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Modified atmosphere packaging maintains postharvest quality of loquat fruit

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Abstract

The effects of modified atmosphere packaging (MAP) on the storage life of loquat fruit (*Eriobotrya japonica* Lindl. cv. Mogi) were investigated. Fruit in MAP had minimal water loss (0.9–1.5%), while perforated polyethylene (PE) packaged fruit had 8.9% water loss after storage for 60 days at 5 °C. MAP significantly retained loquat organic acid levels, although total sugars were not significantly affected. Lower gas permeance MAP increased fruit physiological disorders, including internal browning (or core-browning). Storage temperature was very important for loquat fruit in MAP conditions. Fruit stored at high temperature (20 °C) sustained severe decay, and MAP increased the incidence of decay. Bagging loquats with 20 µm thickness PE at 5 °C resulted in an in-bag atmosphere of approximately 4 kPa O₂ with 5 kPa CO₂, and in the highest scores for appearance and chemical compounds. Loquat fruit packaged under these atmosphere conditions could be stored for 2 months at 5 °C with a higher quality and minimal risk of disorder development. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: *Eriobotrya japonica* Lindl.; Loquat; Modified atmosphere packaging; Polyethylene bag; Quality

1. Introduction

Loquat (*Eriobotrya japonica* Lindl.) is widely cultivated in subtropical regions of Asia and other continents. The harvest season of loquat in China and Japan is rather short, lasting only

from mid-May to mid-June in open field cultivation. Loquat fruit are susceptible to decay, mechanical damage and moisture and nutritional losses during their postharvest life. Various experiments have been conducted to identify treatments and techniques that can maintain fruit quality and extend their postharvest life (Shaw, 1980). While lower temperatures can extend loquat storage periods, they do not completely inhibit the decline of organic acid levels or water loss during prolonged storage (Ding et al., 1998).

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A modified atmosphere (MA) is created when fruit are sealed in polyethylene (PE) bags with a relatively low permeability to gases. Consequently, as the fruit respire, the O₂ level decreases, and the CO₂ level increases in the bags (Kader, 1995). Under these atmospheric conditions, the respiration rate of the fruit is decreased, and as a direct effect, the consumption of respiration substrates such as organic acids and sugars is retarded. Therefore, simple MA storage with polyethylene film bags can maintain fresh fruit quality, although gas concentrations in PE bags during storage cannot be controlled accurately. The atmospheric conditions can be regulated partially by the selection of films of different gas permeability. This method provides a relatively low-cost alternative to controlled atmosphere storage.

The few studies that have been carried out on MA storage of loquats have only involved individual fruit packaging. Guelfat-Reich (1970) indicated that polyethylene wraps increased internal browning and postharvest rotting of loquat fruit. Singh (1959) showed that polyethylene bags appeared to cause adverse chemical changes in loquat fruit. Since then, little research has been reported, and there is very limited information on the effect of packaging on several quality parameters. In addition, no data have been reported concerning changes in gas composition within the package during storage.

When designing an MA system, the aim is to achieve equilibrium inside the package at which the particular commodity will be surrounded by its specific optimal atmosphere and relative humidity. Such equilibrium is determined by the commodity's respiration rate, storage temperature and the type of film with respect to its thickness and permeability to O₂, CO₂ and water vapor (O'Beirne, 1991). In order to explore the MA storage method for commercial purposes, the objective of the present study was to evaluate the use of polyethylene bags for storage of loquat fruit. The changes of gas composition and quality of fruit packaged with different thicknesses of PE bags were investigated.

2. Materials and methods

2.1. Fruit material

Loquat fruit were obtained from the farm of the College of Agriculture, Osaka Prefecture University, Osaka, Japan. The fruit were hand-picked, and five fruit (approx. 180 g) were packed per polyethylene bag (28 × 20 cm). Different thickness (20, 30 and 50 μm; PE-20, PE-30 and PE-50) and perforated polyethylene (PE-pf) (0.15% perforation) bags were used. The O₂ permeances were 58.5, 39.0, and 23.5 pmol s⁻¹ m⁻² Pa⁻¹ for PE-20, PE-30 and PE-50, respectively, and the CO₂ permeances were 204.5, 136.3, and 82.2 pmol s⁻¹ m⁻² Pa⁻¹ for PE-20, PE-30, and PE-50, respectively. The permeance data were provided by the manufacturer and converted into SI units according to Banks et al. (1995).

