HortScience 17(4):678–679. 1982.

Postharvest Respiration, Ethylene Production, and Compositional Changes of Chinese Jujube Fruits[1]

Adel A. Kader, Yu Li,[2] and Alexander Chordas
Department of Pomology, University of California, Davis, CA, 95616

Additional index words. Zizyphus jujuba, Chinese date, maturation, ascorbic acid, chilling injury

Abstract. **Production rates of CO_2 and C_2H_4 by fruits of jujube (*Zizyphus jujuba* Lam.), picked at the whitish-green stage and held at 20°C for 15 days, followed a nonclimacteric pattern. Skin color changed from whitish-green to reddish-brown with fruit maturation. Relative to most other fresh fruits, Chinese jujubes are lower in water content and titratable acidity, and higher in total sugars (mostly reducing sugars) and phenolics. Chinese jujubes are very rich in ascorbic acid (Vitamin C) content which increased with maturation to 559 mg/100 g fresh weight. Fruits held at 0° for 26 days exhibited sheet pitting due to chilling injury.**

Chinese jujube (*Zizyphus jujuba*) is a deciduous tree, while the Indian jujube or Ber (*Z. mauritiana*) is an evergreen tree; both are of tropical and subtropical origin (8). The latter species has been erroneously referred to as *Z. jujuba* in some reports (1, 13). While Chinese jujube (Chinese date) is an important fruit crop in countries such as China and the U.S.S.R., its production in the United States is still largely limited to home backyards in the southeast and southwest (7, 8, 9). The fruit, a drupe, has a thin reddish-brown skin when ripe, and a whitish, sweet, and somewhat dry flesh enclosing a hard 2-seeded stone (7, 8, 9). Fruits are eaten fresh, dried, or candied. Lyrene and Crocker (9) listed inability of green fruit to ripen after picking, variation in ripening time, and poor storability of ripe fruits on the tree among the factors limiting the potential of jujube as a commercial shipping fruit in the United States.

Published information about postharvest physiology and composition of Chinese jujubes is very limited. The following ranges are reported from the U.S.S.R. (3, 10) for various cultivars and production areas: 185–972 mg/100 g ascorbic acid, 335-1190 mg/100 g phenolics, and 12–42% total sugars. Much lower levels of ascorbic acid and sugars have been found in Indian jujubes (1, 2, 13).

We report here on the postharvest behavior and compositional changes of Chinese jujube fruits picked at the whitish-green stage and held at 20°C for 15 days, and on the susceptibility of fruits picked whitish-green or partially ripe to chilling injury. Fruits (unknown cultivar) were harvested on Sept. 2, 1981 from the Pomology Teaching Orchard of the University of California, Davis, and were sorted to eliminate immature (green) fruits. Fruit lots used in each test were matched for size and skin color.

Respiration and ethylene production. Five replicates of 20 whitish-green fruits each were held under continous humidified air flow at 20°C. CO_2 and C_2H_4 concentrations were determined daily by the Claypool and Keefer method (4) and flame ionization gas chromatography, respectively. Respiration rate fluctuated between 15 and 20 ml CO_2/kg-hr during the 15 days of storage at 20° (Fig. 1). C_2H_4 production rates remained below 0.1 µl/kg-hr for 7 days, then increased slightly, but did not exceed 0.25 µl/kg-hr until the end of storage (Fig. 1). These data indicate that Chinese jujubes have a nonclimacteric pattern of CO_2 production and do not exhibit accelerated C_2H_4 production during ripening. As these fruits ripened, brown-colored spots, which appeared on the skin, increased in size until the fruit became entirely brown. After 15 days at 20°, 75% of the fruits in the 5 replicates were more than 75% brown, 15% were 50-75% brown, 7% were 25-50% brown, and 3% were less than 25% brown. Thus, fruits picked whitish-green can continue their maturation and ripening after harvest.

Color, firmness, and composition. Quality evaluations were made initially, then every 3

