# A COMPARISON OF GROWING LOCATION AND YEAR ON THE IMPACT SENSITIVITY OF RUSSET BURBANK POTATO TUBERS

by
Andre Baritelle and Dr. Gary M. Hyde
Department of Biological Systems Engineering, Washington State University

## Abstract

Three dynamic testing procedures (Statistical thresholding, Constant Height Multiple Impact and Dynamic Axial Compression) were used to determine the effect of cultural practices from four commercial growing operations on the impact sensitivity of Russet Burbank potato tubers for two years (1995 and 1996). Significant differences were found among the growing operations (cultural practices) and years for each of the three tests. The growers showed consistent influences on the tuber toughness from one year to the next, even though the fields were different (but nearby) the second year. In general, tubers from these operations were not as sensitive to impact in 1996 as in 1995, and the three testing methods showed similar results.

## Introduction

Bruising is important to potato growers because up to 20% of their income may depend on the quantity of impact related defects (Thornton, 1974). In years such as 1993, it is estimated that bruising-related defects cost Washington State Potato Growers somewhere between $20 and $60 million.

For many years research has been done on potato bruising to try to quantify it. The results have often been conflicting. One possible reason for this could be seasonal variations. Bajema et al. (1996) used three dynamic testing procedures to find a fast (< 1 day) method of determining if a given lot of potatoes were susceptible to bruise. His findings were that at this point there is no instant method of determining a tuber's propensity to bruise. However, his methods did prove to be valuable as evaluation tools for determining and evaluating tuber physical properties as relevant to their impact sensitivity.

Impact Sensitivity has two components: Bruise Threshold and Bruise Resistance. Bruise Threshold is the drop height at which bruising begins to occur or the inverse would be the percent of tubers bruised at a given drop height. Bruise Resistance is the bruise energy per unit of bruise volume, and the inverse of this is the bruise size for a given drop height.

Finney et al. (1964) found that the applied force, deformation and energy at the point of rupture were less at the time of harvest in Michigan-grown tubers than those values one month earlier.

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He also stated that these parameters were dependent on soil moisture content. Massey et al. (1952) found significant differences in the blackspot indices of different varieties grown in different locations.

## Objective

The purpose of this work was to use the three dynamic testing procedures outlined in Bajema et al. (1996) to compare the impact sensitivity of Russet Burbank potato tubers grown at four different commercial operations over a period of two years.

## Methods And Materials

Tubers were hand harvested on September 7, 20, and October 4, 1995 and the same harvesting dates were used in 1996. All tubers were carefully hand dug. Samples were in the 227 to 311g (8-11 ounce) size range and all tubers used were well shaped "US number 1's". Baritelle and Hyde (1997) found that the fundamental tissue failure properties were not significantly different for Russet Burbank potato tubers in this size range. All growing locations for both years were in close proximity (within 25km) of each other in the Columbia River Basin in the central part of Washington State. While the same growers were surveyed the actual growing locations were different for each year, due to crop rotation schemes. It should be noted that in 1996 growing locations 2 and 4 were harvested before October 4, so harvest 3 samples were not attainable.

Experiments were performed on tubers in 10 days or less from the harvest date. Interim storage conditions were 10°C and > 95% relative humidity. Specific gravity's were measured using 10 tubers for each growing location at each sample date using the weight in air/weight in water method. For the entire experiment a total of 3080 tubers were used.

## Testing Methods

Bajema et al. (1996) outlined in detail the three methods used in determining potato tubers impact sensitivity: statistical thresholding, constant height multiple impacting and dynamic axial compression. Statistical thresholding and constant height multiple impacting (CHMI) use whole tubers, while dynamic axial compression (DAC) uses tissue samples.

## Whole Tubers

Statistical thresholding consists of dropping 10 tubers onto their stem end from one of four drop heights. This is repeated for two temperatures, 8 and 15°C . The resulting information is the percent of tubers bruised for a given drop height (inverse of bruise threshold) and an estimate of the volumes of those bruises.

The CHMI procedure (Hyde et al. 1994) consists of dropping a tuber from a known damaging drop height (200mm) onto the same location five times. With each successive impact the tuber absorbs less energy until an equilibrium bruise size is reached for that drop height (Figure 1). The sum of the bruise energy's is then divided by the volume of the resulting bruise to obtain the bruise resistance of the tuber (Hyde et al. 1994). Ten tubers were used for each temperature.

