Quality of Picual Olive Fruits Stored under Controlled Atmospheres

José M. Castellano,* José M. García, Ana Morilla, Salud Perdiguero, and Francisca Gutierrez

Instituto de la Grasa y sus Derivados (CSIC), Avenida Padre García Tejero 4, E-41012 Seville, Spain

Olive (*Olea europaea* cv. Picual) fruits were stored under different conditions of controlled atmosphere (CA) and temperature. Decay incidence for olives kept at ambient temperatures (6–17 °C; 65–70% relative humidity) reached nearly 100% after 15–30 days, with a rapid decrease in all of the quality indexes assayed. The severe loss of water, because of the low relative humidity, caused shriveling. Storage in air at 5 °C gave the lowest incidence of physiological disorders and decay. Storage at 5 °C and 3% CO_2 + 5% O_2 for up to 30 days delayed ripening as indicated by retention of green color and flesh firmness. However, this storage system for longer than 30 days resulted in higher incidence of chilling injury and rot.

INTRODUCTION

The olive oil industry has difficulty in coordinating fruit harvesting with extraction of oil and is often forced to store the fruits for up to several weeks, during which time they may be subjected to unfavorable environmental conditions. Fruits suffer mechanical, physicochemical, and physiological alterations that result in their quality deterioration.

In attempts to alleviate these difficulties, alternative storage conditions such as dipping in brine, modified atmospheres with SO_2, N_2, ammonia, CO_2, or propylene oxide, or vacuum packaging have been evaluated (Cantarelli, 1965; Petruccioli et al., 1970; García, 1990).

Olive varieties vary in their sensitivity to chilling injury and responses to controlled atmospheres (Maxie, 1964). With Manzanillo, Sevillano, Ascolano, and Mission varieties, Woskow and Maxie (1965) described that below 2.2 °C all varieties exhibited severe incidence of chilling injury and that above 5 °C ripening was not adequately delayed. Likewise, they applied a controlled atmosphere (CA) (up to 10.5% CO_2 or decreasing O_2 concentration to 2%) at 5 °C to Mission and Sevillano varieties, finding that after 10 weeks the ripening was delayed and there was no evidence of chilling injury, although all lots showed considerable numbers of decayed fruits. Subsequently, Kader (1985a) reported benefits with 2–5% O_2 or 5–10% CO_2 at 7 °C.

Kader et al. (1990) advised against the use of CO_2 concentration above 5% for Manzanillo olives. However, they obtained favorable responses with a 2% O_2 atmosphere. García and Streif (1991), using Gordal olives, observed that a 5% CO_2 or higher led to physiological disorders. The same response was obtained by decreasing O_2 concentration to 1%.

In the present work, we studied the effect of cold storage with or without controlled atmospheres on ripenning and quality of ripe Picual olives (the most commonly grown cultivar in Spain) destined for oil extraction.

MATERIALS AND METHODS

Biological Material. Olive (*Olea europaea* cv. Picual) fruits grown in Seville, Spain, were picked ripe from 20-year-old trees in early December. Random lots were sorted and matched for the different treatments.

Fruit Storage. Five storage conditions were tested: three in controlled atmosphere at 5 °C and 90–96% relative humidity (RH) (20% O_2 + 77% N_2 + 3% CO_2; 5% O_2 + 92% N_2 + 3% CO_2; 5% O_2 + 94% N_2 + <1% CO_2) and two in air [one at ambient conditions (6–17 °C and 65–70% RH) and the other in a cold room at 5 °C and 90–96% RH].

The fruits used in the three CA storage conditions were maintained in sealed plastic containers of 60 × 40 × 40 cm. The fruits used in the two storage conditions involving air were kept in similar containers that were kept open.

Four trays (one per sampling date), each containing 6 kg of fruit, were put in each container. Sampling was carried out after 15, 30, 45, and 60 days of storage. An additional sample of 6 kg was taken for the initial quality evaluation.

The concentrations of O_2 and CO_2 were monitored daily using an infrared gas analyzer (Servomex 1400, range 0–10%) for CO_2, and a paramagnetic gas analyzer (Servomex 1400) for O_2. The corrections of atmospheric composition were made by injection of pressurized N_2 and CO_2 and/or air. Excess of CO_2 was corrected by bubbling the gas mixture through an aqueous solution of 2 N KOH.

