Maturation of loquat fruit (Eriobotrya japonica Lindl.) under Spanish growing conditions and its postharvest performance

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Maturation of loquat fruit (*Eriobotrya japonica* Lindl.) under Spanish growing conditions and its postharvest performance

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SUMMARY – Changes in fruit colour, acidity, soluble solids content, respiration rate and ethylene production were determined in loquat fruit cv. Algerie, throughout maturation and during postharvest storage at 2ºC. Maturation-associated changes appeared not to be coordinated, since fruit colour progressively increased, but the decline in fruit acidity was initiated latter than the increase in soluble solids content. The rate of fruit respiration and that of ethylene production progressively decreased through maturation, and also in fruits stored at 20ºC. Thus, the ripening physiology of Algerie loquat fruit can be considered as non-climacteric. The rate of weight loss increased during fruit storage at 2ºC and it was enhanced after simulation of shelf-life conditions (7 days at 20ºC). Colour development progressed during these postharvest conditions, but the content of soluble solids remained with minor alterations. Acidity of the fruit decreased during cold storage and more markedly after fruit rewarming. This pattern of changes led stored loquat fruits to lose their characteristic flavour due to an unbalanced ratio between acids and sugars. Thus, the loss of acidity is the main factor affecting loquat fruit quality during cold storage.

Key words: Acidity, cold storage, ethylene, loquat, maturity, postharvest, respiration.

RESUME – *"Maturation des nèfles (*Eriobotrya japonica *Lindl.) en conditions de culture d'Espagne et performances post-récolte". Les changements de la couleur du fruit, les solides solubles, l'acidité, le taux de respiration et la production d'éthylène ont été déterminés chez les nèfles du cv. Algérie, pendant toute la maturation et pendant le stockage à 2ºC. Les changements liés à la maturation ont paru ne pas être coordonnés, depuis que la couleur du fruit a augmenté progressivement, mais la baisse de l'acidité du fruit a commencé plus tard que l'augmentation du contenu en solides solubles. Le taux de respiration du fruit et celui de la production d'éthylène ont diminué progressivement pendant la maturation, et aussi dans les fruits entreposés à 20ºC. Donc, la physiologie de la maturation des nèfles du cv. Algérie peut être considérée comme non-climatérique. Le taux de perte de poids a augmenté pendant le stockage du fruit à 2ºC et il s'est accéléré après simulation des conditions des étagères (7 jours à 20ºC). Le développement de la couleur a progressé pendant ces conditions post-récolte, mais le contenu en solides solubles s'est maintenu avec des modifications mineures. L'acidité du fruit a diminué pendant le stockage à froid et de façon plus marquée après réchauffement du fruit. Ces tendances des changements chez les nèfles entreposées ont mené à une perte de leur parfum caractéristique dû à un ratio déséquilibré entre acides et sucres. Donc, la perte d'acidité est le facteur principal qui affecte la qualité du fruit pendant le stockage au froid.*

Mots-clés : *Acidité, éthylène, nèfle, maturation, post-récolte, respiration.*

Introduction

Loquat (*Eriobotria japonica* Lindl.) is a subtropical tree originated in cool regions of China, that has been very well adapted to mild-temperature climate countries, such as those of the Mediterranean areas (Lin *et al*., 1999). In Spain, the production of loquat fruit is mainly concentrated in the area of Alicante, with more than 45% of the total area of loquat production. In the latter years the production of loquat fruits has considerably increased, mainly due to the good adaptation of several cultivars to the environmental conditions, cultural practices and to the consumers acceptance (Martínez-Calvo *et al*., 2000). One of the problems of the loquat production in Spain is that most of the production is concentrated in only one cultivar, Algerie, which account for about 95% of the total production (Martinez-Calvo *et al*., 2000). The harvesting period of Algerie loquat is concentrated around the beginning of May and, therefore, there is a saturation of fresh fruits in the market in a narrow period of time. Postharvest studies in loquat fruit aimed to extend their marketing period keeping fruit quality.