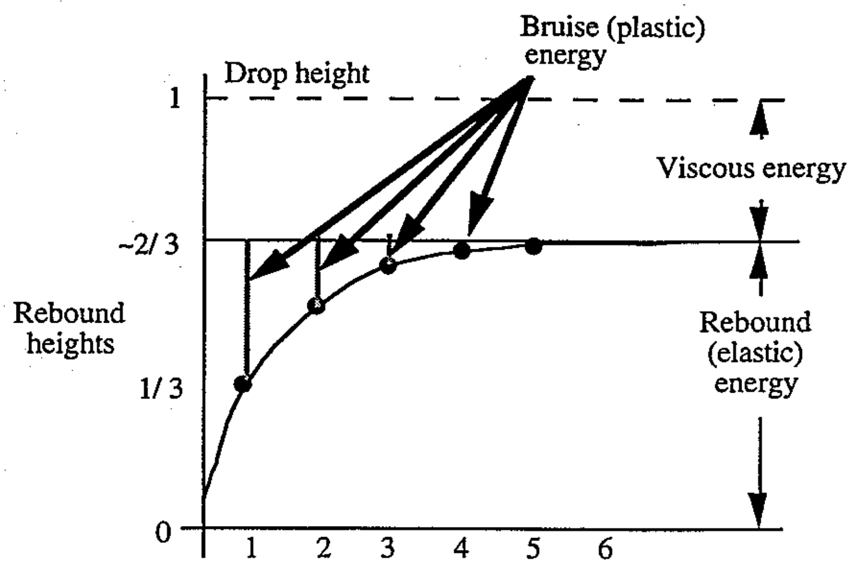


Figure 1. Typical constant height multiple impact response (Hyde et al. 1994).

### Tissue Samples

Variation in radius of curvature at the point of impact is a problem encountered when comparing potatoes. Cylindrical tissue samples eliminate geometric variation effects. Six tissue samples (10 mm dia. by 15.1 mm long) were removed from each tubers stem end and then adjusted to the appropriate temperature (Bajema et al. 1997). The samples were then tested to failure under dynamic axial compression (DAC) using a strain rate of 80 mm/mm*s. The total number of tubers used for each cell in this experiment was 20 (10 per temperature).

### Bruise Classification

For the whole commodity tests (statistical thresholding and CHMI) bruise classification was performed using the classification system developed by Bajema et al.(1996). Once the experiments were performed the tubers were stored at room temperature (≈ 23°C) for a period of 72 hours before measurements were made. The tubers were cut into one mm slices through the bruise and the bruise diameter was measured to the closest millimeter in each of three directions. Treating the bruise as an ellipsoidal shape the three diameters were compiled to determine the total bruise volume. Only bruises 0.380 $cm^3$ or greater in volume were scored, this is equivalent to a 4.5 mm diameter sphere (the size of a standard BB, 0.177 in). This bruise size was chosen to make the classification of the data more practical.

### Equipment

For the whole commodity testing (statistical thresholding and CHMI), a pendulum apparatus which is described in Bajema et al. (1995) was used.

It consists of an instrumented three-meter pendulum which suspends the commodity and the approach and rebound velocities are measured by the elapsed time between two infrared relays. A contact area sensor is mounted to a force transducer which enables the measurement of contact area and force resulting in pressure. Each of the devices are sampled at 10,000 samples per second.

The instrumentation used for the tissue sample experiments is described in detail in Bajema et al. (1995). Axial compression was performed by horizontally mounting samples onto a rigid one meter pendulum. The samples were mounted on a force transducer with a small amount of vacuum grease (10 mm diameter and <0.2 mm thick). The samples were lightly pressed onto the grease and then twisted to allow for adequate adhesion, for the testing procedure, and to force out most of the grease.

Piezoelectric force transducers (445N) are mounted in both the hammer and the anvil, allowing for determination of shock wave propagation time. Hammer position was measured by an angular displacement transducer. Hammer position and both force transducers are each sampled at 25,000 Hz using a National Instruments™ NB-MIO-16L data acquisition board and data acquisition software developed using LabView™ software. Failure stress, failure strain, shock wave speed and tissue toughness (area under the stress strain curve) were derived from the recorded data. Figure 2 shows how each parameter is defined.

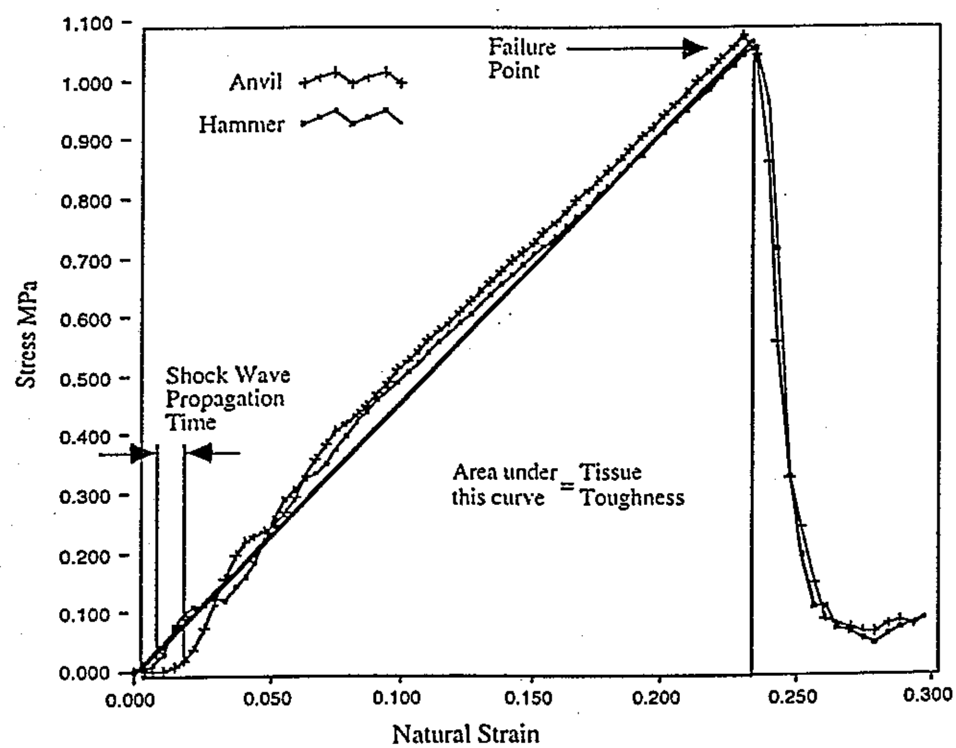


Figure 2. Typical stress versus strain curve for potato tuber tissue sample (15 mm length and 10 mm diameter) for the approach velocity of 1.21 m/s with the various curve characterization parameters illustrated (Bajema et al.1997a).

