Effects of Subatmospheric Pressure Storage on Ripening and Associated Chemical Changes of Certain Deciduous Fruits[1]

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Abstract. Subatmospheric pressure (hypobaric) treatments increased the storage life of apricots by 15 to 37 days, peaches by 7 to 27 days, sweet cherries by 16 to 33 days, pears by 1.5 to 4.5 months, and apples by 2.5 to 3.5 months. In general, chlorophyll and starch degradation, losses of sugars and titratable acidity, and formation of carotenoids were delayed by the subatmospheric pressure treatments.

The effects of low O_2 and high CO_2 levels on storage life and chemical changes in fruits[2] have been well documented (1, 3, 4, 9, 10, 11, 13, 14, 16, 17, 18, 19, 22, 24). The storage life of several fruits has been increased from 20 to 92% with refrigeration plus subatmospheric pressure (hypobaric) of 658 to 709 mm Hg (12). Subatmospheric pressure storage, a form of controlled atmosphere with reduced atmospheric pressure, has been developed in recent years. The storage life of tomato, avocado, mango, sweet cherry, lime, and guava was extended when stored at subatmospheric pressure (7, 23, 25).

We determined the effects of various levels of subatmospheric pressures on ripening behavior and associated chemical changes of apricots, peaches, sweet cherries, pears, and apples.

Materials and Methods

We used fruits of apricot cv. Large Early Montgament; peach cv. Gleason Early Elberta; sweet cherry cv. Bing; pear cv. Bartlett; and apple cv. Red King and Golden Delicious obtained from the University orchard, Pleasant View, Utah. Apricots were harvested July 20, 1971; peaches, September 5; sweet cherries, July 6; pears, September 18; and apples, October 1. Firmness was determined by a Magness-Taylor pressure tester with a 5/16-inch plunger. The following fruits with indicated firmness measured in lb. pressure per 0.0797 in^2 (or Kg/0.5142 cm^2) were selected for use: apricots, 12.8 lb. (5.8 Kg); peaches, 19.2 lb. (8.7 Kg); pears, 23.0 lb. (10.4 Kg); and apples, 'Red King', 20.0 lb. (9.1 Kg) and 'Golden Delicious', 21.0 lb. (9.5 Kg). For sweet cherries, only red-ripe (firm) fruits without injuries and with the green pedicels intact were used. Three subatmospheric pressure treatments (471 mm Hg, 278 mm Hg, and 102 mm Hg) and 1 control (646 mm Hg--the atmospheric pressure at Logan, Utah) were used on apricots, peaches, sweet cherries, and pears. For both cultivars of apples, we used only 278 mm Hg and 646 mm Hg. In all cases, treatments were replicated 3 times.

Each replication [100 apricots, 80 peaches, 50 pears, 50 apples (each cultivar), and 2 Kg sweet cherries] were stored in 19-liter steel drums that were maintained at $0^{\circ} \pm 1^{\circ}C$ and continuously evacuated by means of a vented-exhaust oil-sealed pump. Constant ventilation was achieved by admitting air to each chamber through a vacuum regulator (Matheson Model 49) that maintained the selected vacuum (none in the controls) by bleeding air into the system at the proper rate. Incoming air was saturated with moisture by passage through a humidifier. Air flow through the apparatus was regulated at the rate of 30 ml/min. Relative humidity was maintained at 90 to 95% and measured periodically with an Abbeon relative humidity and temp indicator (Model No. M2A4, Abbeon Incorporated).

Fruits were sampled periodically for firmness and chemical composition. Partial vacuum was interrupted when fruits were removed. Carotenoids and anthocyanins were determined colorimetrically using procedures outlined by McCollum (15) and Sondheimer et al. (20), respectively. Chlorophyll was analyzed according to the method of AOAC (2). Total sugars were extracted with ethanol and measured by the method of Somogyi-Shaffer in AOAC (2). Total titratable acidity was determined by homogenizing 50 g of fruits with 200 ml of distilled water and then titrating to pH 8.1 with 0.1 N NaOH.

