

## FINAL PROGRESS REPORT

**PROJECT NO.:** WSU - 9753

**TITLE:** Fruit Maturity Assessment of Various Fuji Apple Strains

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**REPORTING PERIOD:** 1990-1996

### ACCOMPLISHMENTS:

1. Determined background color, starch and watercore to be useful indicators of physiological development at harvest. Soluble solids content, titratable acidity and firmness were also found to be useful as indicators of fruit quality at harvest and for estimation of storage potential.
2. Determined 'Fuji' produced in Washington is susceptible to CO<sub>2</sub> injury and found injury potential to be related to maturity at harvest, CO<sub>2</sub> concentration in storage, storage duration and storage temperature.
3. Determined 'Fuji' harvested at proper maturity can be successfully stored for 9 months in low oxygen CA storage.

### RESULTS

The maturation and ripening process of 'Fuji' is similar to other apples in that fruit picked pre-climacteric (prior to the onset of ethylene production) usually stores well in long-term CA. Several unique properties of 'Fuji' apples also exist that complicate the picture. 'Fuji' softens at a slow rate even when picked at a late stage of development. This means firmness is not the primary concern at harvest as it often is for other varieties. 'Fuji' is a bi-colored variety, therefore harvest can occur according to a change in background color from green to greenish-yellow. This change has consistently been a useful index for initiating harvest. As the season progresses, background color becomes less indicative of fruit maturity, fruit inside the canopy are the last (if ever) to undergo this color change. By the time the color change occurs, other indicators, particularly starch and watercore, are past the limit for CA storage because these apples are now post-climacteric. To date we have found no effective postharvest treatments to hasten ripening of these

late "green" apples on a practical scale. The ideal situation appears to be getting the ground color break relatively early in the maturation process. This allows fruit to be harvested with starch present and watercore at the initial stage or absent. Apples of this type likely are pre-climacteric meaning the rapid phase of ripening is yet to begin. Fruit picked at this stage presents the most options for storage and handling, it will fare well in CA and RA. Background color is important because 'Fuji' apples picked green do not undergo a rapid change in ground color in RA or CA storage. The loss of green color can take 5 months in RA storage, and CA is even slower. Another characteristic that accompanies the green appearance is poor development of flavor and aroma. Apples harvested green don't produce the ripe flavor volatiles associated with fruit picked with a color break even after de-greening occurs in storage. Although 'Fuji' does not appear to be an extremely scald sensitive variety when produced in the Pacific Northwest, the risk is increased by harvest at the green background color stage of development.

'Fuji's can be picked with comparatively little starch remaining and still have excellent quality after storage. This is due to the late onset of ethylene production by 'Fuji' compared to the early onset relative to starch conversion in 'Delicious'. The range of acceptable starch scores for CA storage of 'Fuji' is also wider compared to 'Delicious'. In years where watercore comes on slowly, 'Fuji' harvest can occur for long term storage with starch values ranging from 3 to nearly 5. That was the exception during the period of these studies, usually watercore is apparent soon after starch values reach 3-3.5 in many orchards. As harvest is delayed, firmness usually decreases slowly, however other ripening related processes progress faster resulting in reduced decay resistance and titratable acid loss. 'Fuji' apples have proven to be quite tolerant of freezing on the tree, however it should not be assumed these apples are still optimal for CA storage because ripening is accelerated after a sublethal freeze.

During the 6 years we have followed the progression of 'Fuji' maturation, the optimum condition at harvest for long-term CA storage has been a change in background color from green to greenish-yellow, no to slight watercore, starch 3-4.5 on a 1-6 scale (1 full, 6 none), 16 lbs firmness, 13% soluble solids content, 0.400% acid. This combination of maturity values may be difficult to achieve in some orchards in some years and is presented as a target. The most critical index at harvest for long-term storage is the amount and intensity of watercore developed at harvest in relation to starch hydrolysis. Early watercore is not as dangerous as late watercore because apples are usually still pre-climacteric when early watercore occurs.

## Storage Conditions

Assuming proper maturity at harvest, 'Fuji' apples are very tolerant of low oxygen CA storage. Tolerance is dependent on maturity at harvest, specifically whether the fruit is pre- or post-climacteric, starch score, and the incidence and severity of watercore. As starch scores and watercore ratings increase, tolerance to low oxygen storage decreases.

'Fuji' is also sensitive to storage CO<sub>2</sub> concentrations. The likelihood of injury increases with advanced maturity (high starch, watercore ratings), increased storage CO<sub>2</sub> concentration and increased duration of storage. In some storage trials we have also seen more injury at lower storage temperatures (31-32°F) in combination with elevated CO<sub>2</sub>. Because 'Fuji' apples have a poorly developed cuticle, low temperatures necessitating frequent defrost should be avoided anyway to prevent excessive fruit moisture loss and shriveling.

Based on 6 years of storage experiments and assuming fruit maturity at harvest approximates the conditions listed previously, a CA environment of 1 to 1.5% O<sub>2</sub> with 1% CO<sub>2</sub> will effectively preserve fruit quality for 9 months. When starch scores and watercore incidence and severity are more advanced, O<sub>2</sub> concentrations should be increased to at least 2% and long term storage should not be planned. We have observed considerable injury at 5% O<sub>2</sub> when severely watercored fruit was placed into CA storage, therefore careful segregation at harvest is critical for this variety. Our experiences with delaying CA of watercored 'Fuji' have been mixed, however, because this variety ripens slowly, quality loss from delayed CA at the beginning of storage is not likely to be as much of a problem compared to other varieties such as 'Gala' and 'Delicious'.

## **PUBLICATIONS**

Fan, X., Mattheis, J.P., Fellman, J.K., and Patterson, M.E. 1994. Changes in amylose and starch content in 'Fuji' apples during maturation. HortScience 30: 104-105.

Plotto, A., Azarenko, A.N., Mattheis, J.P., McDaniel, M.R. 'Gala', 'Braeburn' and 'Fuji' apples: Maturity indices and quality after storage. Fruit Varieties Journal 49: 133-147. 1995.

Fan, X., Mattheis, J.P., Fellman, J.K., and Patterson, M.E. Variation in quality of 'Fuji' apples with different ground color at harvest and after storage. In preparation.

Fan, X., Mattheis, J.P., Fellman, J.K., and Patterson, M.E. Characteristics of fruit development and storage potential of 'Fuji' apples. In preparation.

Fan, X., Mattheis, J.P., Fellman, J.K., and Patterson, M.E. CO<sub>2</sub> Sensitivity of 'Fuji' apple fruit is related to fruit maturity, Storage conditions and storage duration. In preparation.

Mattheis, J.P., Buchanan, D.A., Fellman, J.K. Volatile production by 'Fuji' apples following controlled atmosphere storage. In preparation.

Mattheis, J.P., Buchanan, D.A., Fellman, J.K. Relationship between ethylene and ester production during maturation of 'Fuji' apples. In preparation.

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