During the storage period, samples were collected at 7 day (20 °C) or 15 day (5 °C) intervals, and 30 ~ 40 loquats were analysed each time. The fruit were manually peeled, cut into small pieces, and the composite fruit samples ranging from 10 ~ 20 g of pulp were weighed and frozen in liquid nitrogen, then stored at -38 °C until analysis.

2.2. Measurements of gas concentrations

A 1 ml gas sample was taken from the storage bag containing five fruit stored at the experimental temperatures for the measurement of gas concentrations. Carbon dioxide and O₂ concentrations were determined on a gas chromatograph equipped with a Polapak Q column (50–80 mesh, 2 m × 3 mm, 60 °C) and a thermoconductivity detector (TCD). Ethylene concentrations were determined on a gas chromatograph with an activated alumina column (60–80 mesh, 1 m × 3 mm, 60 °C) and flame ionization detector (FID).

2.3. Sugars and organic acids

A 20 g sample of frozen pulp was homogenized in 80 ml of cold MeOH (95%) solution for

1 min and shaken for 10 min. The homogenate was filtered and the residue extracted twice with 80% cold MeOH. The combined extracts were evaporated under vacuum at 35 °C until the MeOH was removed and the volume made up to 20 or 100 ml with water. The resulting extract was used for sugars and organic acid analyses.

Five millilitres of extract were passed through a Sep-Pak C₁₈ cartridge (Waters, Milford, MA), and the eluate was used for sugar analysis. A 20 µl eluate was injected into an HPLC with a Shim-Park SCR-101P column, a refractive index detector, and a flow rate of 1.0 ml min⁻¹ using water as eluent and a column temperature of 80 °C. Comparison peak areas of individual sugar standards quantified individual sugars.

Organic acids were analysed using an HPLC Organic Acid Analysis System (Japan Spectroscopic). A 20 µl sample of the eluate was auto-injected into a Shodex Ionpak C-811 column. The flow rates were 1.0 ml min⁻¹ using 3 mM HClO₄ as eluent, and 1.5 ml min⁻¹ using 0.2 mM Bromothymol Blue (BTB) in 15 mM Na₂HPO₄ as reagent. The column temperature was 60 °C. Organic acid components were detected at a wavelength of 445 nm. Quantification of individual organic acids was made using peak areas of individual acid standards.

2.4. Skin colour and carotenoids

Samples of 20 fruit were used for measuring skin colour. The surface colour of the individual fruit was measured at opposite sides of the equator of each fruit using a Colour Difference Meter (Nippon Denshoku Kogyo Co., 1001 DP) and expressed as Hunter *L*, *a* and *b* values. The hunter colour data were converted to hue angle (*h*°) as an indicator of loquat ripeness (McGuire, 1992). Data of hunter *L* (ranging from black = 0 to white = 100) were used as a surface browning indicator without further conversion.

For extracting carotenoids, 10 g of pulp was homogenized with 0.2 g of MgCO₃ and 0.2 g of butylated hydroxytoluene (BHT) in 80 ml of cold 40% aqueous MeOH (–20 °C) in a High-Flex Homogenizer (SMT, Company). This mixture was filtered through 1 cm of layered Celite 545, the

filtrate discarded and the residue extracted with acetone until colourless. Extraction and saponification of carotenoids were carried out according to the method by Kon and Shimba (1988) and analysed by HPLC (Hamauzu et al., 1997). Chromatographic peaks were identified by comparing both the retention times and absorbance spectra obtained at each peak with those in the literature. The concentrations were determined using published 1% absorption coefficients (Davis, 1976).

2.5. Disorder evaluation

Internal browning (IB) manifest as browning discoloration near the core was evaluated visually after cutting the fruit. The IB assessment was based on five stages, ranging from 0 to 4 as follows: 0 = none; 1 = slight; 2 = moderate; 3 = moderately severe; 4 = severe. Results were expressed as an IB index calculated using the following formula:

$$\text{IB index (between 0 and 4)} = \frac{\sum(\text{IB level}) \times (\text{number of fruit at the IB level})}{\text{Total number of fruit in the treatment}}$$

3. Results and discussion

3.1. Changes in in-package gas concentrations

The effects of PE thickness and storage temperature on the composition of atmospheres in PE bags are presented in Fig. 1. Because the fruit in PE-50 stored at 20 °C had a higher incidence of decay, evaluations were discontinued after 10 days. It was noted that fruit stored at higher temperatures accumulated higher concentrations of CO₂ inside the PE bags (Fig. 1). At a given temperature, the PE-50 bag accumulated the highest levels of CO₂ concentration. The peak of CO₂ accumulation occurred within 2–4 days, and the highest CO₂ concentrations were 11.9 kPa and 15.5 kPa inside PE-50 packages for 5 °C and 20 °C storage temperatures, respectively (Fig. 1). CO₂ concentrations then decreased steadily there-

after. The highest CO₂ concentration in PE-20 and PE-30 bags was reached in 4 days, and an equilibrium was reached after 1 week at 20 °C or 10 days at 5 °C. The equilibrium values in higher permeance bags (PE-20 and PE-30) were around 5–7 kPa and 10–12 kPa for storage temperatures of 5 °C and 20 °C, respectively.