The data were tested for analysis of variance and the means were compared according to Tukey's ω-procedure (21).

Results and Discussion

Apricots. Subatmospheric pressure storage significantly (at 1% level) delayed softening and extended the storage life of apricots (Fig. 1A). The apricots were harvested at hard mature stage, therefore they could be stored longer than those harvested at soft mature stage as in commercial practice. Storage life of control apricots was 53 days while that of apricots stored at 102 mm Hg was 90 days. They were marketable after 90 days of storage. Subatmospheric pressure delayed formation of carotenoids beyond initial values (Fig. 1B). Formation of carotenoids was delayed for 60 days when apricots were stored at 102 mm Hg. There was no significant difference (at 5% level) in the total carotenoid content between treated and control apricots at the end of the storage. Subatmospheric pressure slowed down the losses of sugars and acid; the lower the pressure, the slower were these losses (Fig. 1C and 1D). The sugars and acidity of the treated apricots were almost the same as those of the control fruits at the end of storage.

Peaches. The softening of firm mature peaches was significantly (at 1% level) delayed by subatmospheric storage (Fig. 2A). The firm mature peaches were stored much longer than soft mature or ripened peaches as those in commercial practice. The storage life at 102 mm Hg was 93 days whereas that of control peaches was 66 days. The 102 mm Hg peaches were marketable at the end of the storage. In the control peaches, total carotenoids increased steadily during ripening. Subatmospheric pressure delayed the formation of carotenoids (Fig. 2B). At 102 mm Hg, carotenoid formation was completely inhibited for 45 days. At the end of the storage, control and treated fruits contained equal amounts of carotenoid. During ripening of the control peaches, the sugar content increased somewhat, then decreased. The rate of these changes was significantly affected by the subatmospheric pressure storage (Fig. 2C). But at the end of the storage, there was no significant difference (at 5% level) in the sugar contents of treated and control peaches. Titratable acidity of the peaches decreased during storage and these decreases were delayed by

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[2]Li, P. H. 1963. Metabolism of pears in modified atmospheres. Ph.D. Dissertation, Oregon State University, Corvallis.

