PROJECT NO.: 10034 ARS

TITLE: Sweet Cherry Response to Controlled and Modified Atmospheres

YEAR INITIATED: 1994-1995 **CURRENT YEAR**: 1998-1999
TERMINATING YEAR: 1998-1999

PERSONNEL: James Mattheis, Plant Physiologist
USDA, ARS, Wenatchee, WA

JUSTIFICATION:

Modified atmosphere packaging is currently being used commercially to extend the postharvest life of sweet cherries. MAP has been used successfully, however, information regarding optimum atmosphere conditions during storage is lacking. This project was initiated to identify oxygen (O_2) /carbon dioxide (CO_2) combinations that effectively prolong sweet cherry storage life while avoiding anaerobic metabolism at commercial storage temperatures. Sweet cherry respiration parameters, O_2 uptake and CO_2 evolution, are determinants of fruit tolerance to packaging systems. Knowing (1) O_2/CO_2 combinations that slow quality loss under aerobic conditions, (2) rates of fruit O_2 uptake and CO_2 evolution as a function of storage O_2/CO_2 and temperature, and (3) package O_2/CO_2 permeability coefficients, packaging materials can be selected to achieve O_2/CO_2 concentrations that prolong postharvest life and provide a safety factor for high temperature exposure during shipping and handling.

Lot to lot variability is another potential factor determining sweet cherry response to storage conditions. Information regarding physiological/quality parameters useful for predicting storage potential of sweet cherries is currently unavailable. As the sweet cherry industry in the PNW expands, storage for short periods (2-6 weeks) may become an important means of dampening price fluctuations.

OBJECTIVES:

1. Determine sweet cherry O_2 consumption/ CO_2 evolution as a function of storage temperature, O_2/CO_2 concentrations and storage duration.

2. Determine O_2/CO_2 combinations that result in anaerobic metabolism and ethanol accumulation.

3. Identify physiological/quality parameters useful for predicting sweet cherry storability.

SUMMARY AND CONCLUSIONS, 1994-1998

1. Titratable acidity loss occurs faster compared to loss of soluble solids during ripening of 'Bing' sweet cherry fruit. The rate of acid loss can be slowed by CA or MA storage, particularly at O_2 concentrations below 5%. An additive effect of high CO_2 to slow acid loss only occurs at O_2 concentrations above 12%. Although titratable acidity loss was slowed by CA conditions compared to RA storage, considerable acid loss still occurred. This was evident even at the lowest O_2 and highest CO_2 combination (1% O_2, 10% CO_2) where no ethanol accumulation occurred. Acidity is a major factor determining sweet cherry flavor, therefore use of CA to slow acid loss to maintain flavor during extended storage (greater than 4 weeks) cannot be expected to be consistently successful.

2. High CO_2 promoted increased firmness retention during storage compared to fruit stored in air. The CO_2 response was dependent on O_2 concentration, particularly when O_2 was less than 10%. In that O_2 range, CO_2 up to 10% promoted firmness retention. Firmness loss appeared to be enhanced in that O_2 range when CO_2 was greater than 10%. This may be due to the onset of anaerobic conditions that developed over time in O_2/CO_2 combinations where O_2 was less than 10% and CO_2 was greater than 10%. At O_2 concentrations above 10%, CO_2 does not appear to induce softening at concentrations below 30%.

3. 'Bing' sweet cherries are very tolerant of low O_2 / high CO_2 conditions for short periods. No ethanol accumulation occurred when fruit were stored for 7 days at 33^o in 0.25% O_2 with up to 10% CO_2. As storage duration increased, ethanol accumulation was CO_2 dependent within a fixed O_2 concentration. In general, ethanol accumulation was avoided when the O_2/CO_2 concentrations were 10% or less. At higher O_2 concentrations (10-20%), CO_2 up to 30% did not result in ethanol accumulation. The high CO_2 in these conditions resulted in enhanced fruit softening as previously mentioned.

4. Stem browning increased with CO_2 concentration when O_2 was low (1-6 %). This result was most evident when CO_2 concentration was greater than 10%. This increase may be related to anaerobic conditions that developed over time in the same atmospheres, because low O_2 and high CO_2 combinations that avoided ethanol accumulation did not have an increase in stem browning.

5. Internal browning increased with CO_2 concentration and storage duration within all O_2 concentrations evaluated. This increase was most evident when ethanol accumulation was greatest, particularly when CO_2 was greater than 20%. Internal browning was also orchard specific as some lots were much more prone to development of internal browning than others when all fruit was stored under the same CA regime. No indication of internal browning susceptibility was evident in measures of fruit quality, appearance or respiration at harvest.

6. Fruit color changes are slowed by a wide range of CA conditions compared to fruit stored in air. This response to CA was the most consistent of all quality attributes that were measured in these studies. The reduction in darkening of red color was also evident in CA combinations where ambient O_2 was used with high CO_2 (up to 20%). It appears fruit color changes are effectively slowed by high CO_2 alone although low O_2 (3% or less) also was effective at lower CO_2 concentrations. The difference in fruit color between fruit stored in CA compared to air was evident in as little as 1 week, however, this result was orchard specific and dependent on color at harvest.