Since O₂ is consumed during the respiration process, its concentration decreased rapidly in the first 1–2 days of storage and then reached equilibrium in all treatments (Fig. 1). The O₂ concentration was lowest in the PE-50 bag stored at 20 °C. The equilibrium values of O₂ concentration stored at 5 °C and 20 °C were around 3–7 kPa and 2–4 kPa, respectively (Fig. 2).

The pattern of changes in ethylene concentration inside the package was similar to that of CO₂. The concentration of ethylene at 20 °C was almost 10-fold higher than that at 5 °C. The maximum ethylene concentration was found in the PE-50 package at 20 °C, and the minimum concentration was in the PE-20 package after 5 days storage at 5 °C (Fig. 2).

3.2. Effects of MAP on the physical quality of loquat fruit

The gas concentration within the package significantly affected physical quality. During a higher-temperature storage, MAP hastened the decay of loquat fruit. The decay reached 10% after 5 days at 20 °C in PE-50 bags. The incidence of decay packaged in PE-pf, PE-20, PE-30 and PE-50 bags reached 25%, 40%, 50% and 100%, respectively, at the end of 21 days storage at 20 °C. At 5 °C, the decay incidence in PE-pf, PE-20, PE-30 and PE-50 bags was 8%, 10%, 15% and 20%, respectively, after 60 days of storage (Fig. 3). The higher gas permeance MAP showed a lower incidence of decay. The decay of loquat fruit was caused predominantly by an internal physiological disorder that started with internal flesh browning followed by complete rotting during storage. At a storage temperature of 20 °C, the highest CO₂ concentrations inside the PE-20, PE-30 and PE-50 bags were 12.1 kPa, 13.4 kPa and 15.5 kPa, respectively. In a previous report, a controlled atmosphere of 12 kPa

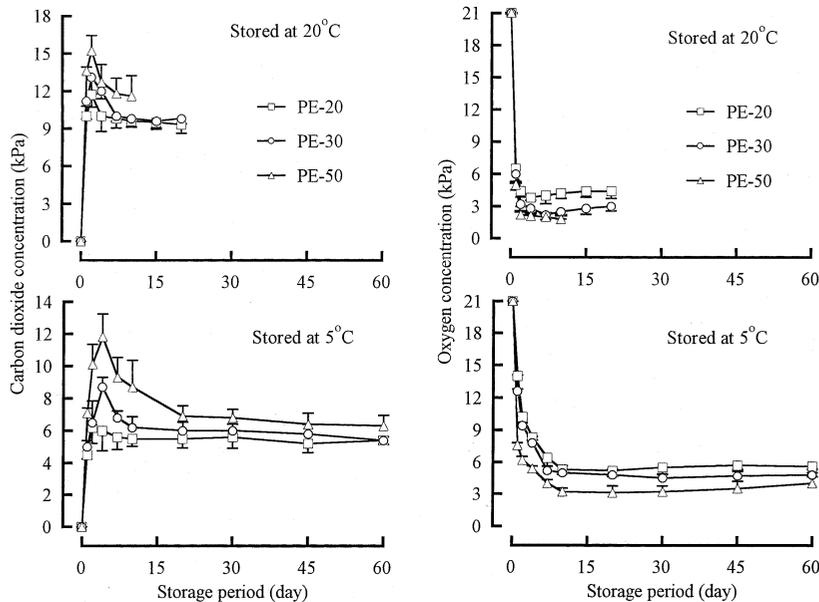


Fig. 1. CO₂ and O₂ concentrations in the PE bags of loquat (cv. Mogi) fruit during storage at 5 °C and 20 °C. The thicknesses of PE-20, PE-30 and PE-50 were 20, 30 and 50 μm, respectively. Data are the means ± S.E. of five replications. Vertical lines are not shown when smaller than the symbol.

