The Washington State Apple Revolution:
Innovative Production, Storage, and Merchandizing
Techniques Extend the Marketing Season

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Few agricultural commodities have enjoyed the tremendous success achieved by the Washington State apple industry. The apple acreage in Washington has increased from about 80,000 to over 125,000 acres in recent years. The production reached 72 million boxes in 1981 and will increase to about 85 million by 1985. This expansion is directly related to the improved technology in the production, storage, and marketing of the fruit, which has provided a constant supply of quality fruit to consumers for 11 to 12 months of the year. Much of the success is credited to a strong research effort and the immediate application by the fruit industry of the new technology developed from research.

During the past 20 years we have witnessed a revolution in the apple industry of Washington State. Production of ‘Delicious’ apples has increased about 560,000 boxes/year and ‘Golden Delicious’ about 460,000 boxes/year since 1962 (Fig. 1, 2). Much of the increased production has been used to develop markets from May through August, well beyond previous limits for storage of these cultivars. The increased production has been closely paralleled by use of controlled-atmosphere (CA) storage which has increased at a rate of 760,000 boxes/year for ‘Delicious’ since 1962 and at a rate of 430,000 boxes/year for ‘Golden Delicious’ since 1970. Currently, over 50% of the ‘Delicious’ and 40% of the ‘Golden Delicious’ are stored in CA. The cumulative sales (Fig. 3, 4) illustrate a consistent marketing pattern based on confidence that a portion of the apples can be stored for 11 months. Washington-grown apples dominate the market throughout the United States during the months of May, June, and July and even constitute a barrier to importation of apples from the southern hemisphere.

What factors are responsible for such a strong marketing record? The answer to this question is perhaps more complicated than it appears on the surface. Much of the success is because of the keen observation and cooperation of growers, nurserymen, fieldmen, extension agents, research scientists, and apple sales promotion agents, along with strong support for research by the industry. The resultant improvement and adaptation of new production, storage, and marketing techniques have completely revolutionized the apple industry.

Production Technology

Three major developments have occurred in production. The first was the use of chemical thinning to provide annual crops of large-size quality fruit. Over 95% of the growers

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use aggressive chemical thinning programs to improve fruit quality and yield. Biennial bearing has nearly been eliminated in Washington State apple orchards (15).

The second major development was the discovery of the red and super-red sports of 'Delicious'. To date, over 60 of these natural mutations have been discovered. Essentially 100% of the 'Delicious' planted in the last 15 years are the super-red strains. The early formation of red color allows a more orderly harvest of the fruit for early, intermediate, and long-term storage. Highly colored, firmer fruit with optimum maturity became available for CA storage.

The third major contribution to improved production practices was the discovery of biochemical plant growth regulators for improving fruit quality and extending storage life. In 1964, Williams et al. (13) found that diminozide (butanedioic acid mono (2,2-dimethyl hydrazide)) controlled vegetative growth of apple trees, produced firmer, redder fruit, and delayed watercore development. Since then many fruit trials have confirmed these benefits, apples from trees sprayed 2 months before harvest are firmer at harvest and retain firmness and a crisp texture longer in storage. Thus, use of this chemical has contributed to the extended storage life of apples. Another chemical bio-regulant, ethephon [(2-chloroethyl) phosphonic acid], stimulates ethylene production in the fruit (4, 5) and is sprayed on the trees shortly before the desired harvest to increase the soluble solids content and lower the astringency in super-red strains of 'Delicious'. The result is improved dessert quality of early-harvested apples and an extension of the early marketing season by chemically advancing the time of harvest. These two bio-regulators have become very important for extending the storage and marketing periods. Research has shown that the best apples are grown on trees maintained in a moderate state of vigor. Moderate vigor is achieved by using intermediate levels of nitrogen fertilization, moderate pruning, and uniform cropping (10, 14). These practices may slightly limit production and not all growers are willing or able to sustain optimum conditions in the orchard. Excessively vigorous trees produce large crops of poor-quality apples that are low in sugar, astringent, sour, starchy at harvest, and tasteless after storage. If left on a vigorous tree long enough to reach acceptable quality, the fruit will break down more quickly in storage than fruit from a moderate- or low-vigor tree. Therefore, optimum fertilization contributes to optimum production of quality fruit. Detailed knowledge derived from both experience and research on tree response to fertilizer, irrigation, weather, and growth regulators is used to keep trees at the ideal vigor level to produce the maximum number of quality apples.

Depending on the growing and harvesting conditions, certain lots of fruit are suitable for either immediate sale, short-, intermediate-, or long-term storage. Therefore, it is important for the warehouses that store and market apples to carefully monitor and control the lots of apples delivered to the warehouse. Selection of fruit for these categories is not an exact science and periodic examination of the apples during storage is generally practiced. Without these improvements in production practices, little change would have occurred in the storage and marketing of Washington State apples.

Storage Technology

Major changes in the storage of apples have occurred in the last 20 years. Standard storage and refrigeration conditions have been supplemented or replaced by CA storage. Three important factors have accounted for the changes in storage technology. First, the advent of CA storage (12) meant apples could be stored longer. CA regulations required the apples to be firm ripe at the time of sale, and the industry learned to produce and harvest apples to meet this requirement.

