CONDITIONING TO REDUCE IMPACT BRUISING IN FRUITS AND VEGETABLES

G. M. Hyde, A. L. Baritelle, and J. Varith
Biological Systems Engineering Dept.,
Washington State University, Pullman, WA
gmhyde@wsu.edu

ABSTRACT

This article discusses recent research findings on the relationship between fruit and vegetable tissue strength and stiffness, resulting bruise thresholds, and how conditioning; i.e., adjustment of temperature and turgor, can improve bruise threshold. In general for apples, turgor (hydration) has more effect than temperature on bruising, which both turgor and temperature are important in at least Bartlett pears. For further information, see the following web site:
http://www.wsu.edu/~gmhyde/ImpactProperties.html

OVERVIEW

The conference presentation discussed the following topics:

- Why bruises occur
- What conditioning can do
- Bruise threshold prediction
- Tissue results-apples
- Whole fruit results-apples
- Tissue results-Bartlett pears
- Conclusions

Why Bruises Occur

Bruises occur under impact loading when the stress (force/area) induced in the fruit by an impact exceeds the failure stress of the fruit tissue. If we know the strength (failure stress) and stiffness of the tissue, and the size (mass) and shape (smallest radius of curvature) of the fruit, we can predict bruise threshold using a recently developed equation.

What Conditioning Can Do

Conditioning, by adjusting fruit turgor (hydration) and/or temperature can change either or both the fruit failure stress and failure strain (Figure 1). (Tissue stiffness is also important but is simply the ratio of stress to strain). In apples, slight reductions in hydration (2 to 3% mass loss) can reduce turgor enough to double the bruise threshold, as we shall see later. Temperature has a statistically significant but very small effect, increasing threshold with increasing temperature at lower turgor levels.

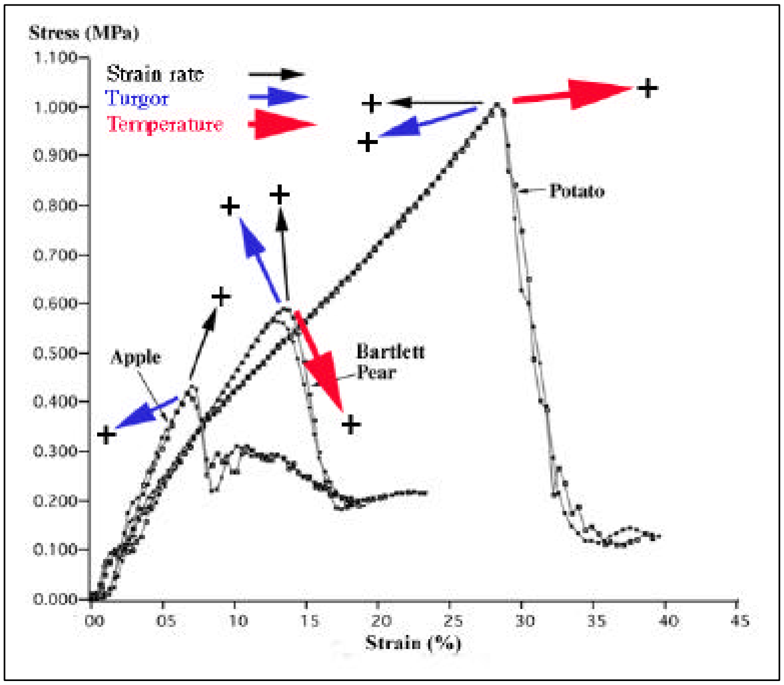

Figure 1. Stress-strain profiles under impact loading for apples, Bartlett pears and potato tubers, showing movement of the failure point with increasing (+) strain rate, turgor and temperature.

Bruise Threshold Prediction

Our research indicates that all of the variables discussed above (fruit mass, radius of curvature, failure stress, and failure strain) can be used to predict bruise threshold in the following equation:

$$h = \frac{7600\,(\sigma_{failure})\,(\varepsilon_{failure})^4\,R^3}{m\,g} \qquad \text{equation (1)}$$

where:
- h = bruise threshold (mm)
- σ_f = failure stress (MPa)
- ε_f = failure strain
- R = radius of curvature (m)
- m = individual fruit mass
- g = acceleration due to Earth's gravity (9.81 m/s^2)

Notice that failure strain and radius of curvature are to the 4^{th} and 3^{rd} power, respectively. Those powers mean that these two factors are much more important in determining bruise threshold than are failure stress and mass.