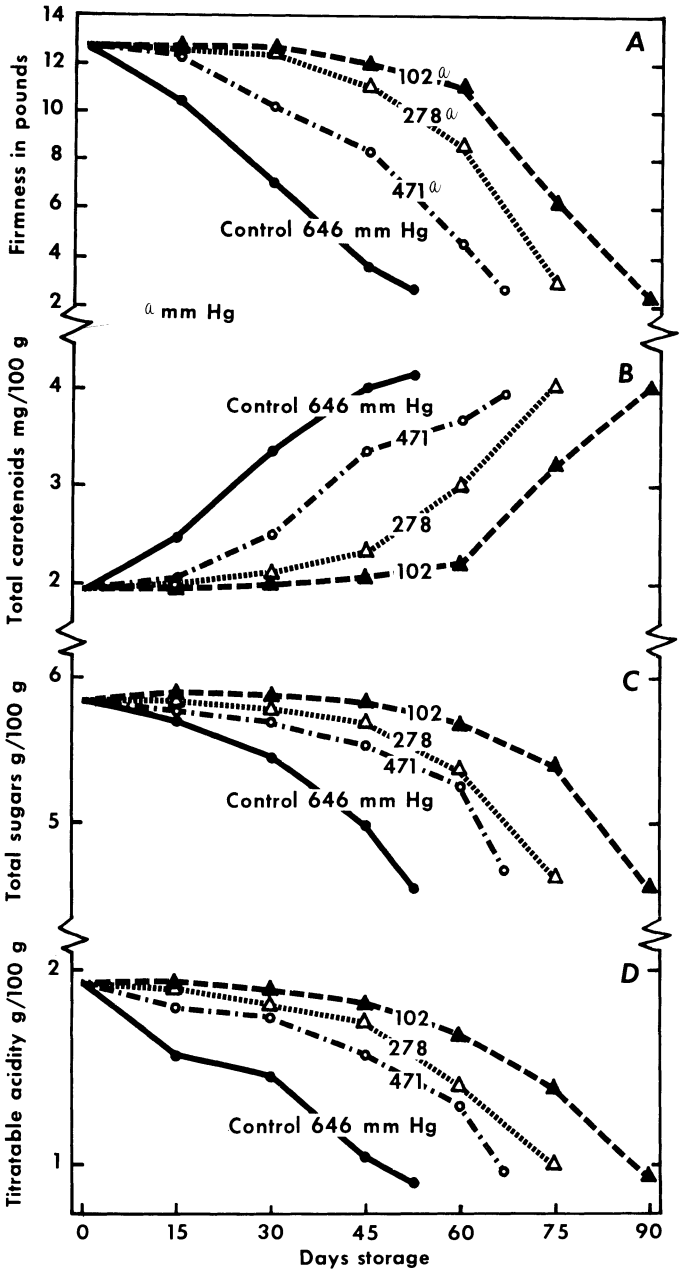

Fig. 1. Effects of subatmospheric pressure storage on (A) firmness, (B) total carotenoids, (C) total sugars, and (D) titratable acidity of apricots.