## Results And Discussion

The Results and Discussion section is organized into 4 sections discussing the effects of; growing location and sample date, growing location and year, sample date and year and the effect of temperature, respectively. Within each of these sections the results are presented for statistical thresholding, CHMI and DAC.

The average specific gravities over all harvest dates for farms #1-4 were 1.092, 1.085, 1.088 and 1.090 respectively for 1995 and 1.085, 1.079, 1.092 and 1.094 respectively for 1996. In 1995 and 1996 the specific gravity's from farms 1 and 2 were significantly different from one another and they were also significantly different from farms 3 and 4. The specific gravity's for each harvest were not found to be significantly different for sample date for either year, but the specific gravity was significantly different for the two years.

### Effect Of Farm And Sample Date

All tests were started within two to three days of the sample date for each harvest, except for sample date 2 in 1995 which was started 10 days after sample date.

### Statistical Thresholding

Sampling date significantly affected bruise volume (Figure 4) but not the percent of tubers bruised (Figure 3). Both varied significantly from one farm to the next (Figures 3&4).

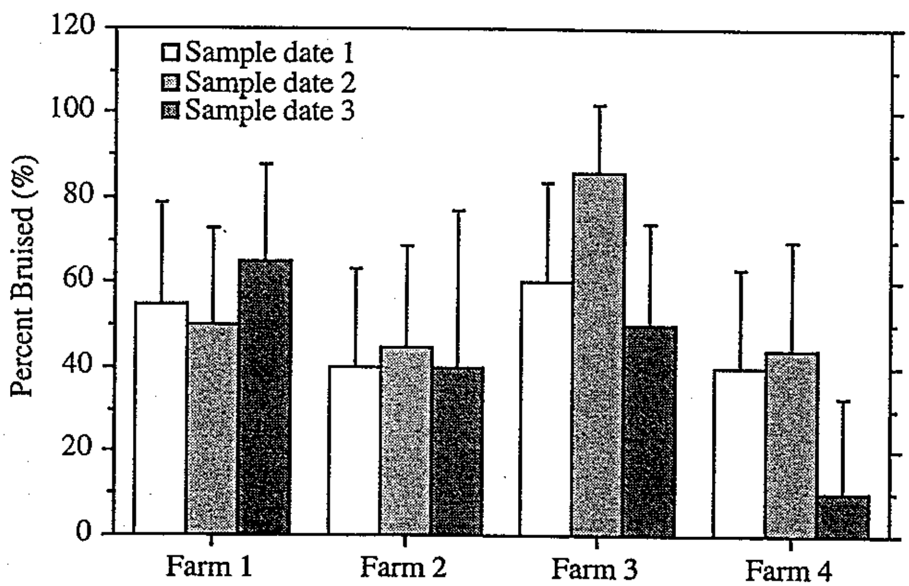


Figure 3. Percentage of tubers bruised versus farm by harvest date at 100mm (≈4 in) drop height at a temperature of 8°C (≈46°F) for both years (95% confidence intervals).

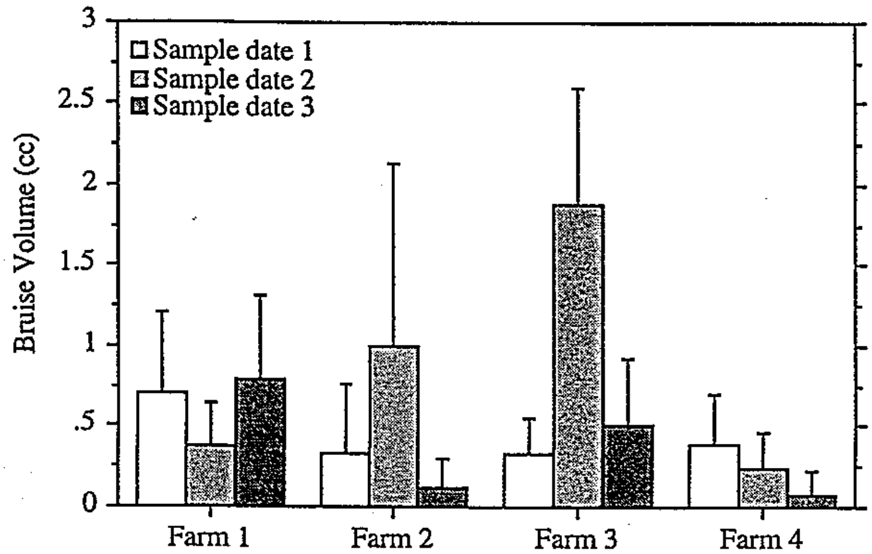


Figure 4. Bruise volume versus farm by harvest date at 100mm (≈4 in) drop height at a temperature of 8°C (≈46°F) for both years (95% confidence intervals).