Tissue Results-Apples

Figures 2 and 3 show, respectively, the failure stress and strain values and corresponding bruise thresholds for Golden Delicious apples as affected by percent mass loss (due to slight dehydration) and temperature. In general tissue failure stress and especially strain increased with mass loss, except that at the 29 °C (84 °F) temperature some rather strange things happened. In general, bruise threshold improved (increased) with moisture loss but temperature had only a small effect at the lower turgor level.

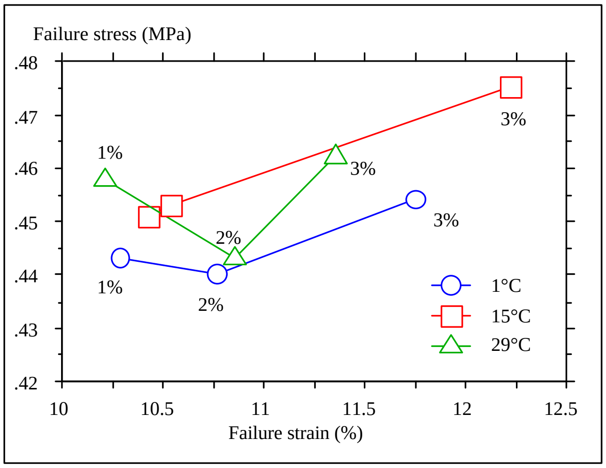

Figure 2. Golden Delicious apple failure stress and strain by temperature and turgor.

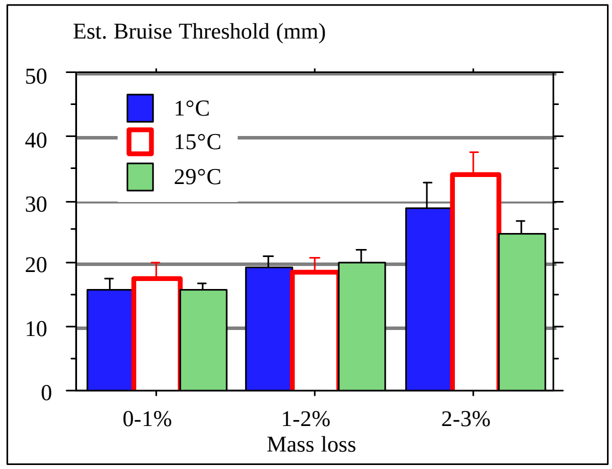

Figure 3. Golden Delicious apple bruise thresholds by temperature and turgor calculated from equation 1.

Figures 4 and 5 show, respectively, bruise thresholds by mass loss and temperature for Golden and Red Delicious apples. Note that, as in other research at other institutions, Goldens have higher bruise thresholds than do reds.

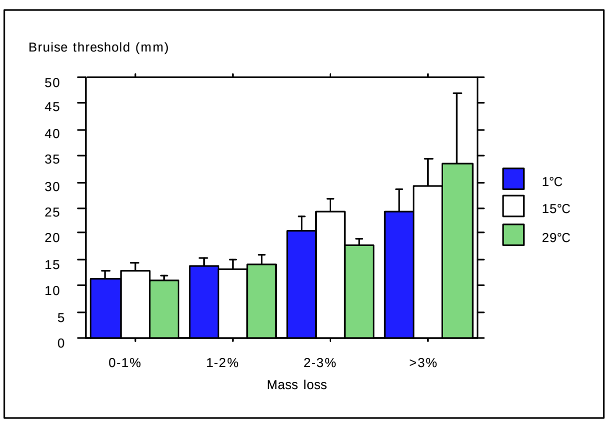

Figure 4. Golden Delicious estimated bruise threshold by mass (moisture) loss and temperature (8 apples per mean except 3-13 at > 3%).