Loquat fruit is very susceptible to mechanical damage during harvesting and handling, and can easily develop browning spot on the fruit surface and in the pulp (Lin *et al*., 1999). Storage at low temperature has been shown to be effective in extending the postharvest life in fruit of the Mogi cultivar. Ding *et al*. (1998) reported that fruit can be stored at 1 or 5ºC for up to 30 days. However, fruit weight and acidity were progressively lost and, consequently, fruit quality was adversely affected. These authors did not observed increases in respiration and in ethylene production during storage at 20ºC, and concluded that Mogi loquat behaved as a non-climacteric fruit, in agreement with other results (Hamauzu *et al*., 1997). Recently, Ding *et al*. (2002) established that loquat fruit can be stored in the modified atmosphere created by low density polyethylene bags at 5ºC for 2 months. Due to the relatively high respiration rate of loquat fruit, low temperature storage was required to maintain the internal carbon dioxide and oxygen concentration below 5 kPa and 4 kPa, respectively.

In Algerie loquat, there are not available reports on their maturation behaviour and their postharvest performance. Therefore, the objectives of this work were to: (i) study maturation-associated changes in fruit harvested at different ripening stages; (ii) determinate the evolution of these parameters during storage of mature fruits at 20ºC; and (iii) to study the effect of cold storage (2ºC) and subsequent simulation of shelf-life conditions (7 days at 20ºC), on the quality and physiological changes of loquat fruit.

Material and methods

Plant material and storage conditions

Loquat (*Eriobotrya japonica* Lindl. cv. Algerie) fruits have been used throughout this work. Fruit at mature dark-green (DG), breaker (BR), light-green (LG), turning (TR) and yellow color (CL) ripening stages, were harvested from adult trees growing in the experimental orchards of the Cooperative Ruchey (Callosa d'En Sarria, Alicante, Spain). Fruit were delivered to the laboratory and used without any further treatment.

Mature loquat fruits were harvested at commercial maturity (ºBrix > 10). In order to reproduce postharvest conditions close to commercial conditions, fruits were sized, graded and packed in the Cooperative Ruchey. Boxes containing about 5 kg fruits were transported to the IATA and stored at the desired postharvest conditions. To study ripening changes, fruits were stored at 20ºC and 85-95% RH for up to 4 weeks, and samples were analysed every week. A second set of fruit samples were stored at 2ºC and 80-90% RH for up to 8 weeks. At different intervals, a box of fruit were directly used for quality, respiration and ethylene production analysis, and a second box were transferred to 20ºC and 85-95% for 7 days, to simulate shelf-life conditions.

Determination of weight loss, color, acidity and soluble solids content

Percentage of weight loss were determined by measuring the weight of replicate fruit samples before and after the storage period.

Peel colour was measured in 3 replicate samples of 10 fruit using a Minolta CL200. Hunter *a*, *b* and *L* parameters were determined on two locations around the equatorial plane of the fruit, and results are expressed as the mean ± SD of the ratio *a/b.* Values lower than 0 represent green colour, 0 indicates colour break, and values higher than 0 are yellow to orange colour.

After colour measurement, the peel was removed and the pulp of 5 fruits were combined for juice extraction using a food-chopper machine. The content of soluble solids (ºBrix) was determined with an Atago X-1000 refractometer. Acidity was measured by titration and is expressed as equivalent of malic acid/100 ml of juice.

Analysis of respiration rate and ethylene production

Respiration rate and ethylene production from the whole loquat fruits were determined by incubating 3 replicate of 5 fruits in 1 l jars. After 1 h incubation at either 20 or 2ºC, replicate samples of

1-ml air from the head space of the jars were withdrawn with a hypodermic syringe and injected into a gas chromatograph (Perkin Elmer Autosample). Carbon dioxide concentration was analysed using a thermal conductivity detector coupled to a Chromosorb column at 60ºC. Ethylene production was determined using a flame ionisation detector and an activated alumina column kept at 140ºC. The rate of respiration is expressed as µl CO_2/g/h, and that of ethylene as nl C_2H_4/g/h.