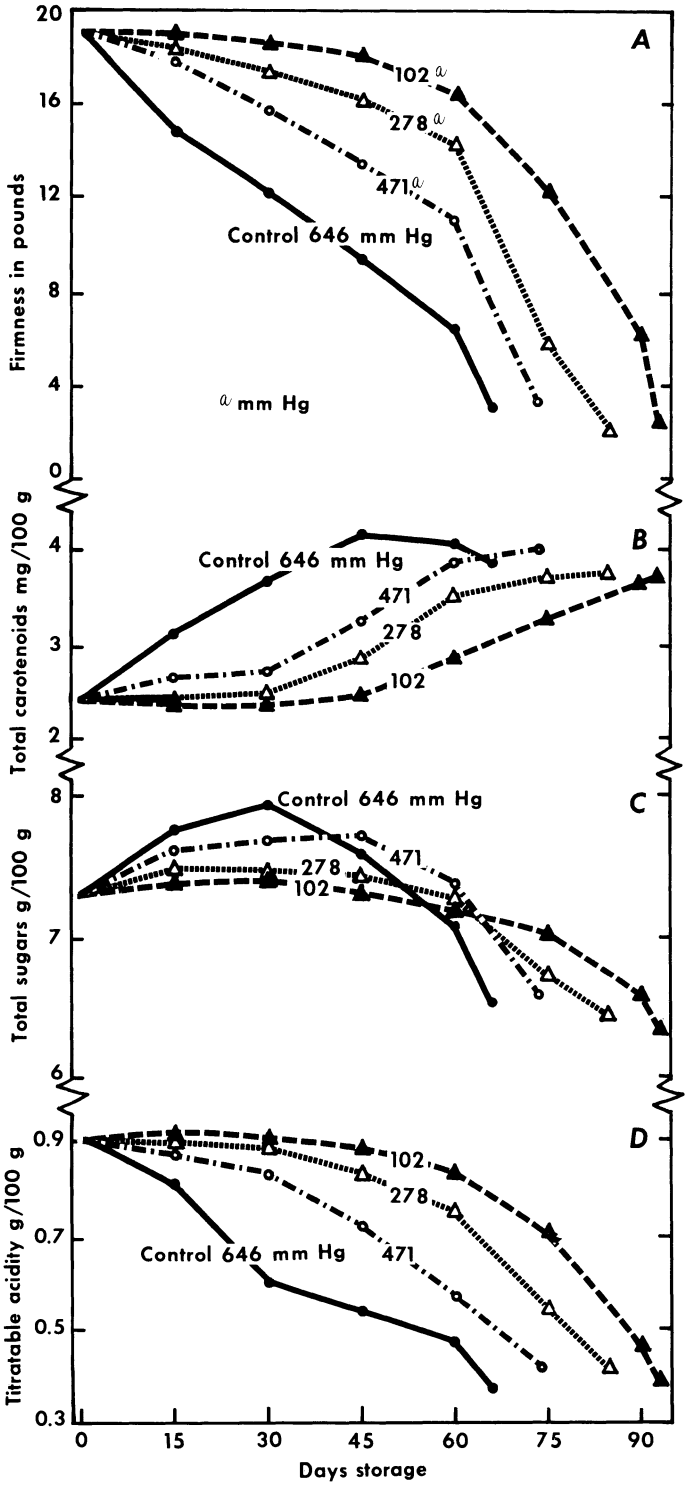

Fig. 2. Effects of subatmospheric pressure storage on (A) firmness, (B) total carotenoids, (C) total sugars, and (D) titratable acidity of peaches.

subatmospheric pressure (Fig. 2D). However, there was no significant difference (at 5% level) in final titratable acidity between treated and control peaches.

Sweet cherries. Storage life of the control firm sweet cherries was 60 days whereas that of 102 mm Hg treated cherries was 93 days. The treated cherries were still marketable at the end of storage. The pedicels of the treated fruits were green after 60 days of storage whereas those of the control fruits were brown and moldy. Anthocyanins did not change even in conventional or subatmospheric pressure storage. As with apricots and peaches, subatmospheric pressure delayed sugar loss in sweet cherries (Fig. 3B).

Pears. Subatmospheric pressures significantly (at 1% level) softened and extended the storage life of pears. Pears were stored for 3.5 months under normal refrigeration. At 471 mm Hg, they were stored up to 5 months; at 278 mm Hg, 7 months; and at 102 mm Hg, 8 months (Fig. 4A). The decrease of firmness was especially delayed at 102 mm Hg. The green color of the pears was retained fairly well up to 5 months at 102 mm Hg. Degradation of chlorophyll was delayed by subatmospheric pressure (Fig. 4B). The lower the pressure, the longer the chlorophyll was retained. Subatmospheric pressure delayed the loss of sugar of pears (Fig. 4C). At the end of the storage, the sugar contents of pears from subatmospheric pressure were significantly (at 1% level) less than that of control fruits, however, the treated pears were still marketable at that time.

Apples. Subatmospheric pressures significantly (at 1% level) extended the storage life of both apple cultivars (Fig. 5A). The

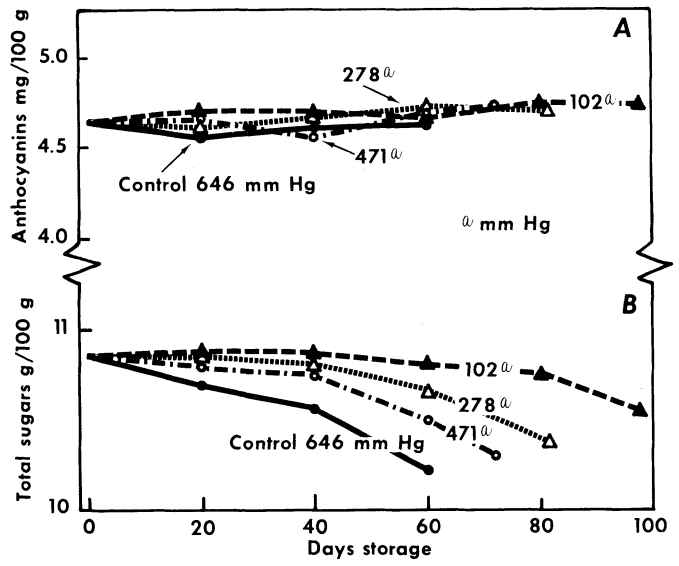

Fig. 3. Effects of subatmospheric pressure storage on (A) anthocyanins and (B) total sugars of sweet cherries.