Postharvest Losses. The percentages of loss due to fungal attack, chilling, and low O_2/high CO_2 injuries were determined in randomly selected samples of 20 fruits for each of five replicates per storage condition.

The most apparent symptoms of chilling injury in olives were surface pitting and necrotic areas. Some tissues became affected both internally and externally, developing a brown discoloration of the flesh. Damaged mature-green olives commonly failed to ripen normally during storage.

Olive fruits were considered to be decayed when fungal mycelium was observed.

Color. Color was measured on a scale $L^*a^*b^*$ in 100 fruits, using a Minolta CR-200 Chromameter, with an 8 mm diameter measuring aperture, diffuse illumination, and an angle of vision of 0°. The colorimetric index $L^*(b^* - a^*)/100$ was used, adequately expressing olive color change from green to purple-black.

Firmness. Firmness was determined by resistance of flesh to penetration, using a penetrometer (Dayton Electric MFG Co.) fitted with a 1.5 mm diameter tip. The measurement was made on 100 fruits and expressed in newtons.

Water Content. Water content was determined in triplicate samples of 30 fruits placed in an oven at 105 °C for 24 h, at which time they reached constant weight.

Statistical Treatment of the Data. Variance analysis and least significant differences (LSD) at $P = 0.05$ were calculated for comparison of means.

RESULTS AND DISCUSSION

Physiological Disorders. The assessment of losses by chilling injury in olive fruits stored at ambient temperature was not included because these fruits did not show disorders during the first 15 days of storage, and beyond 15 days the high incidence of rot made measurement impossible. In CA storage, symptoms of chilling

0021-8561/93/1441-0537$04.00/0

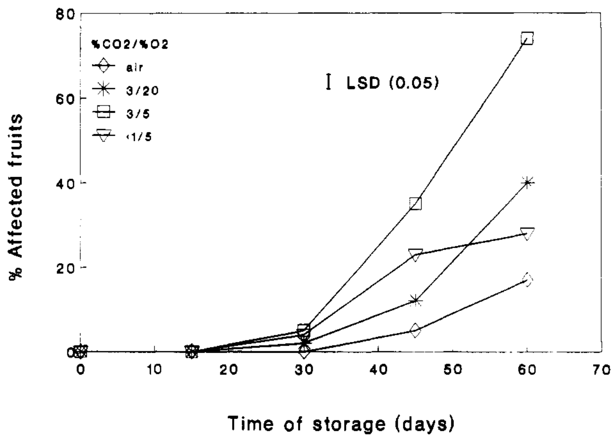

Figure 1. Changes in percent of chilling injury affected Picual olive fruit during storage at 5 °C.

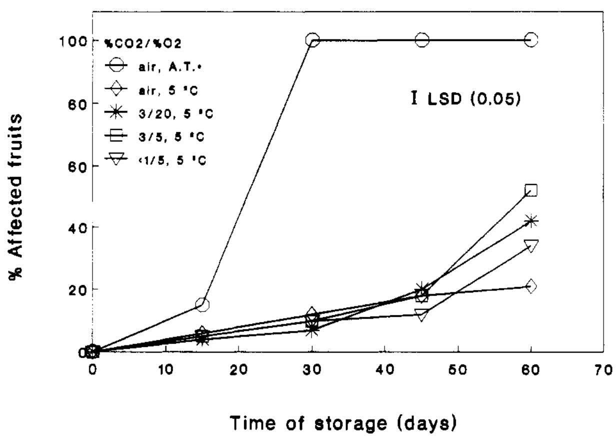

Figure 2. Incidence of fungal rotting (percent) in Picual olive fruit during storage. *A.T., ambient temperature.

injury began to be observed after 15 days of storage. In air at the same temperature (5 °C) these injuries began to occur only after 30 days; fruits stored under these conditions exhibited the least chilling injury after 45 and 60 days of storage (Figure 1).

Exposure to 3% CO_2-enriched air considerably increased the percentage of damaged fruits. A similar effect was obtained by decreasing the level of O_2 to 5%. These harmful effects were additive in an atmosphere combining both factors (3% CO_2 + 5% O_2). This was the most harmful atmosphere for fruits after 30 days of storage at 5 °C.