The CA storage program in Washington became effective because of its inherent value and because of the law which established CA stored apples as a premium product. The law requires the fruit to be exposed to the required atmospheres for a minimum of 90 days and to meet U.S. Export Standards (1). Therefore, the apples must be at least firm ripe with less than 5% internal defects at the time of sale. Apples are generally bought and sold on the basis of grades which refer only to flesh firmness, color and external defects. The apples meeting export standards are generally those labeled "Washington CA."

![Fig. 1. Sales of Washington-grown 'Delicious' apples. Total sales, sales from controlled-atmosphere storage, and percent of sales from controlled-atmosphere storage. Data from Wenatchee Valley Traffic Association.](image1)

![Fig. 2. Sales of Washington-grown 'Golden Delicious' apples. Total sales, sales from controlled-atmosphere storage, and percent of sales from controlled-atmosphere storage. Data from Wenatchee Valley Traffic Association.](image2)
Apples for the extended CA storage requires a relatively early harvest, and considerable research effort was directed toward determining the optimum harvest time for apples intended for prolonged storage (6). A program developed by research, extension, fieldmen, and growers is presently used to assess optimum maturity of the fruit. Most of the apples sold after April are from CA storage, and the increased storage life is attributed to CA storage, which also provides optimum temperature and humidity. Cultivars, such as ‘McIntosh’, ‘Yellow Newtown’, and ‘Cox’s Orange Pippin’, which do not tolerate temperatures below about 4°C respond very well to atmospheres containing 2–3% O₂ and 3–5% CO₂. ‘Delicious’, ‘Golden Delicious’, and ‘Winesap’ cultivars can be stored at temperatures near −1 °C. Under the lower temperatures, atmospheres of 2–3% O₂ and 1–2% CO₂ are recommended (8) because the apples are increasingly sensitive to CO₂ injury as the temperature is reduced.

CA storage requires a room that is gas-tight. Many of the older storages were unsuitable for CA and were not designed for forklift trucks and pallets. The growth of CA has encouraged construction of new, well-designed storages which not only maintain CA conditions but also maintain uniform low temperature and high relative humidity. Industry experience has shown that the difference between CA and the regular storage fruit increases as the storage season is extended into July and August.

The second major factor contributing to success in storage is the treatments developed for the control of apple scald and decay. Scald occurs when the apples are harvested at optimum maturity for long-term storage. In 1957, Smock (11) found that ethoxyquin and diphenylamine provided adequate control of scald. Further tests (9) indicated good control of scald and the commercial development of the treatment permitted apples to be harvested earlier at the optimum time for long storage periods.

Apples are subject to various types of decay in storage. Historically the most damaging was blue mold incited by Penicillium expansum. Earlier harvest and good storage conditions reduced the inherent susceptibility of the apples to decay and the use of some recently developed fungicides, thiabendazole and benomyl, has reduced blue mold to negligible proportions. Other fungi which are resistant to these fungicides may be troublesome at times, thus good sanitation continues to be important.

Without the scald and decay control, apple production and marketing would still be in the "dark ages".

The third major contribution to the long-term storage of cultivars like ‘Golden Delicious’ is the recent innovations of CA storage (2, 3). Short-term treatment with high levels of CO₂ immediately after harvest has markedly prolonged the life of ‘Golden Delicious’. In 1975, Couey and Olsen (2, 3) found that the subsequent storage response of the fruit in CA was altered by exposing ‘Golden Delicious’ to 15–20% CO₂ for about 10 days immediately after harvest. Treated apples remained firm and crisp into June and July. The increased firmness helped the fruit withstand the rigors of packing until February or March. Although it is recommended that the apples be packed by the end of April at the latest, ‘CO₂-treated’ ‘Golden Delicious’ have been packed with success as late as July. The need for care in growing, harvesting, and storage is especially important for the ‘Golden Delicious’ cultivar. ‘Golden Delicious’ also differ from ‘Delicious’ in their response to low-temperature storage. They lose firmness, crispness, and the ability to withstand handling in the warehouse during the first few months in storage, and it is difficult to pack them later than December without serious bruise damage. With the increase in production it became increasingly difficult to pack all of the ‘Golden Delicious’ by December.

The most recent innovation in CA storage technology is referred to as “rapid CA” which involves the reduction of oxygen (O₂) levels in the CA room immediately after harvest (7). The O₂ is lowered to 1.0–1.5% as quickly as is practical, and the fruit are then held in low-oxygen CA storage. The key to success with this technique is adequate and constant monitoring of the storage atmospheres to prevent anaerobic conditions for any extended period which would damage the fruit. Tremendous success has been realized with this latter technique but care must be taken to not lower the oxygen or extend the storage to the point where fruit flavor and quality are reduced. These optimum O₂ and CO₂ levels with uniform temperatures and high relative humidity have greatly improved the storability of apples. This, along with the treatments for the control of scald and decay, has helped revolutionize the marketing of both ‘Delicious’ and ‘Golden Delicious’ apples, making it possible to maintain consistent retail sales on a year-round basis.