7. A residual suppression of fruit respiration was detectable after CA storage. This response was not detectable until 28 days in storage, indicating a possible relationship with the initial increased rate of acid loss after harvest. Reduced respiration was not evident even at 1% O_2 over short periods. The lack of a inhibitory effect of respiration at the beginning of CA (or MA) treatments contributes to the lack of an effect of these storage technologies on acid retention. One of the main effects of CA with climacteric fruit (such as apple and pear) is to reduce ethylene production and action. Both of these responses result in reduced respiration and increased acidity retention during storage. Because sweet cherries are a non-climacteric fruit, ethylene regulation is not an effective means of slowing fruit ripening.

8. Decay was also reduced by CA conditions. The most effective combinations of O_2 and CO_2 reduced decay during storage and also gave a residual suppression during return of fruit to air. The importance of CO_2 in suppressing decay was evident from these studies, with values as low as 5% slowing the progression of decay. The residual suppression after CA storage decreased as storage duration increased. This was most evident, however, after 8 weeks storage, a duration that is usually too long for maintenance of optimal fruit quality.

9. Development of fruit pitting was not significantly reduced by CA conditions except in one experiment where pitting was reduced by delaying CA for 24 hours after harvest. Injury leading to pitting appears to occur prior to storage,

and the CA conditions used in these studies were not effective for reducing the manifestation of this damage.

10. Onset of anaerobic metabolism as a function of storage temperature and atmosphere was examined by monitoring ethanol production by 'Bing' sweet cherries held in O_2/CO_2 combinations at various temperatures. Fruit were held in 1, 5, or 10% O_2 with 0.03, 5, 10 or 20% CO_2 at 32, 36, 39, 46, 54, or 61^o. Over a six hour period, ethanol production increased to concentrations that would be detectable by consumers for fruit held in 1% O_2 with 0.03, 5, 10 or 20% CO_2 at 39-46^o; in 5% O_2 with 5, 10 or 20% CO_2 at 46-54^o; and in 10%O_2 with 20% CO_2 at 46-54^o. For each O_2 concentration examined, initial detection of ethanol occurred most rapidly at higher CO_2 concentrations. No ethanol accumulation occurred at the other O_2/CO_2 combinations over the 6 hour period regardless of temperature. These results illustrate that the storage atmosphere developing in a MA package is critical in determining fruit response to temperature mishandling. Atmospheres that are best in promoting fruit quality retention are the most susceptible to anaerobic problems if temperature increases above a critical value.

11. Considerable lot to lot variability exists for 'Bing' sweet cherries grown in central Washington state. The variability is particularly evident for soluble solids, titratable acidity and fruit size at harvest. Results from two years study indicate using titratable acidity values at harvest may serve as a useful indicator of storability. Based on regression analysis over a two year period, soluble solids values at harvest can also be used but only when values are quite high (greater than 21%). This is because fruit with very high solids tends to have high acidity, and acidity is what determines flavor quality after storage. Fruit with high acid at harvest tend to have high acid after storage and this fruit usually has less deterioration in other quality and appearance characteristics during storage. Respiration rate at harvest was not a useful predictor of storage potential in these studies.

Storage life of 'Bing' sweet cherries can be extended using atmosphere control or modification. These technologies consistently reduced the rate of fruit color change over a wide range of O2 and CO2 concentrations. In CA storage, fruit appearance and quality was maintained over 6 weeks in an atmosphere of 1% O_2 with 10% CO_2. This combination avoided ethanol accumulation and excessive stem or internal browning. At temperatures approaching 40^o, this CA combination went anaerobic in less than 6 hours, therefore it is not advisable for MA systems where temperature problems could arise. To balance the risks of ethanol accumulation and accompanying quality loss with quality retention, particularly appearance, CA or MA systems that have O_2 in the range 5-15% with 5-15% CO_2 appear to be acceptable. At higher O_2 concentrations, the atmosphere effects will be primarily on appearance characteristics rather than flavor retention because acid loss will not be slowed. For MA systems, the risk of temperature mishandling with the benefits of atmosphere storage should be considered when selecting a packaging system. Based on 5 years results, the most effective atmospheres for maintaining all aspects of fruit quality are the most at risk for developing temperature related problems. Increasing O_2 is the most effective way to reduce this risk, however, flavor management via acid retention will be reduced. The other benefits of atmospheres, particularly color, decay and firmness management, will still be present under these conditions.

TECHNOLOGY TRANSFER

1. Oral and poster presentations

    a. Cherry Commission reports, 1994-1998.
    b. Oral presentation at Oregon Horticulture Association meeting, Jan. 1994.
    c. Oral presentation at Wash. Tree Fruit Postharvest Conf., Mar. 1995.
    d. Poster presentation at ISHS Hort. Congress, Aug. 1998.

2. Publications

    a. Mattheis, J.P., and Reed, N. Response of 'Bing' Sweet cherries to modified atmosphere packaging. Proc. Oregon Hort. Soc. 85: 22-28. 1994.

    b. Mattheis, J.P., D.A. Buchanan, J.K. Fellman. Volatile constituents of 'Bing' sweet cherry fruit following controlled atmosphere storage. J. Agric. Food Chem. 45: 212-216. 1997.

BUDGET:

1. Amount allocated by the Commission in FY1998-1999: $8,500

2. Request for FY1999-2000: $-0-