In Picual olives metabolic imbalance induced by chilling stress at 5 °C seems to be aggravated by CA-induced alteration of normal functions. This fact is also known in other commodities such as cucumber and bell-pepper fruits (Eaks, 1956; Kader, 1985b). The efficacy of CA in ameliorating chilling injury symptoms is dependent upon the variety, the concentrations of O_2 and CO_2, and storage duration and temperature.

Fungal Rots. Low temperature (5 °C) considerably reduces fungal growth. In contrast, in fruits stored in air at ambient temperatures, rot affected the entire batch at 30 days of storage (Figure 2).

The four conditions tested at 5 °C showed a similar behavior, with differences becoming significant only after 60 days of storage. Neither the increase of CO_2 to 3% nor the decrease of O_2 to 5% in the storage atmosphere reduced the incidence of fungal disease. In fact, the fruits stored under these conditions showed a higher degree of infection after 60 days of storage than those stored at the same temperature in air. This may be due to a lowered resistance

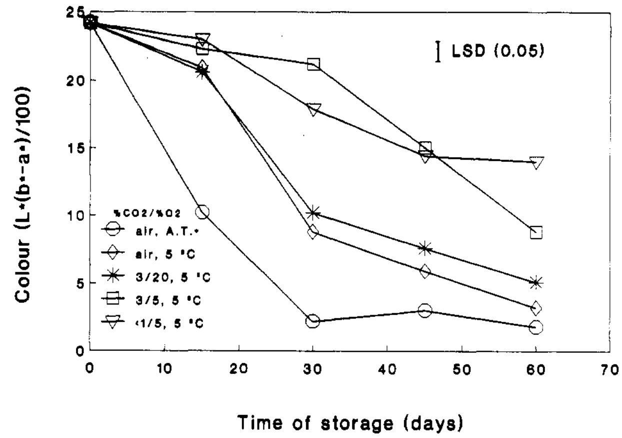

Figure 3. Color change in Picual olive fruit during storage. *A.T., ambient temperature.

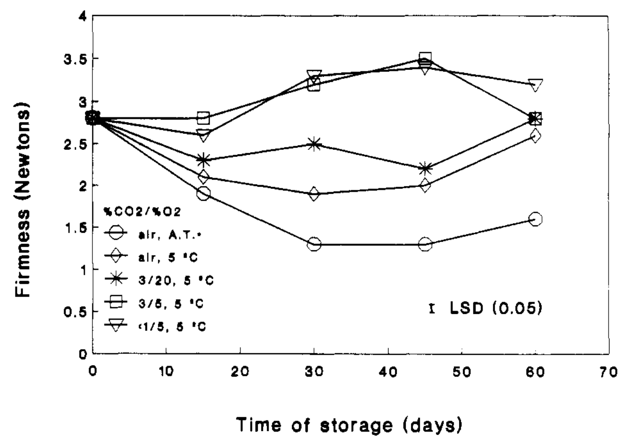

Figure 4. Flesh firmness of Picual olive fruit during storage. *A.T., ambient temperature.

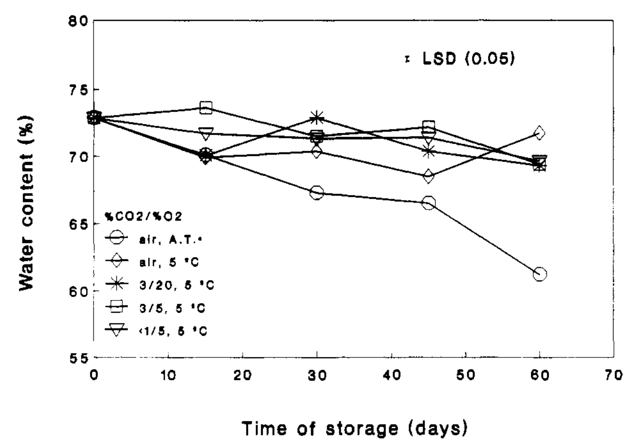

Figure 5. Water content in Picual olive fruit during storage. *A.T., ambient temperature.

of the product to molds, as a consequence of the injurious effects of the combined action of high CO_2 and/or low O_2 and low temperature.