Estimation of Chilling Injury (CI) index

Fruit were visually scored to estimate the extent of CI development. A rating scale from 0 (no damage) to 3 (severe damage), based on surface and intensity of browning, was used to evaluate CI. The average CI index was determined as indicated in the following formula: CI index = S [CI scale (0-3) x number of fruit in each class]/total number of fruit estimated.

Results and discussion

Changes during fruit maturation

Figure 1 shows changes in peel color, acidity and soluble solids content in loquat fruits harvested at five maturation stages. The mature dark-green (DG) stage correspond to fruit in which final size was already reached but signals of chlorophyll degradation were not initiated. This stage are equivalent to the stage 709 described by Martinez-Calvo *et al*. (1999) according to the extended BBCH scale of phenological growth stages for cultivated plants (Bleiholder *et al*., 1996). Light-green (LG) and colored fruit (CL) are the corresponding to the stages 801 and 805, respectively. Fruit color development increased progressively throughout maturation, reaching at the last stage analyzed a light-orange color. Analysis of the changes in juice acidity revealed that the decrease in this parameter was not coordinated with the increase in soluble solids content. While acidity decreased after color break, the increase in soluble solids was initiated at the turning stage, when fruit chlorophyll have almost disappeared (Fig. 1).

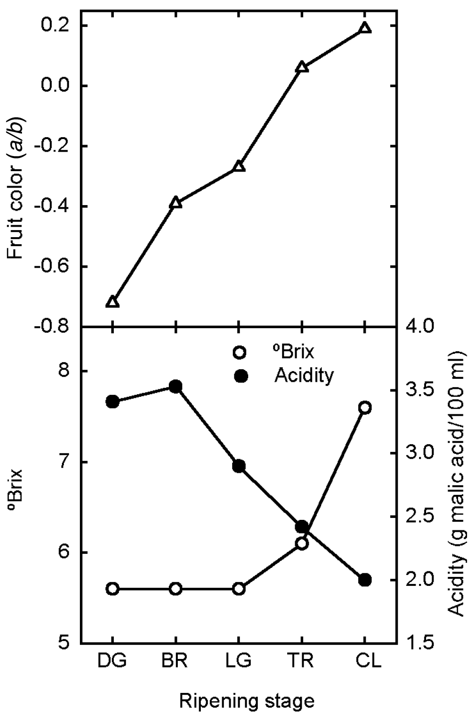

Fig. 1. Changes in fruit colour, acidity and soluble solids content in loquat fruit (cv. Algerie) harvested at different ripening stages. The ripening stages were: DG, mature dark-green; BR, breaker; LG, light-green; TR, turning; and CL, coloured fruits.

These results indicated that in loquat fruit, the evolution of these ripening-related processes appears not be coordinated, and do not take place at the same time, as have also been observed in fruit of other species (Lelievre *et al.*, 1997; Giovanonni, 2001). Probably different developmental, environmental or nutritional signals may act in the stimulation of the different physiological and biochemical processes associated with fruit maturation.

The rate of fruit respiration was relatively high and constant in fruit up to the light-green stage and declined thereafter. Ethylene production gradually declined during fruit maturation (Fig. 2). A climacteric-like increase in respiration and ethylene production was not found in loquat fruit of the Algerie cultivar through the maturation process, and even in fruit harvested at commercial maturity, the rate of both processes was similar to that of unripe fruits (Fig. 6). The rate of both fruit respiration and ethylene production found in the present study (30-50 µl CO_2/g/h and 1-1.7 nl C_2H_4/g/h, respectively) were in the same range of that obtained by Ding *et al.* (1998) at 20ºC in fruit of the Mogi cultivar. Although the rate of fruit respiration for loquat fruit is relatively high and comparable to that of other climacteric fruit (Biale and Young, 1981), the results indicate that Algerie loquats have a non-climacteric ripening physiology, in agreement with the observations in fruits of other cultivars (Hamauzu *et al.*, 1997; Ding *et al.*, 1998).