## CHMI

Bruise resistance was not significantly affected by either sample date or farm. An interesting problem occurred at sample date 2 for Farm 3 (Figure 5). It had a much lower bruise resistance than the other farms, This trend can also be seen in the large bruise volume for Farm 3 from the statistical thresholding (Figure 4). However, bruise resistance and bruise volume for Farm 3 greatly improved in going from sample date 2 to sample date 3, and the growers harvested the field at about 90% bruise-free. The reason for the improvement may be that the field dried out significantly between samples dates 2 and 3, the tubers became slightly less turgid, and bruised less easily. Bruise chemistry improved as well over the same period.

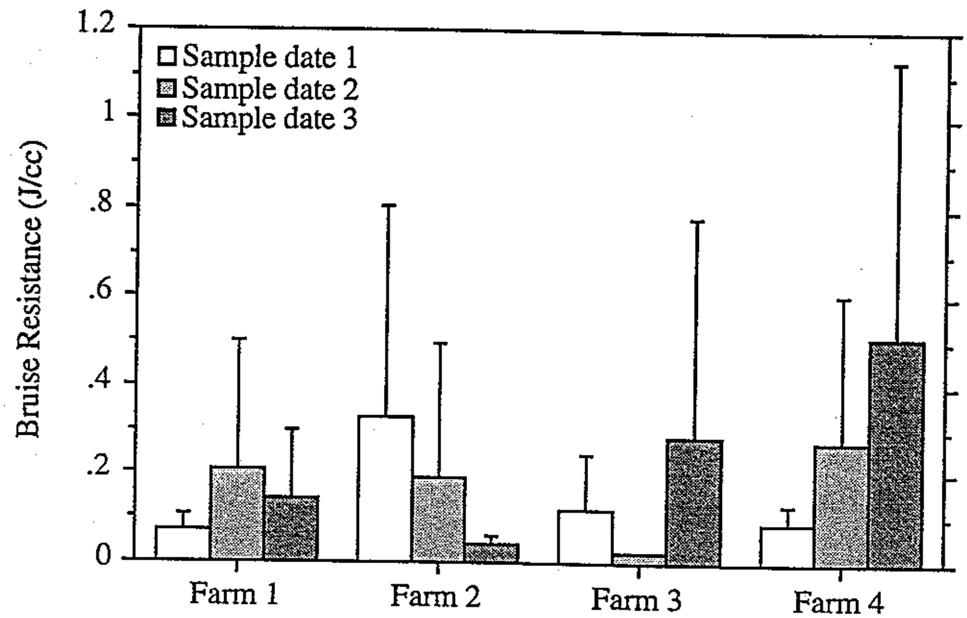


Figure 5. Bruise resistance versus growing location by harvest date pooled over temperature for both years (95% confidence intervals).

## Dynamic Axial Compression

Both failure stress and failure strain (Figure 6) increased with the later sample dates for both years for all four farms, and these increases were significant (P=0.0001 for both failure stress and failure strain). This corresponds with the trend seen in Figure 7, which shows an increase in tissue toughness for all farms at the later sample dates. Differences in the shock wave speed were significant for farms 2-4 with a trend towards increasing with time. This translates into an increase in tuber hydration or crispness over time (Bajema et al. 1997b).