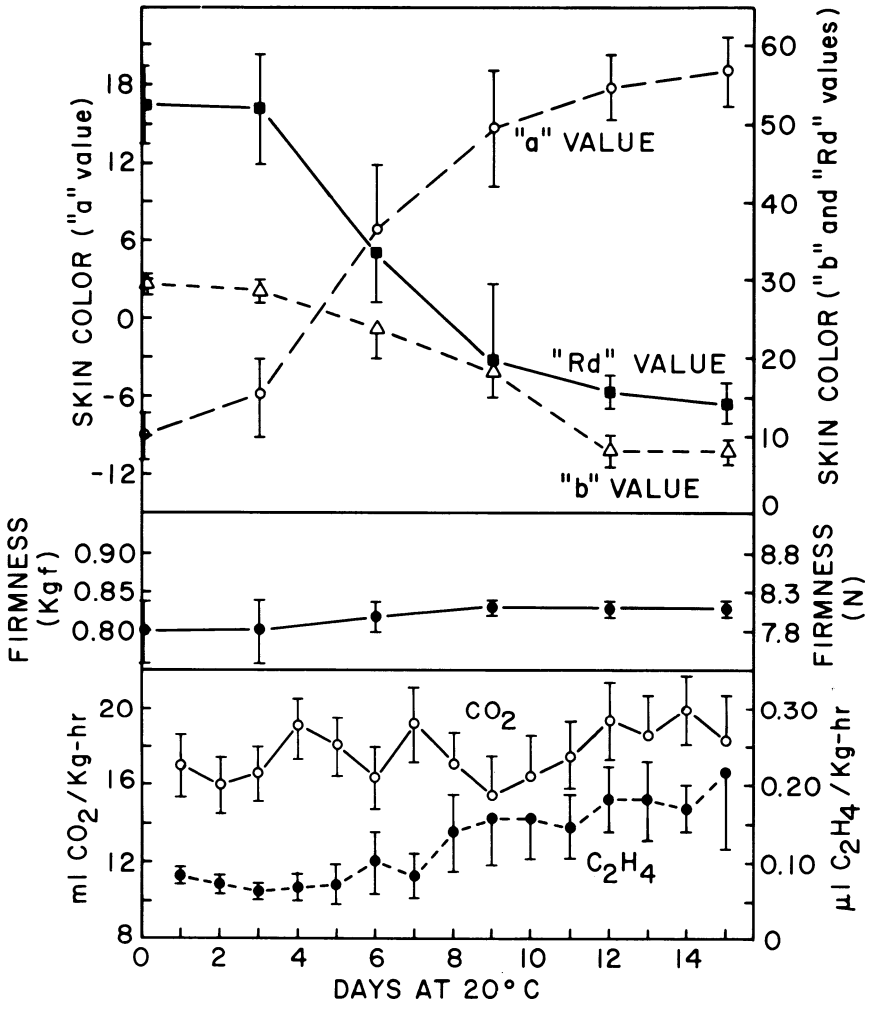

Fig. 1 Mean values and their standard deviations (vertical bars) for respiration and ethylene production rates (n=5), flesh firmness (n=40), and skin color (n=20) of jujube fruits during holding at 20°C for 15 days.

[1]Received for publication March 15, 1982.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.
[2]Permanent address: Institute of Botany, Academie Sinica, Peoples Republic of China.

Table 1. Compositional changes (means of 3 replicates ± SD) in jujube fruits during holding at 20°C for 15 days. All data are expressed on fresh weight basis.

Days at 20°C	Moisture (%)	Soluble solids (%)	Total sugars (%)	Reducing sugars (%)	pH	Titratable acidity[z] (mg/100 g)	Total phenolics[y] (mg/100 g)	Total ascorbic acid
0	75.7 ± 1.8	20.7 ± 1.6	20.1 ± 0.2	13.9 ± 0.4	4.98 ± 0.08	0.15 ± 0.01	314 ± 13	432 ± 11
3	75.5 ± 3.0	21.7 ± 0.8	21.1 ± 0.4	18.0 ± 0.5	4.79 ± 0.09	0.19 ± 0.02	295 ± 8	499 ± 15
6	74.3 ± 0.6	22.3 ± 0.6	21.1 ± 0.4	18.6 ± 0.2	4.73 ± 0.09	0.20 ± 0.02	299 ± 11	476 ± 14
9	72.9 ± 0.6	22.8 ± 0.6	21.7 ± 0.2	18.8 ± 0.3	4.71 ± 0.07	0.22 ± 0.02	292 ± 8	503 ± 20
12	74.2 ± 1.3	22.2 ± 0.3	21.2 ± 0.5	18.0 ± 0.3	4.68 ± 0.06	0.23 ± 0.03	268 ± 13	546 ± 11
15	73.7 ± 2.0	22.8 ± 1.0	21.5 ± 0.3	16.9 ± 0.2	4.68 ± 0.06	0.23 ± 0.04	305 ± 16	559 ± 17

[z]As malic acid.
[y]As gallic acid equivalent phenol.

days during storage at 20°C for 15 days. One lot of 20 fruits picked at the whitish-green stage was used for each evaluation. Changes in skin color (measured by a Gardner XL23 Tristimulus Colorimeter) are shown in Fig. 1. The increase in "a" values reflects loss of green color, while the decrease in "Rd" values indicates brown color development with ripening. The decrease in "b" values was also due to brown color development. Changes in flesh firmness (determined by a UC Fruit Firmness Tester with a 0.48-cm tip, after skin removal) during storage were small (Fig. 1). This may be due to the spongy nature of the flesh and its relatively low water content.