**Merchandizing techniques**

The continued expansion of markets for Washington State apples has required the ability to supply the markets with a constant supply of high-quality fruit over a long period.

Another major factor in the market expansion was the formation of the Washington State Apple Commission, which is financed by grower assessment. Sufficient funds are...
collected to provide support for several sales promotion representatives across the nation and in important foreign markets. Constant advertisement by radio and television has built the image of the Washington apple with the consumers. Contests are constantly being staged to encourage better and more attractive apple displays in supermarkets.

The ready availability of railroad, truck, and air transportation facilities, along with the improvements in packaging, have greatly contributed to the ability of the apple salesmen to consistently provide quality fruit to the consumers in all parts of the nation and the world. The expansion of foreign markets allowed the export of some 13 million boxes of apples from Washington State in the 1980–81 season. The total production for the 1980–81 season was 72 million boxes. Production of apples will increase sharply in the next 5 years as new plantings come into production in Washington State. When the production potential of 85 million boxes of apples is realized by 1985, other new and innovative storage and merchandizing techniques will be needed to maintain a profitable industry.

**Register of New Fruit and Nut Varieties List 32**

Reid M. Brooks and H. P. Olmo

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**ADDITIONS AND REVISIONS**

**APPLE**


**NECTARINE**

*Stark Sweet Melody.* *(Anderbrite. Bright).* — Originally introduced as 'Bright' in List 29. Plant pat. 3329; Aug. 1, 1978 reassigned to Stark Bro's Nurseries, Louisiana, Mo. and reintroduced by them in 1980 under new name.

**ALMOND**

*Bell.* — Orig. in Durham, California, by James C. Bell. Plant pat. 4,378; Feb. 13, 1979. Introd. in 1979. Whole tree mutation, disc. in 1960 in a row of Ne Plus Ultra. Nut: large. elongated; shell paper-thin, well-sealed; percentage of kernel to nut 68.6%. Tree: medium size, foliage dense; total absence of brown rot; good pollinizer, especially for Nonpareil; flowers pink, blooms early; more upright than Ne Plus Ultra making it easier to knock.

**COOPERATING HORTICULTURISTS**

**CANADA**

Anderson, E. T.: Ontario
Craig, D. L.: Nova Scotia
Daubeny, H. A.: British Columbia
Lane, D.: British Columbia
Layne, Richard E. C.: Ontario
Quamme, Harvey: British Columbia
Stushnoff, C.: Saskatchewan

**UNITED STATES**

Bailey, Catherine H.: New Jersey
Beutel, James A.: California
Boudreaux, James E.: Louisiana
Callan, Nancy W.: Montana
Cook, Jim: Wyoming
Dana, Malcolm N.: Wisconsin
Fogle, Harold W.: Maryland
Fry, B. O.: Georgia
Galletta, Gene: Maryland (USDA)
Hagerstrom. Introd. in 1977 by Herschel L. Boll, Champaign, 111. Jersey
Hill, Robert G.: California
Hinrichs, Herman A.: Oklahoma
Holland, Neal S.: North Dakota
Janick, Jules.: Indiana
Jaynes, Richard A.: Connecticut
Kamas, James S.: Texas
Meader, E. M.: New Hampshire
Mickey, Warren C.: California
Moore, James N.: Arkansas
Okie, W. R.: Georgia (USDA)
Ramming, Dave.: California (USDA)
Rutledge, Alvin D.: Tennessee
Sanford, John C.: New York
Scott, D. H.: Maryland (USDA)
Sherman, W. B.: Florida
Soost, R. K.: California
Swasey, James E.: Maine
Walker, David R.: Utah
Way, Roger D.: New York

**LITERATURE CITED**


**APPLE**

August Delicious. — Orig. in Monticello, Minnesota, by Marion Hagerstrom. Introd. in 1977 by Herschel L. Boll, Champaign, Ill. Jersey Sweet x Sweet Delicious. Cross made about 1943. Fruit: resembles Delicious, but slightly larger, ripens late Aug. in Minn. Tree: highly productive, vigorous, hardy.

Hazen. — Orig. at Mandan, North Dakota, by Neal S. Holland, Dept. of Hort., N. Dak. State Univ., Fargo, and USDA. Introd. in 1980. Named to commemorate the town Hazen and the late Dean Arlon G. Hazen, Dean of College of Agr., and Director of N. Dak. Expst. Sta. while cultivar was under his name.

Stark Puregold. *(Goldenshoots #2).* — Orig. in Louisiana, Missouri, by Paul Stark Jr. Plant pat. 4,731; June 2, 1981; assigned to Stark Bro's Nurseries, Louisiana, Mo. Introd. in 1980. Bud mutation of Goldenshoots (Belgolds). Fruit: resembles Goldenshoots and similar to Golden Delicious, but skin smooth; skin resistant to russet. Tree: identical to Belgolden except that it is a standard size tree; Belgolden is a spur-type.