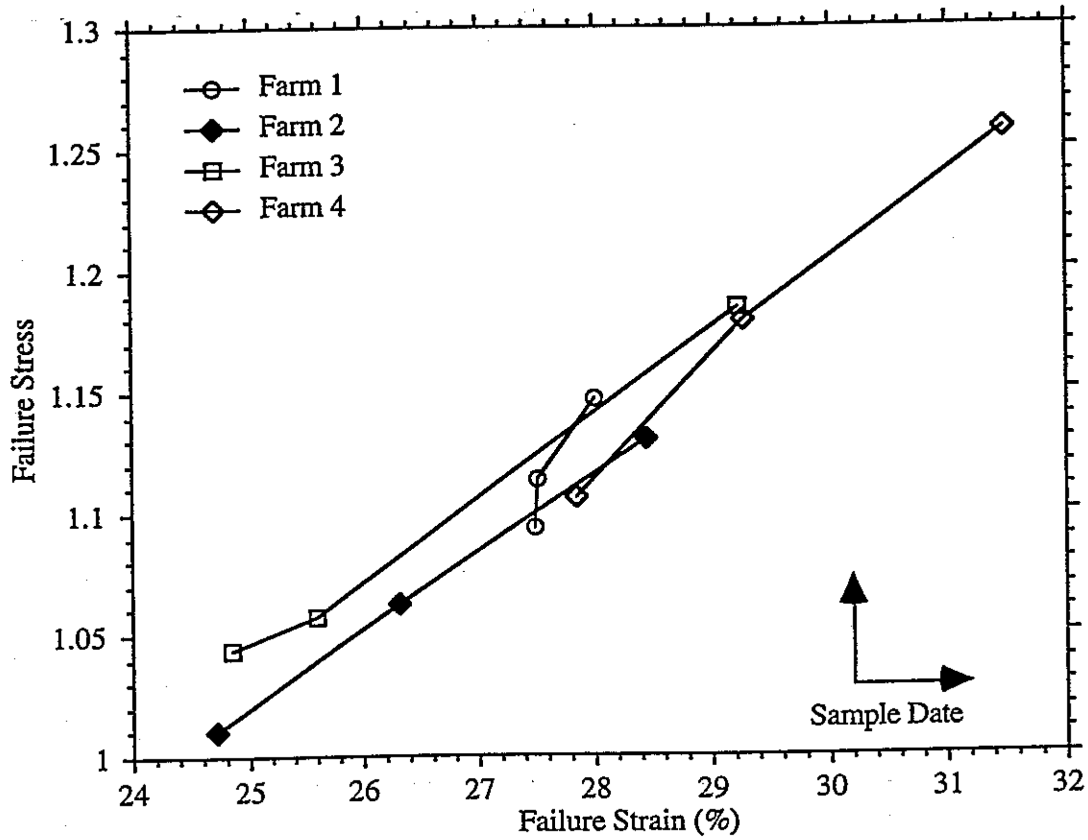


Figure 6. Failure stress versus failure strain split by farm for the three sample dates for both temperatures and years (95% confidence intervals).

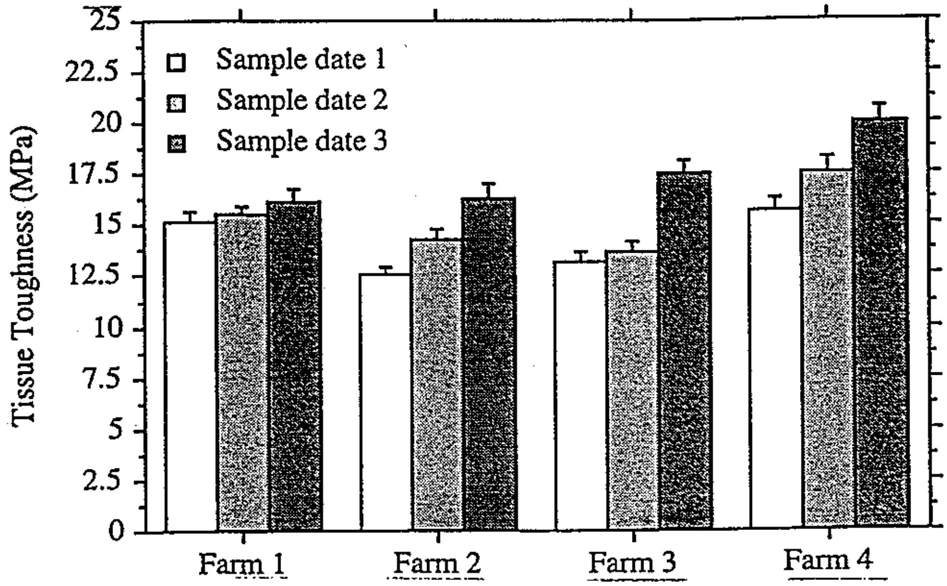


Figure 7. Tissue toughness versus growing location by sample date for both temperatures and years (95% confidence intervals).

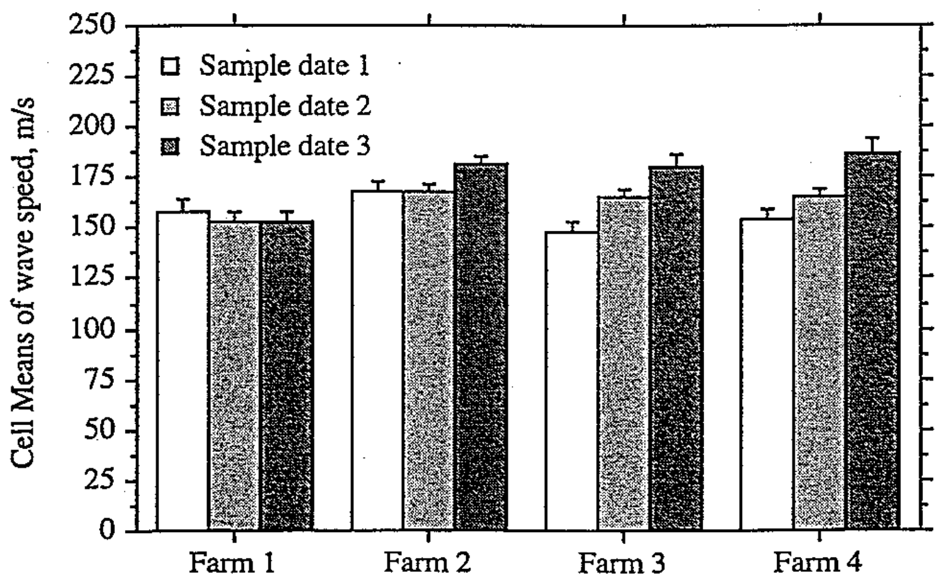


Figure 8. Shock wave speed versus growing location by sample date for both temperatures and years (95% confidence intervals).