Each 20-fruit lot was divided into 3 replicates for chemical analyses. Soluble solids content (SSC) was determined using an Abbe refractometer, and acidity was determined by titrating 6 g of the juice with 0.1 N NaOH to pH 8.1. Total and reducing sugars were determined by the methods of Dubois et al. (5) and Somogyi (12), respectively. Total ascorbic acid and total phenolic methods were those described by Freed (6) and Singleton and Rossi (11), respectively. Since high concentrations of ascorbic acid interfere with the method used to determine phenolics (K. Ryugo, personal communication), standard curves for gallic acid alone and with 500 mg ascorbic acid were developed, and a correction factor was used in calculating phenolics content. We found no interference of phenolics with the ascorbic acid determination method. Moisture content was measured by drying fruit tissue samples in a vacuum oven at 70°C and 660 mm Hg of vacuum for 24 hr.

An increase in SSC, total sugars, reducing sugars, titratable acidity, and ascorbic acid, and a decrease in pH and total phenolics were found after 3 days at 20°C (Table 1). Subsequent compositional changes were relatively small, except for an increase in ascorbic acid content. Fluctuations in SSC between the 9th and 15th days of storage may have been due to variation in water content among samples (Table 1).

Compared with most other fresh fruits, Chinese jujubes contain more sugars and much less acidity, which results in their sweet and subacid taste. They also have a much higher content of phenolics, which were responsible in combination with other pigments for the brown skin color. Fruits attain their maximum content of ascorbic acid when fully ripe (reddish-brown in color). The extremely high ascorbic acid content reported here places Chinese jujubes near the top among all fresh fruits as a source of Vitamin C (14).

Susceptibility of chilling injury. In a preliminary test, fruits picked at the whitish-green and partially (20–50%) brown stages were placed at 0 and 20°C (50 fruits per treatment) for 26 days, then transferred to 20° for 9 days. Brown color development followed by skin wrinkling occurred faster in fruits picked partially ripe and in fruits held at 20° than in those picked whitish-green and in fruits held at 0°, respectively. Fruits held at 0° exhibited some sheet pitting (relatively large sunken areas), which became much more pronounced upon transfer to 20°, indicating their susceptibility to chilling injury.

Literature Cited

1. Ahmad, M., A. Sattar, A. Hussain, M. Jamil, W. A. Farrooqi, and A. M. Hussain. 1972. Some physiochemical changes in irradiated Ber (*Zizyphus-Jujuba*) during storage and ripening. Pak. J. Sci. Ind. Res. 15:163–166.
2. Bal, J. S. and S. S. Mann. 1978. Ascorbic acid content of Ber during growth and maturity. Sci. Cult. 44:238–239.
3. Buzhak, F. T. and G. V. Nastas. 1980. Biochemical peculiarities of jujube (in Russian). Sadovodstvo, Vinogradarstvo i Vinodelie Moldavii 1980(2):59–60.
4. Claypool, L. L. and R. M. Keefer. 1942. A colorimetric method for CO_2 determination in respiration studies. Proc. Amer. Soc. Hort. Sci. 40:177–186.
5. Dubois, M., K. A. Gilles, J. K. Hamilton, P. A. Rebers, and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350–356.
6. Freed, M. 1966. Methods for the determination of ascorbic acid. p. 293–320. In: Methods of vitamin assay. Interscience, New York.
7. Lee, B. W. 1975. The jujube or "Chinese date." Univ. Calif. Div. Agr. Sci. Leaflet 2729.
8. Lyrene, P. M. 1979. The jujube tree (*Zizyphus jujuba* Lam.). Fruit Var. J. 33:100–104.
9. Lyrene, P. M. and T. E. Crocker. 1979. The Chinese jujube. Univ. Florida Fruit Crops Fact Sheet, FC-50.
10. Nastas, G. V. 1978. Jujube—a fruit crop (in Russian). Sadovodstvo, Vinogradarstvo i Vinodelie Moldavii 1978(7):55–57.
11. Singleton, V. L. and J. A. Rossi, Jr. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Amer. J. Enol. & Viticult. 16(3):144–157.
12. Somogyi, M. 1952. Notes on sugar determination. J. Biol. Chem. 195:19–23.
13. Ullah, M. and M. A. Haq. 1976. Ber (*Zizyphus jujuba*) quality as affected by the stage of ripeness. Agr. Pak. 27(1):53–54.
14. Watt, B. K. and A. L. Merrill. 1963. Composition of foods, raw, processed. U.S. Dept. Agr., Agr. Handb. 8.