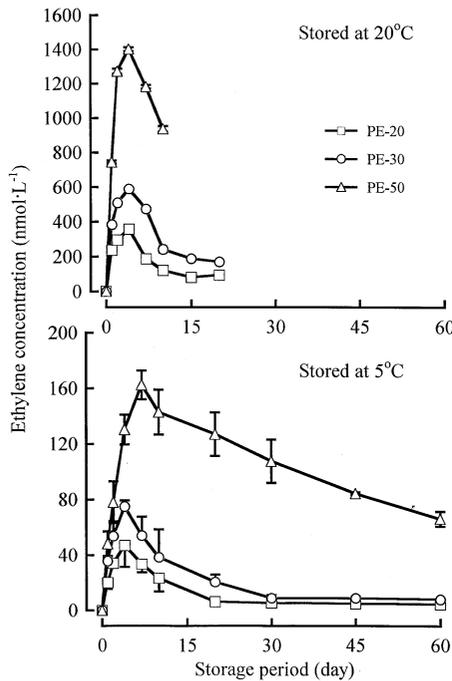


Fig. 2. Ethylene concentrations in the PE bags of loquat (cv. Mogi) fruit during storage at 5 °C and 20 °C. The thicknesses of PE-20, PE-30 and PE-50 were 20, 30 and 50 μm, respectively. Data are the means ± S.E. of five replications. Vertical lines are not shown when smaller than the symbol.

CO₂ induced severe internal browning in loquat fruit (Ding et al., 1999). Therefore, we suggest that the high CO₂ concentrations in fruits stored in lower gas permeance bags are the cause of their higher incidence of decay. These results indicated that MAP was not appropriate for loquat stored at ambient (20 °C) temperatures. In view of this, all storage experiments at 20 °C were discontinued.

The weight loss of loquats packaged in perforated and MA bags stored at 5 °C is shown in Fig. 3. In general, the loss of weight progressively increased with storage time and was linear for all treatments. The total weight loss of fruits packaged in PE-pf was 8.9% at the end of storage, while the fruit in MAP storage had less than 1.5% weight loss after 60 days storage (Fig. 3). The loss of water from the PE-pf packaged fruit was associated with shrinkage of fruit skin. There was no significant difference in weight loss among the

different MAP treatments. MAP was fairly effective in preventing weight loss.

3.3. Effects of MAP on the chemical composition of loquat fruit

MAP had significant effects on the organic acids of loquats. Malic acid was the principal nonvolatile organic acid and represented about 90% at harvest. During storage at 5 °C, organic

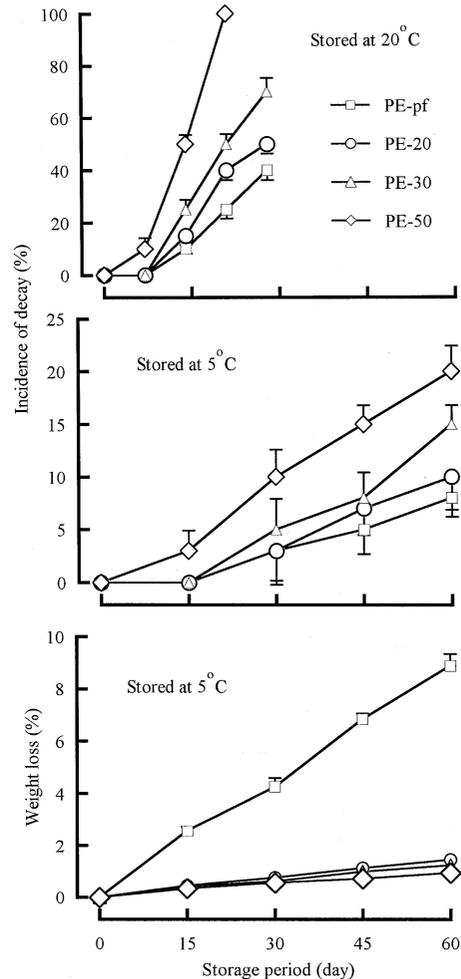


Fig. 3. Effects of PE bag packaging on incidence of decay and weight loss (%) of loquat (cv. Mogi) fruit stored at 5 °C and 20 °C. PE-pf: perforated polyethylene bag; the thicknesses of PE-20, PE-30 and PE-50 were 20, 30 and 50 μm, respectively. Fifty fruit were used for decay evaluation, and the experiments were replicated three times. Data are the means ± S.E. Vertical lines are not shown when smaller than the symbol.