## Effect Of Farm And Year

### Statistical Thresholding

For all of the growing operations the resulting bruise volume (Figure 10) was significantly smaller in 1996 than in 1995. However the percent of tubers bruised (Figure 9) was not significantly affected. In 1996 It can be seen that Farm 3 had a higher percent of tubers bruised (Figure 11) at the 100 mm drop height than the other farms. Also it can be seen that in 1995 Farm 1 and in 1996 Farm 3 had larger bruise volumes (Figure 12) for this drop height

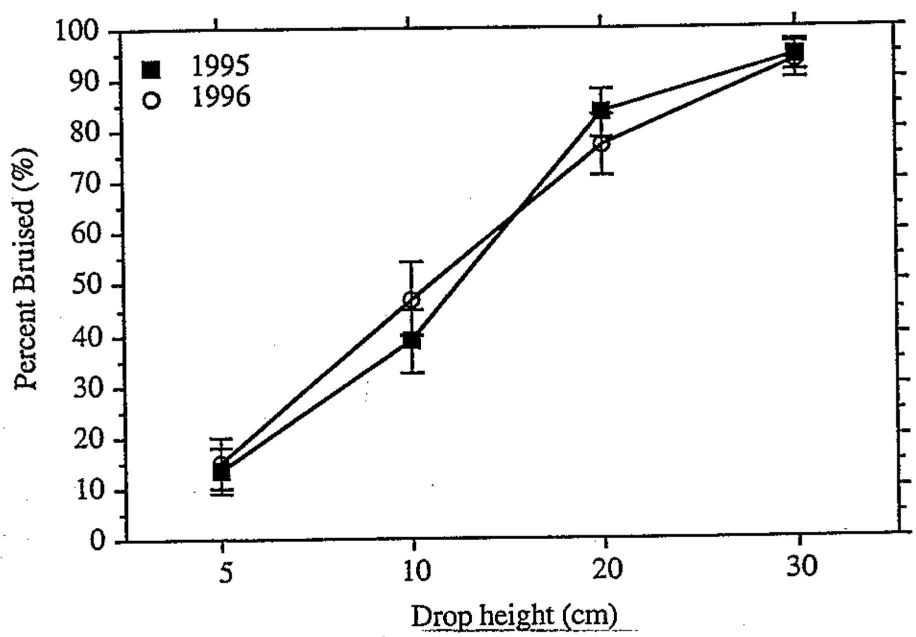


Figure 9. Percentage of tubers bruised versus drop height by year for all farms, sample dates and temperatures (95% confidence intervals).

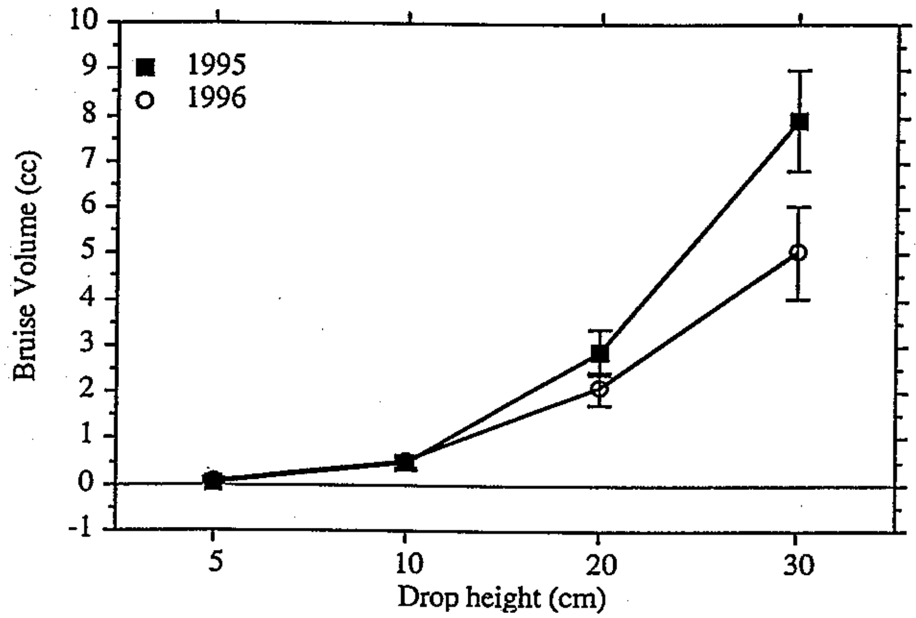


Figure 10. Bruise volume versus drop height by year for all farms, sample dates and temperatures (95% confidence intervals).

