the rigid probe.

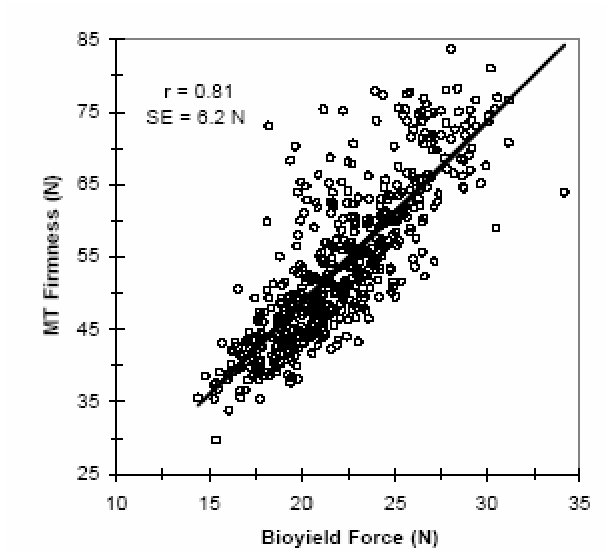



The specially designed soft tip bioyield probe was coupled to a handheld digital force gauge that was mounted on a tabletop motor-driven stand. Bioyield force (or Fbyst = force to cause bioyield by the soft tip probe) and Magness-Taylor (MT) firmness were measured on Delicious and Golden Delicious apples under different storage conditions and/or treatments. The correlation between MT firmness and Fbyst ranged from 0.62 to 0.81 with a standard error between 5.2 N and 6.7 N. Bioyield force decreased at about the same rate as that for MT firmness when apples were stored in refrigerated air at 5°C. When fruits were kept at room temperature (24°C), the percent decline in Fbyst over the test time period was less than that in MT firmness. Bioyield force measurements within individual apples were 42.6% to 46.8%

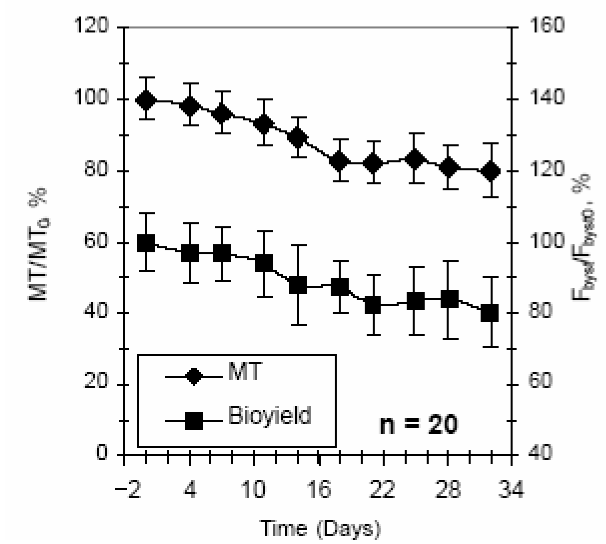
more variable than MT firmness, as measured by the coefficient of variation. Since the bioyield tester does not degrade apple fruit, it will be useful for measuring and monitoring fruit firmness during growth, harvest, and postharvest operations.




Force-deformation curves acquired from an apple fruit with the specially-designed 6.4-mm diameter bioyield tester at a loading rate of 0.37 mm/s




Correlation between Magness-Taylor firmness and bioyield force for the pooled data from three groups of Delicious apples (from cold and room temperature storage. Each data point represents the average of four measurements on each fruit.



Changes in MT firmness and bioyield force ($F_{byst}$) for Delicious apples over time, expressed as a percentage of the respective values for the first test date (day 0) for three groups of apples.

**Objective 2:** Develop new strategies to maintain fresh-cut product quality

Sorption of 1-MCP by non-target materials (Vallejo, Beaudry). The sorption of 1-methylcyclopropene (1-MCP) by a number of 'non-target' materials found in apple (*Malus* x *domestica* Borkh.) and pear (Pyrus communis L.) fruit storages was measured as a function of time, temperature, and moisture content. Materials included bin construction materials [high density polyethylene (HDPE), polypropylene (PP), extensively- and slightly-weathered oak (*Quercus* sp.), weathered fir (*Abies* sp.) plywood, and cardboard] and wall surface materials (polyurethane foam and cellulose-based fire retardant). Bin construction material test pieces had an external surface area of 180 $cm^2$. We placed 'non-target' materials in 1-l glass jars and added 1-MCP gas to the headspace at an initial concentration of approximately 30 µl $l^{-1}$. Gas concentrations were measured after 2, 4, 6, 8, 10, and 24 h. The concentration of 1-MCP in empty jars was stable for the 24-h holding period. There was little to no sorption by HDPE, PP, polyurethane foam, or fire retardant. However, plywood, cardboard, slightly-weathered oak, and extensively-weathered oak absorbed 16, 18, 55, and 75 percent of the 1-MCP after 24 h. Moistening the test material increased the rate of sorption of 1-MCP for cardboard, plywood, weathered oak, and non-weathered oak, resulting in a depletion of approximately 98, 70, 98, and 98 percent, respectively, in 24 h. For oak bin material, the rate of sorption was not impacted by temperature and increasing the surface area by approximately 100% only marginally increased the rate of sorption. When moistened oak bin material was included with apple fruit in a proportion similar to that found in fruit storage, 90% depletion occurred in 6 h compared to approximately 80% in 24 h for fruit alone. The data suggest that 1-MCP levels can be compromised by wooden and cardboard bin and bin liner materials, but not by plastic bin materials or wall surface materials commonly used in Michigan.