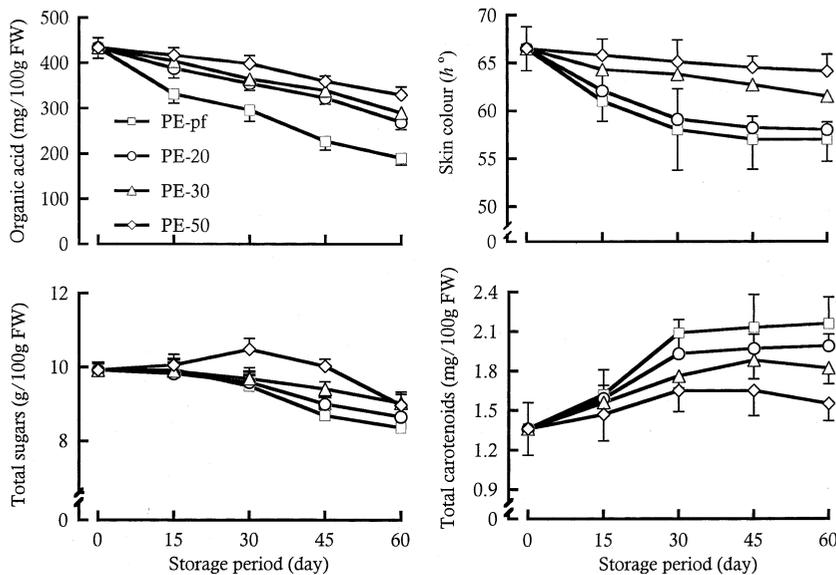


Fig. 4. Changes in organic acids, total sugars, carotenoids and skin colour (h° value) of loquat (cv. Mogi) fruit packaged in PE-bags during storage at 5 °C. PE-pf: perforated polyethylene bag; the thicknesses of PE-20, PE-30 and PE-50 were 20, 30 and 50 µm, respectively. Vertical lines represent SE and are not shown when smaller than the symbol.

acid concentrations in fruit packed in PE-pf bags declined rapidly; however, the decrease was slowed by MAP conditions. After 60 days of storage, organic acids in fruit packed in PE-pf, PE-20, PE-30 and PE-50 bags decreased by 60%, 35%, 30% and 27%, respectively, compared to initial levels (Fig. 4). These results showed that fruit in MAP retained higher amounts of organic acids than those packed in PE-pf bags. Sugars and acids are the main influences on fruit taste. High acidity in fruit has been suggested to contribute in part to the flavour retention of ripened fruit (Ulrich, 1970). An optimal acid concentration (about 0.2 ~ 0.4%) in loquat fruit for preferred flavour quality is necessary. Therefore, the acid retention is beneficial for keeping the 'loquat-like' flavour.

Total sugars (TS) did not change significantly during the first 15 days of storage and then decreased steadily afterwards except in the PE-50 package. After 60 days of storage, the decrease in TS was about 9–16% (Fig. 4).

Mogi loquat has an orange colour in both the skin and pulp, and the main pigment contributing to colour is the carotenoids. Values of h° were

found to decrease during storage with all treatments; however, MAP storage cause a minor inhibition of colour development (Fig. 4). The results indicated that colour became more yellow during storage.

The concentration of carotenoids in all treatments increased significantly during the first 30 days and then showed a slight change. At the end of storage, perforated or higher permeance MAP packaged fruit had higher levels of carotenoids compared with the fruit packed in low gas permeance bags. These results indicated that loquats after harvest would develop more pronounced yellow and orange colour and increased carotenoids, although MAP packaging inhibited the biosynthesis of carotenoids.

3.4. Effects of MAP on the physiological disorders in loquat fruits

Fig. 5 shows the browning tendency of loquat fruit during storage measured using the Hunter L value. The Hunter L value decreased rapidly in fruit packed in PE-30 and PE-50, in the same pattern as that observed with phenolics (data not

shown). These results indicated that some browning might have occurred in fruits packed in PE-30 and PE-50 bags during storage.

With MAP storage, the main cause of loquat fruit quality loss was internal browning. Its incidence was very high in fruits packed in PE-30 and PE-50 bags (Fig. 5). Other disorders noted included corky pulp (dry and lignified pulp tissue) and stuck peel (peel and pulp stuck together, making it difficult to peel). Both of these disorders resulted from tissue lignification. When the storage period was prolonged, the incidence of these disorders increased, particularly in fruit packaged in PE-30 and PE-50 bags (data not shown). Fruit packed in 20 μm polyethylene film bags had low rates of disorder development.