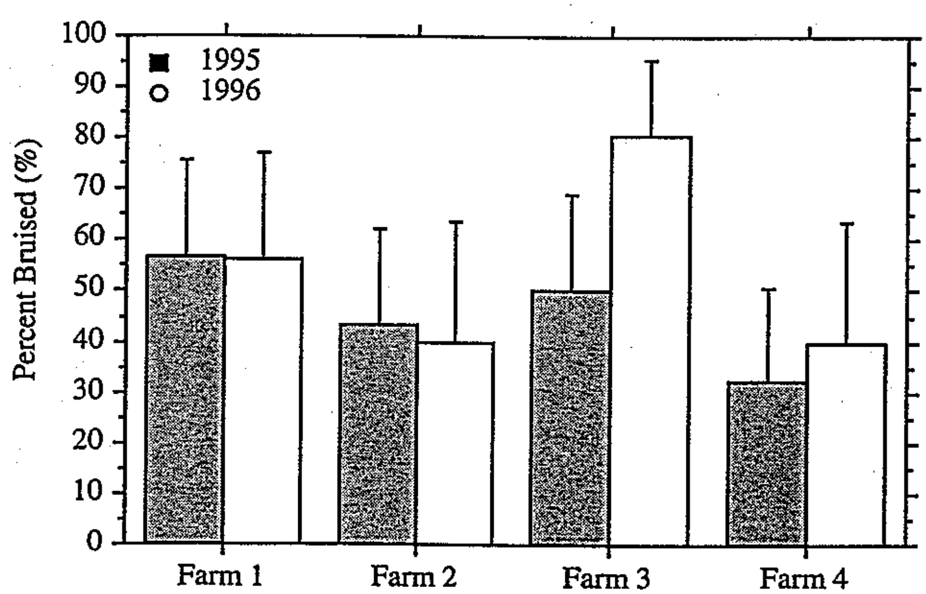


Figure 11. Precentage of tubers bruised versus farm by year at 100mm (≈4 in) drop height at a temperature of 8°C (≈46 °F) for all sample dates (95% confidence intervals).

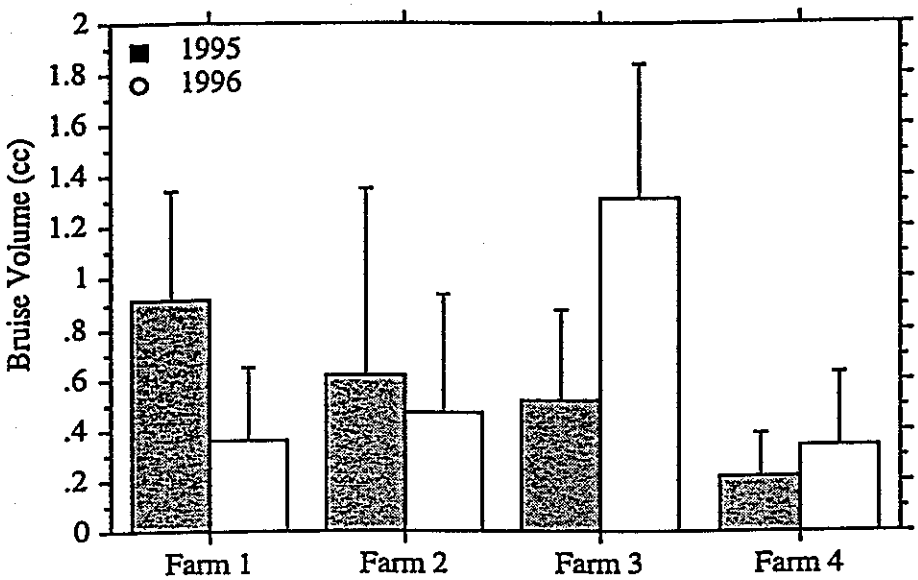


Figure 12. Percentage of tubers bruised versus farm by year at 100mm (≈4 in) drop height at a temperature of 8°C (≈46°F) for all sample dates (95% confidence intervals).

## CHMI

Bruise resistance (Figure 13) was not significantly affected by year, but it is interesting to note that in 1995 Farm 1 and in 1996 Farm 3 had a low bruise resistance. This trend correlates with the information shown in Figure 12.

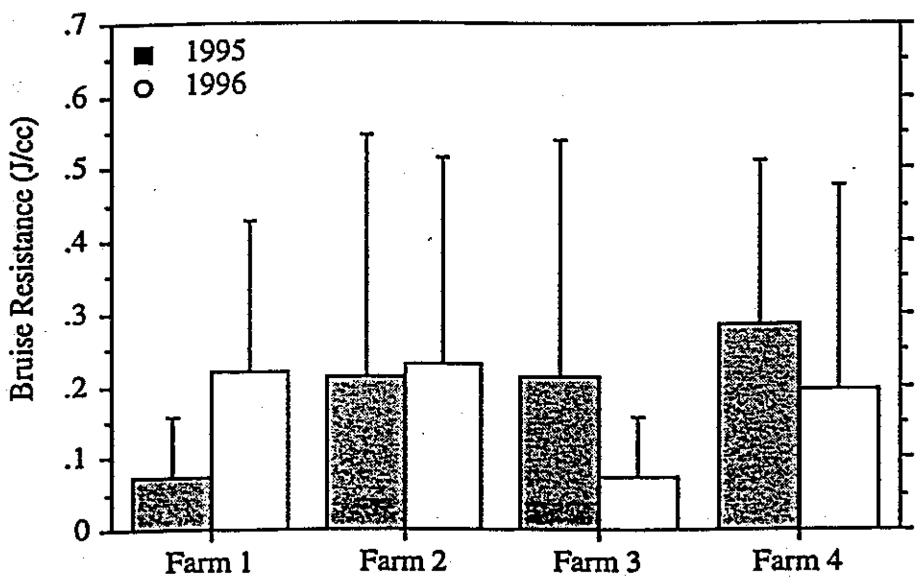


Figure 13. Bruise Resistance versus farm by year for all drop heights, both temperatures and all sample dates (95% confidence intervals).