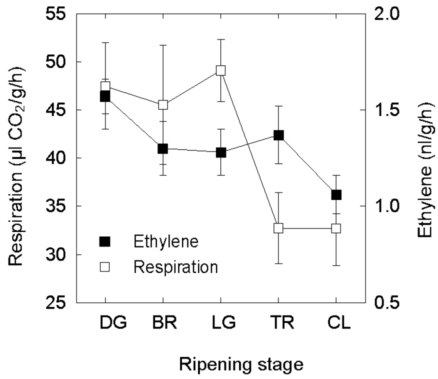

Fig. 2. Respiration rate and ethylene production in loquat fruit (cv. Algerie) harvested at different ripening stages. The ripening stages are describe in legend of Fig. 1.

Storage at 20ºC of fruit harvested at commercial maturity (more than 10ºBrix) from trees growing under field conditions, corroborated also the non-climacteric behaviour of loquat fruit (Fig. 3). After 2 weeks of storage, the respiration rate and ethylene production were reduced by a 48% and 56%, respectively, as compared with that of freshly harvested fruit. Under these storage conditions, fruit colour progressively increased and the content of soluble solids remained without important alterations. Acidity of the fruit juice showed a substantial decrease and after 3 weeks at 20ºC it was about one third of the initial. Malic acid is the main organic acid in loquat fruit, accounting for more than 90% of total acids in ripen fruit, with a minor contribution of citric, succinic and fumaric acid (Lin *et al.,* 1999). Ding *et al*. (1998) determined that the content of malic acid was almost halved after 20 days of storage at 20ºC and others acids remained constant. Thus, the rapid decline in fruit acidity appears to be the main factor affecting loquat fruit quality. Since the content of soluble solids did not suffer major changes during ripening at 20ºC, the progressive lost in acidity is the critical factor for the lack of the characteristic and attractive equilibrated flavour of loquat fruits.

Quality and physiological changes during storage at low temperature

The effect of storage at 2ºC on the evolution of different quality and physiological parameters of loquat fruits harvested at commercial maturity were analysed. Fruits were cold stored for up to 8 weeks and after different periods of time, they were transferred to 20ºC for 7 days to simulate shelf-life conditions. Fig. 4 shows an almost linear rate of weight loss during storage at 2ºC, reaching at the end of the storage period a 6% reduction of the initial weight. This behaviour is also similar to that observed in Mogi fruits during storage at 1 and 5ºC (Ding *et al*., 1998). Simulation of shelf-life induced a rapid and relatively constant effect on the rate of weight loss, since around a 2% of weight was lost after 7 days at 20ºC in fruits stored for different lengths of time at 2ºC. Colour of the skin increased slowly during cold storage but, interestingly, it increased after simulation of the shelf-life. Ding *et al.* (1998) reported that although skin colour slightly declined during cold storage of Mogi fruit, the content of β-carotene increased. In Algerie fruit, development of the skin colour progressed after storage and shelf-life, reaching an *a/b* Hunter ratio similar to that obtained in fruits stored at 20ºC, although at minor rate. This indicates that probably the synthesis of carotenoids is impaired at low temperature but may be stimulated upon fruit rewarming, and then fruit can be marketed after storage with an appropriated peel colour.

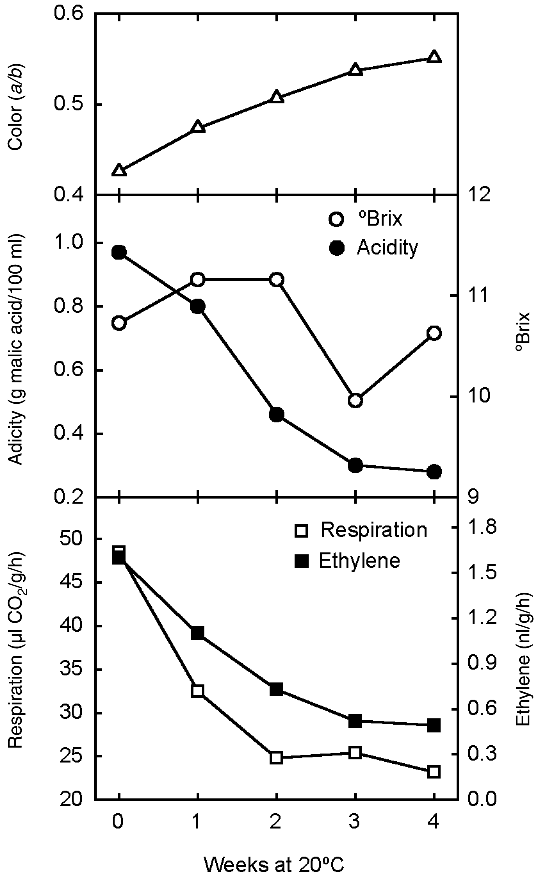

Fig. 3. Changes in fruit color, acidity, soluble solids content, respiration rate and ethylene production in mature loquat fruit (cv. Algerie) stored for up to 4 weeks at 20ºC.