Color. Storage in air at ambient temperatures caused the quickest fall in colorimetric index (Figure 3). Atmospheres containing 5% O_2 gave the best retention of green color throughout the storage period. Increased CO_2 to 3% in the presence of 20% O_2 gave no better retention of color than air after 30 days in storage. The effects of the 3% CO_2 + 5% O_2 and <1% CO_2 + 5% O_2 atmospheres were somewhat similar in controlling development of color, with the 3% CO_2 + 5% O_2 atmosphere being better at day 30 and the <1% CO_2 + 5% O_2 atmosphere better at the end of the storage period (day 60).

A large percentage of mature-green fruits stored at ambient temperatures acquired a brown color as a consequence of a higher metabolic rate and an almost generalized fungal attack, showing an abnormal ripening.

Firmness. As in the case of the other parameters studied, it can be seen that the determining factor for retention of firmness at 5 °C is the decrease in O_2 concentration to 5%, without any apparent improvement from increasing the CO_2 level to 3% (Figure 4). The least favorable condition for retention of firmness was storage in air at ambient temperatures. Storage in air at 5 °C showed an intermediate behavior.

Water Loss. Water loss increased with storage time (Figure 5). Obviously, olives stored in air at ambient temperatures lost water more quickly as a consequence of the higher temperature and lower relative humidity (65–70%). Furthermore, the advanced stage of fungal decomposition of fruits resulted in the leakage of cell fluids.

Storage of olives at 5 °C showed reduced water loss because of the high relative humidity of the atmospheres (90–96%). No clear differences were found between them. No fruits stored at 5 °C showed visible signs of shriveling. Slight variations observed in the moisture level of fruits stored at 5 °C can be explained by greater fluctuations of RH inside the open plastic containers (air control) than inside the sealed containers (CA treatments).

ACKNOWLEDGMENT

We gratefully acknowledge the collaboration of the Bachelor of Biology Ms. A. Pérez and the technical assistance of Mrs. M. C. Martínez. This investigation was supported by Research Grant ALI88-0256-CO2-01 from Comisión Interministerial de Ciencia y Tecnología (Spain).

LITERATURE CITED

Cantarelli, C. New Solutions to Olive Storage: An Experimental Contribution. *Riv. Ital. Sostanze Grasse* **1965**, *42*, 475–481.

Eaks, I. L. Effect of modified atmosphere on cucumbers at chilling and non-chilling temperatures. *Proc. Am. Soc. Hortic. Sci.* **1956**, *67*, 473–478.

García, L. Olive Storage in a Vacuum and under CO_2 atmospheres. *Agricultura* **1990**, *690*, 59–61.

García, J. M.; Streif, J. The effect of controlled atmosphere storage on fruit and oil quality of Gordal olives. *Gartenbauwissenschaft* **1991**, *56*, 233–238.

Kader, A. A. A summary of CA requirements and recommendations for fruits other than pome fruits. In *Fourth National Controlled Atmosphere Research Conference*; S. M. Blankenship: Raleigh, NC, 1985a; pp 445–470.

Kader, A. A. An overview of the physiological and biochemical basis of CA effects on fresh horticultural crops. In *Fourth National Controlled Atmosphere Research Conference*; S. M. Blankenship: Raleigh, NC, 1985b; pp 1–9.

Kader, A. A.; Nanos, G. D.; Kerbel, E. L. Storage potential of fresh Manzanillo olives. *Calif. Agric.* **1990**, *40*, 23–24.

Maxie, E. C. Experiments on cold storage and controlled atmosphere. In *The 43rd Annual Technical Report of the California Olive Association*; California Olive Association: Davis, CA, 1964; pp 12–15.

Petruccioli, G.; Montedoro, G.; Cantarelli, C. New Perspectives in Storage Technology of Olives Destined for Oil Extraction. *Riv. Ital. Sostanze Grasse* **1970**, *47*, 150–156.

Woskow, M.; Maxie, E. C. Cold storage studies with olives. In *The Annual Technical Report of the California Olive Association*; California Olive Association: Davis, CA, 1965; pp 6–11.

Received for review August 3, 1992. Revised manuscript received October 29, 1992. Accepted January 15, 1993.