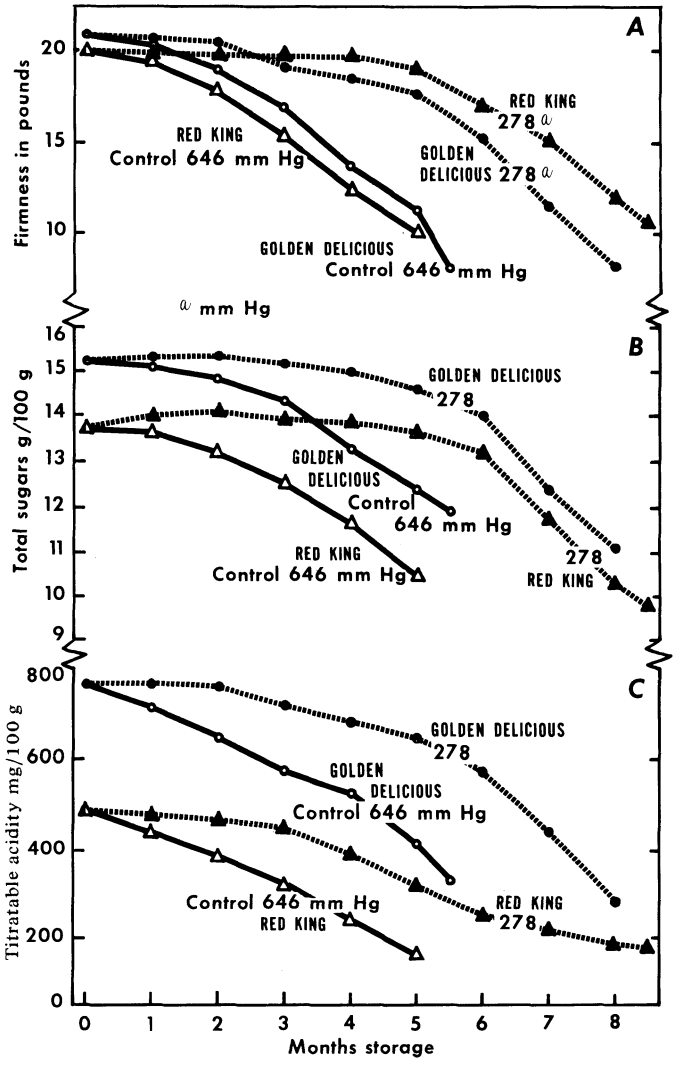

Fig. 5. Effects of subatmospheric pressure storage on (A) firmness, (B) total sugars, and (C) titratable acidity of apples.