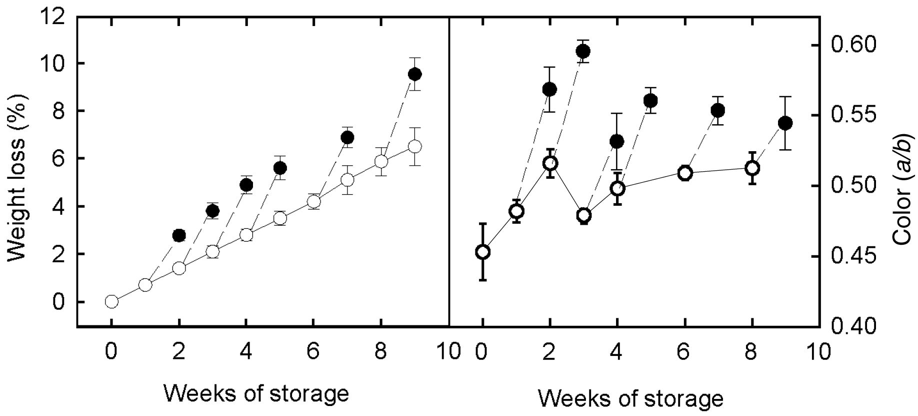

Fig. 4. Weight loss and color changes in loquat fruit (cv. Algerie) stored for up to 8 weeks at 2ºC (open circle) and after simulation of shelf-life for 7 days at 20ºC (close circle).

During storage at 2ºC, fruit maturation index (ºBrix/acidity) increased, doubling the value of freshly harvested fruit after 2 months storage. Transference to 20ºC for 7 days also increased the maturation index, being the effect more prominent after 1 month storage (Fig. 5). This increase in the maturation index is mainly a consequence of the important decline in fruit acidity, that after 2 months at 2ºC was about a 50%. Simulation of shelf-life produced a more marked reduction in fruit acidity, and a 30 to 40% decrease was attained after 7 days at 20ºC (Fig. 5). By contrast, no important alterations in the content of soluble solids were observed under both cold storage and shelf-life conditions, ranging between 10.2 and 11.5ºBrix throughout the whole period. In loquat, sucrose is the main soluble sugar in ripe fruit (Hirai, 1980; Gariglio *et al.*, 2002) but its content declined during cold storage (Ding *et al.*, 1998). However, glucose, fructose and sorbitol remained constant or slightly increased during cold storage, determining that total sugar content remained with minor changes upon storage. Malic acid substantially declined during storage under low temperature (Ding *et al.*, 1998). Taken together, it can be concluded that the rapid loss in fruit acidity is the main factor that determinates the organoleptic quality of loquat. Storage at low temperature has been shown to be inefficient to retain the acid content in the fruit and after stimulation of shelf-life conditions the reduction in acidity was even more prominent. Therefore, special care should be taken to the decrease in acidity during long-term storage, since it is the main factor responsible for the loss of the typical flavour and palatability of loquat fruit.