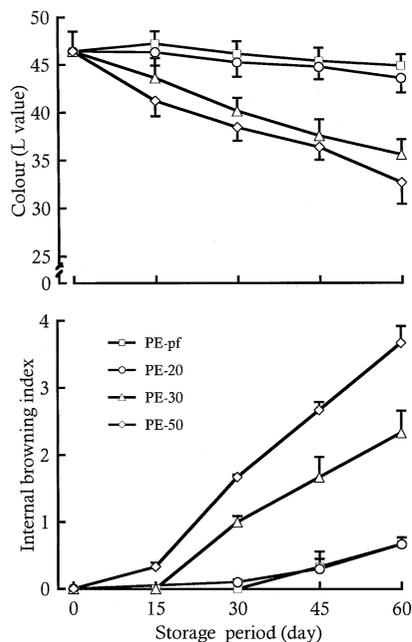


Fig. 5. Effects of PE bags packaging on skin colour (L values) and incidence of internal browning (IB) of loquat (cv. Mogi) fruits stored at 5 °C. IB index was rated on a 0–4 scale, where 0 = none; 1 = slight; 2 = moderate; 3 = moderately severe; 4 = severe. Data are the means \pm S.E. of 20 replications.

4. Conclusion

Loquats seal-packaged in PE-bags established low- O_2 and high- CO_2 atmospheres at both storage temperatures. However, higher temperatures significantly increased the incidence of decay. Therefore, the beneficial effects of MAP storage have to be combined with low-temperature storage. Stored at 5 °C with MAP, the water losses and organic acid decreases were retarded. However, total sugars were not affected significantly by different packaging treatments. Development of carotenoids occurred progressively during storage except in fruits stored in PE-50 bags. Loquats with MAP stored at 5 °C developed physiological disorders, including internal browning. This study indicated that loquat fruits could be stored at 5 °C for 2 months with 5 kPa CO_2 and 4 kPa O_2 MAP using 20 μm PE bags.

References

- Banks, N.H., Cleland, D.J., Cameron, A.C., Beaudry, R.M., Kader, A.A., 1995. Proposal for a rationalized system of units for postharvest research in gas exchange. *HortScience* 30, 1129–1131.
- Davis, B.H., 1976. Carotenoids. In: Goodwin, T.W. (Ed.), *Chemistry and Biochemistry of Plant Pigments*, vol. 2. Academic Press, London, pp. 38–165.
- Ding, C.K., Chachin, K., Hamauzu, Y., Ueda, Y., Imahori, Y., 1998. Effects of storage temperatures on physiology and quality of loquat fruit. *Postharvest Biol. Technol.* 14, 309–315.
- Ding, C.K., Chachin, K., Ueda, Y., Imahori, Y., Kurooka, H., 1999. Effects of high CO_2 concentration on browning injury and phenolic metabolism in loquat fruits. *J. Jpn. Soc. Hort. Sci.* 68, 275–282.
- Guelfat-Reich, S., 1970. Storage of loquat. *Fruits Outre Mer.* 25, 169–173 in French.
- Hamauzu, Y., Chachin, K., Ding, C.-K., Kurooka, H., 1997. Difference in surface color, flesh firmness, physiological activity, and some components of loquat fruits picked at various stages of maturity. *J. Jpn. Soc. Hort. Sci.* 65, 859–865 in Japanese with English summary.
- Kader, A.A., 1995. Regulation of fruit physiology by controlled/modified atmospheres. *Acta Hort.* 398, 59–70.
- Kon, M., Shimba, R., 1988. Cultivar difference of carotenoids in loquat fruits. *Nippon Shokuhin Kogyo Gakkaishi* 35, 423–429 in Japanese with English summary.
- McGuire, R.G., 1992. Reporting of objective color measurements. *HortScience* 27, 1254–1255.

- O'Beirne, D., 1991. Modified atmosphere packaging of fruit and vegetables. In: Gormley, T.R. (Ed.), *Chilled Foods: The State of the Art*. Elsevier Applied Science, Barking, UK, pp. 183–199.
- Shaw, P.E., 1980. Loquat. In: Nagy, S., Shaw, P.E. (Eds.), *Tropical and Subtropical Fruits*. AVI, Westport, CT, pp. 480–481.
- Singh, M.P., 1959. Artificial ripening of loquat. *Sci. Cult.* 24, 335–337.
- Ulrich, R., 1970. Organic acids. In: Hulme, A.C. (Ed.), *The Biochemistry of Fruits and Their Products*, vol. 1. Academic Press, New York, pp. 89–118.