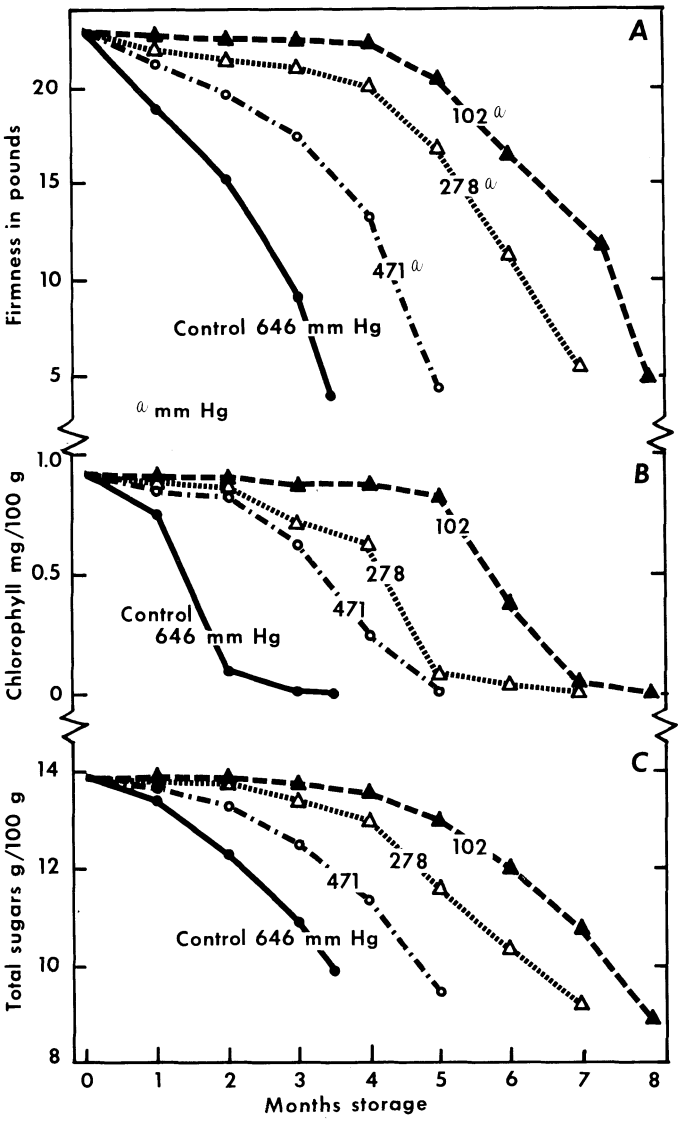

Fig. 4. Effects of subatmospheric pressure storage on (A) firmness, (B) chlorophyll, and (C) total sugars of pears.

278 mm Hg treatment extended the storage life of 'Red King' for 3.5 months over that of the controls. With 'Golden Delicious', it extended the storage life for 2.5 months. There were no visual changes in apples during storage, but the subatmospheric pressure storage delayed losses of sugars in both cultivars. After storage, however, treated apples contained significantly (at 1% level) less sugars than did the control (Fig. 5B). Decreases in titratable acidity of apples were also delayed by subatmospheric pressure storage (Fig. 5C). Treated apples were marketable at the end of the storage.

Subatmospheric pressure storage delayed ripening, softening, and deterioration of fruits. Lowering the air pressure reduced the amount of O_2 available and subsequently delayed ripening of fruits (7). The same effect was produced when the O_2 content of air was reduced (26). However, Burg and Burg stated that something other than O_2 depletion causes fruit to be preserved in a partial vacuum. This may also be due to the removal of the fruit-ripening hormone, ethylene, since when the pressure is reduced, any gas synthesized within a fruit escapes more readily and its cellular concn declines (6). More ethylene is required to ripen fruits when the O_2 is lowered (7, 8). The reduction of O_2 and ethylene contents might be an explanation for increased storage life at subatmospheric air pressures.

For practical application, subatmospheric pressure provided a better way of storage than controlled atmosphere since control of air pressure is easier and simpler than that of O_2 and CO_2 concn.

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A Comparison of Three Nucellar Selections of Red Grapefruit with Old Budline Redblush[1]

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Abstract. Virus-free nucellar budlines of red grapefruit and an old budline selection carrying exocortis and xyloporosis were grafted on sour orange rootstocks and grown under commercial conditions in the orchard. No differences were found in fruit quality. The old line trees produced the greatest tonnage of fruit for the first 7 years. By the tenth year the old budline trees were only 55-62% as large as the nucellar trees and were producing less fruit. Counting numbers of fruit above and below 96 ring size revealed no distinct differences in fruit size. This information should be vital to those concerned with early returns from citrus groves.

Attempts to use citrus cultivars other than 'Rough Lemon' and 'Sour Orange' as rootstocks in the late '40's and early '50's often failed because of viruses in many of the clones then used in the industry. As a result the planting of virus-free selections was recommended (1). Citrus viruses, with the exception of the psorosis virus, are not transmitted through the seed and many new selections were propagated from seedling trees. It soon became apparent, however, that the juvenility of nucellar selections led to excessive vegetative growth and low yields (4). This experiment was designed to determine differences in growth and fruit yield over a 10-yr period among 3 nucellar selections of red grapefruit and 'Webb' selection of old budline 'Redblush', a standard cultivar in South Texas.

Materials and Methods

The trial was located at the Texas A&M University Agricultural Research and Extension Center at Weslaco, Texas, commencing in March 1960. Three nucellar selections, 'CES #3 Redblush' and local selections of nucellar 'Redblush' and 'Ruby' were planted in randomized, complete blocks together with the old budline 'Webb' selection of 'Redblush'. The nucellar trees were virus-free, the old budline trees carried exocortis and xyloporosis. There were 10 trees of each selection, arranged in 5, 2-tree plots. All trees were on sour orange rootstock,

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