## Dynamic Axial Compression

Significant differences were found among farms for tissue toughness (Figure 14). There were no significant differences between the two years within farm. Fingure 14 shows an interesting trend with the different farms; the tissue toughness is very similar even though the actual growing locations were different between the years, the cultural practices employed by the Farms show year to year similarities. Figure 15 shows the differences in the shock wave spped for the different farms by year. From this data it can be concluded that the tubers were not as hydrated in 1996 as they were in 1995. This trend was prevalent in Figure 10, agreeing well with Thornton et al. (1974) in that the more hydrated tubers tend to have more shatter bruise, and at the sever drop heights of Figure 10, shatter burises were large.

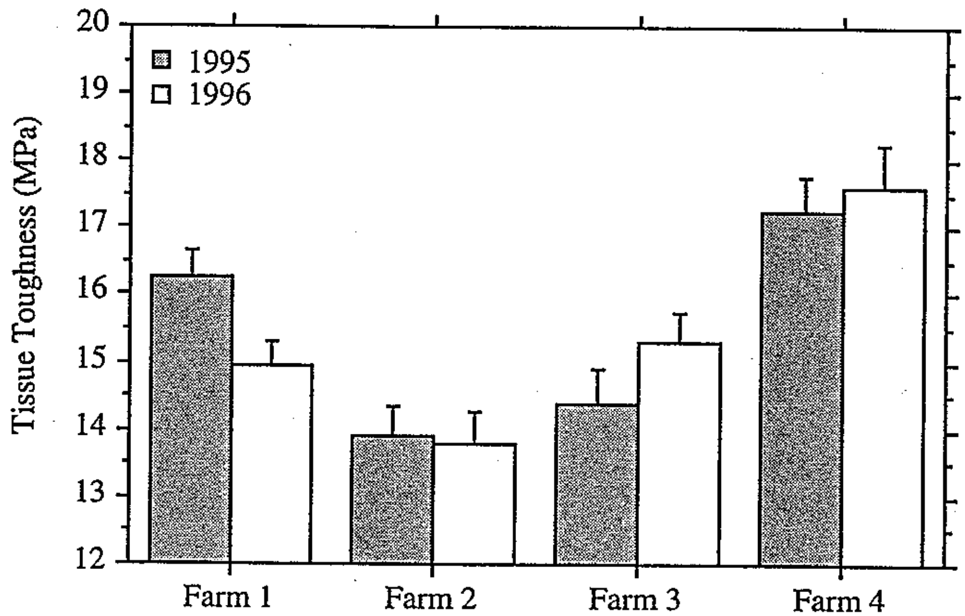


Figure 14. Tissue toughness versus growing location by year for both temperatures and all sample dates (95% confidence intervals).

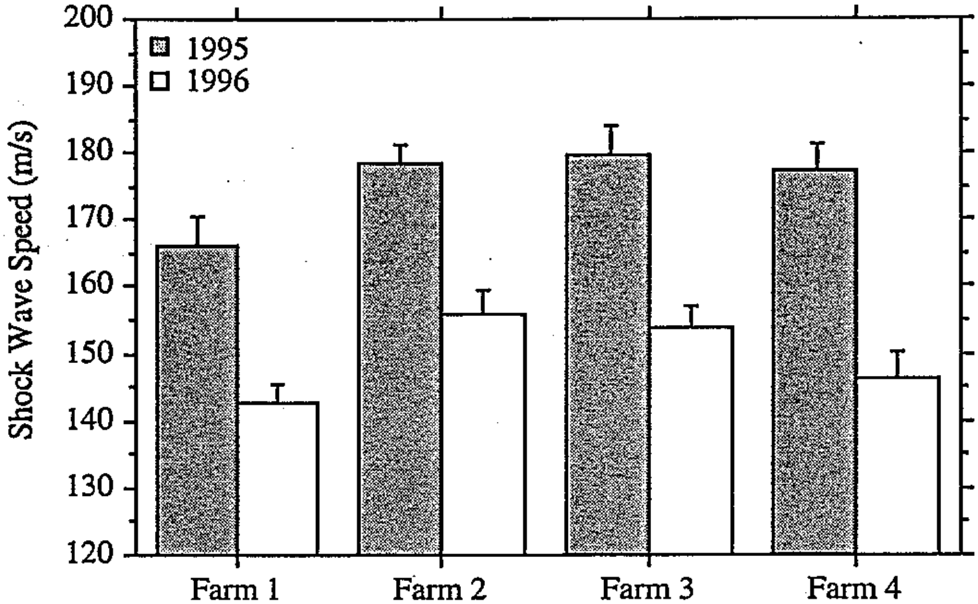


Figure 15. Shock wave speed versus growing location by year for both temperatures and all sample dates (95% confidence intervals).

## Conclusions

Bruising research is often conflicting. These results show that there are variations from year to year, which agrees well with literature. One possible reason for this are differences in tuber hydration level at the time of sampling. Other results show that the sample date can and does make a difference in the impact sensitivity of Russet Burbank potato tubers, and that cultural practices do affect the impact sensitivity of Russet Burbank potato tubers.


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