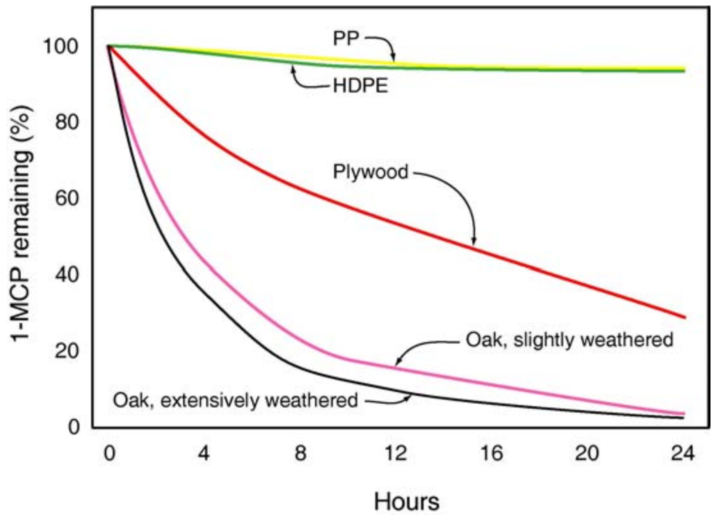



Figure 1. Effect of material on the sorption of 1-MCP at 20 °C for wetted test samples of ‘non-target’ bin materials found in apple and pear fruit storages as a function of time. The initial 1-MCP concentration was approximately 30 ppm.

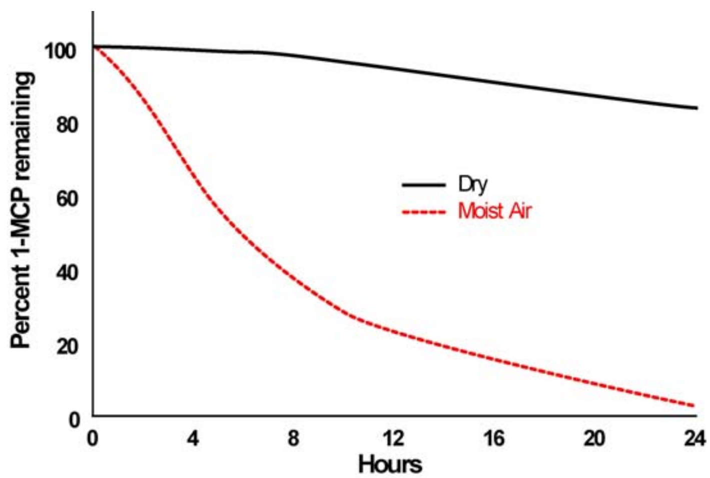



Figure 2. Effect of moistening of cardboard packaging material on time-dependent depletion of 1-MCP at 20 °C.

Bulleted brief synopsis of each major project underway in 2005-2006.

- Evaluated 1-MCP sorption by non-target materials and found that those containing cellulose absorbed significant quantities of 1-MCP (especially when dampened), which might compromise efficacy.
- Participated in a project to develop a prototype that is useful for non-destructive evaluation of apple fruit texture.
- Evaluated the impact of oxygen on the rate and extent of browning of cut leaf lettuce in modified atmosphere packages.

Bulleted brief synopsis of additional major project(s)

- Wrote a review article on modified atmosphere packaging
- Project underway to determine if wood or packing materials scalp sufficient 1-MCP to reduce its efficacy; determining the impact on the lowest effective concentration.
- Evaluated a microarray we constructed for determining the impact of ripening on gene expression in apple with special attention given to changes in genes associated with volatile synthesis and texture.

## Publications


Ben-Yehoshua, S., R.M. Beaudry, S. Fishman, S. Jayanty, and N. Mir. 2005 Modified atmosphere packaging and controlled atmosphere storage In: AEnvironmentally Friendly Technologies for Produce Quality@, S. Ben-Yehoshua, ed., CRC Press, Boca Raton, FL, pp. 61-112.

Watkins, C.B., M. Erkan, J.F. Nock, K.A. Iungerman, R.M. Beaudry, and R.E. Moran 2005. Harvest date effects on maturity, quality and storage disorders of >Honeycrisp= apples. HortScience, 40:164-169.

Gao, Zhifang, S. Jayanty, R. Beaudry, and W. Loescher 2005. Sorbitol transporter expression in apple sink tissues: Implications for fruit sugar accumulation and watercore development. J. Amer. Soc. Hortic. Sci. 130(2):261-268.

Lu, R., A. Srivastava, and R. Beaudry. 2005. A new bioyield tester for measuring apple fruit firmness. Amer. Soc. Ag. Eng. 21(5):893-900.

Carrasco, B., J.F. Hancock, R.M. Beaudry, and J.B. Retamales. 2005. Chemical composition and inheritance patterns of aroma in *Fragaria*H*ananassa* and *Fragaria virginiana* progenies. HortScience, 40:1649-1650.