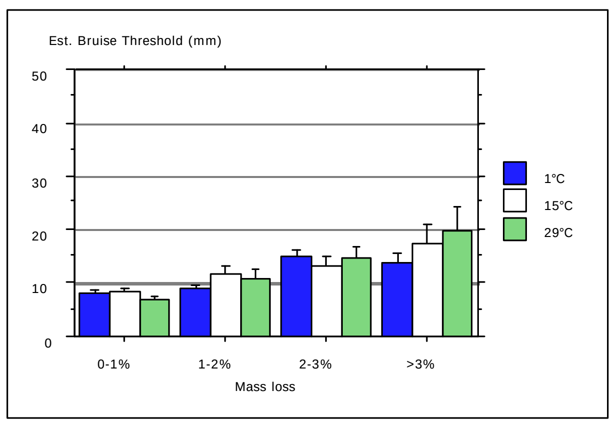

Figure 5. Red Delicious estimated bruise threshold by mass (moisture) loss and temperature (8 apples per mean except 3-12 at > 3%).

Figure 6 shows bruise threshold changes with hydration for Fuji, Golden Delicious, red Delicious, and Rome apples together for comparison. Bruise thresholds increased consistently with increasing moisture loss for all four cultivars.

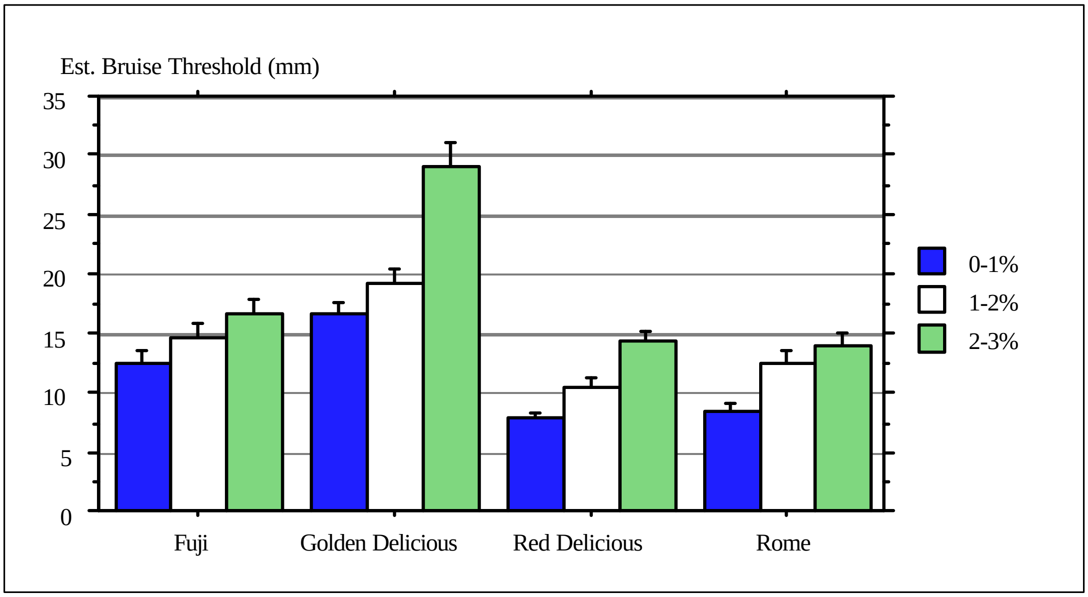

Figure 6. Bruise threshold by cultivar and mass loss for apples of same mass and radius of curvature (~24 apples per mean).

Whole Fruit Results-Apples

Figures 7 and 8 show whole-fruit bruise threshold measurements by hydration level and temperature, respectively. These results show the same trends, as do the tissue results above, with higher thresholds at lower hydration and Goldens higher than reds. Temperature showed no significant effect.

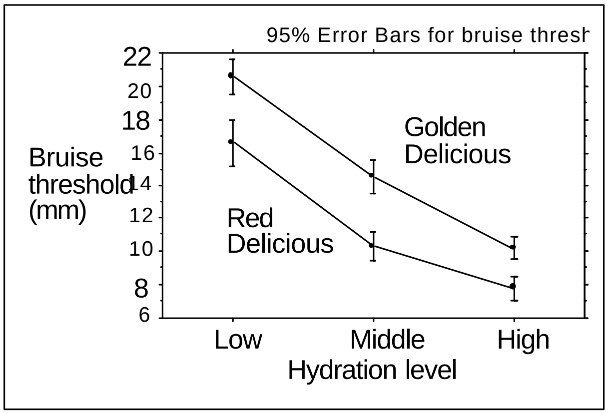

Figure 7. Whole apple bruise threshold by hydration level.

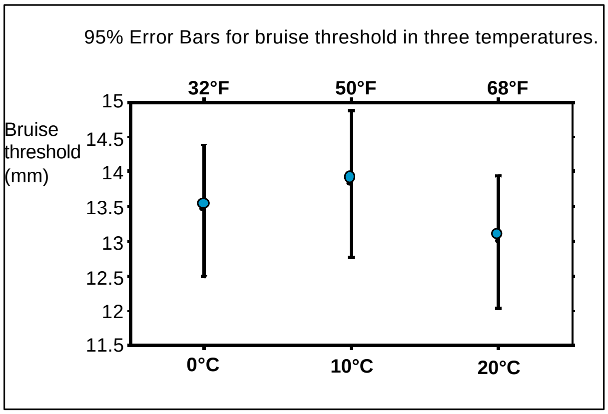

Figure 8. Whole apple bruise threshold by temperature.

Tissue Results-Bartlett Pears

Finally, Figures 9 and 10 show respectively tissue failure stress and strain, and resulting calculated bruise threshold. These results seem to show that turgid Bartlett's should be warmed, but that flaccid ones should be kept cool for handling. The flaccid ones may be softer that packers wish to ship.

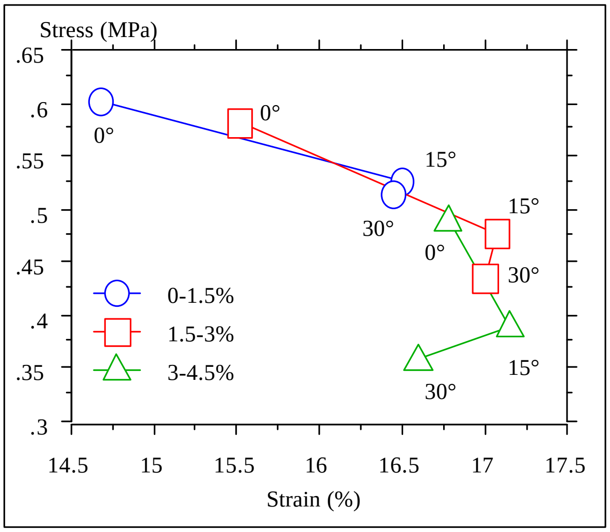

Figure 9. Failure stress and strain for Bartlett pears at three temperatures and turgors.

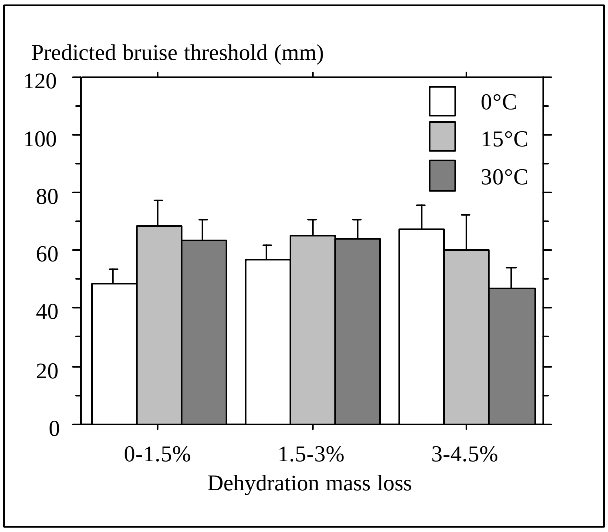

Figure 10. Estimated bruise threshold, using equation 1, for Bartlett pears at three temperatures and three relative turgors (95% confidence intervals, 60 samples/mean)

Conclusions

We can conclude from results so far that bruise threshold and bruising can be controlled to some degree by management of hydration, which influences turgor pressure. Temperature has only a small and probably unimportant influence on bruise threshold in apples, but is more important in pears. The packinghouse compromise is between loss in fruit weight and gain in bruise-free fruit.