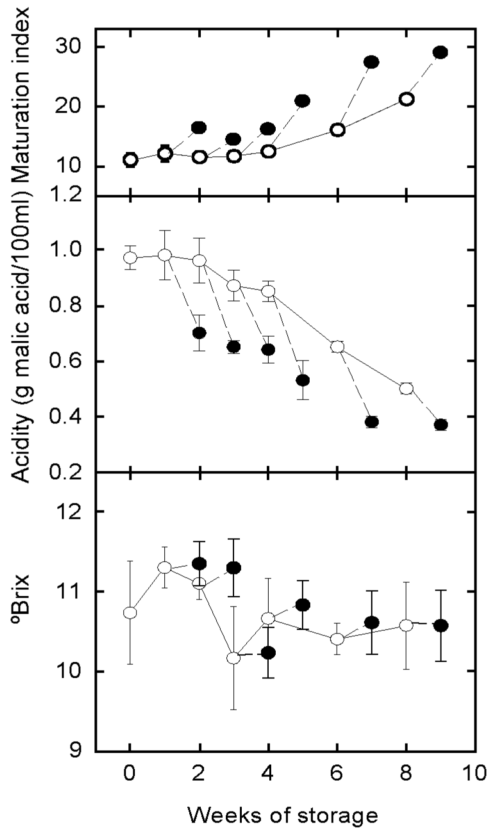

Fig. 5. Evolution of the maturation index (ºBrix/acidity), acidity and soluble solids content in loquat fruit (cv. Algerie) stored for up to 8 weeks at 2ºC (open circle) and after simulation of shelf-life for 7 days at 20ºC (close circle).

Respiration rate and ethylene production were substantially reduced by storage at 2ºC (Fig. 6). After 1 week of cold storage, respiration and ethylene production were 7.4 and 8.4-times lower than in freshly harvested fruit. Prolonged storage at 2ºC slightly increased the respiration rate but ethylene production remained unchanged. In Mogi loquat, similar reduction in respiration and ethylene production by low temperature storage has been also observed (Ding *et al.*, 1998). After simulation of shelf-life conditions, the respiration rate increased, and the magnitude of this response was lower as longer was the time of cold storage. The increase in ethylene production after transference to 20ºC was similar for fruit stored for different periods at 2ºC. Activation of ethylene synthesis upon fruit rewarming is a phenomenon observed in fruits of many species, as persimmon (Woolf *et al*., 1997), grapefruits (Schirra, 1993), pears (Wang *et al*., 1971), cherimoya (Alique *et al*., 1994), squash (Mc Collum, 1989) and nectarines (Zhou *et al*., 2001), and has been associated with development of chilling injury symptoms. In Algerie loquat, chilling injury was low during storage at 2ºC but considerably increased after the fruit were warmed up, reaching a chilling injury index around 1 (slight symptoms) (Fig. 7). Whether the burst in ethylene production is linked to the induction of chilling symptoms remains to be determined, as the role of ethylene production in chilling injury of loquat fruit has not been yet established, and discrepancies in this relationship have been found in fruit of different species (Ben-Amor *et al*., 1999; Lafuente *et al*., 2001; Zhou *et al*., 2001).

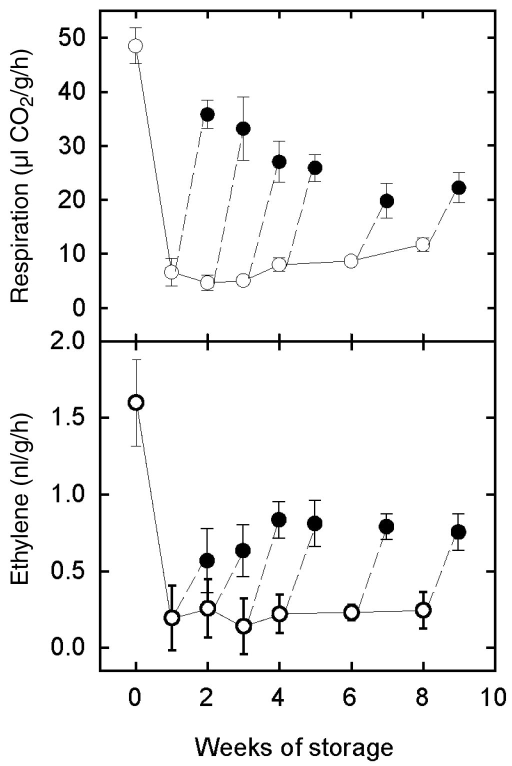

Fig. 6. Respiration rate and ethylene production in loquat fruit (cv. Algerie) stored for up to 8 weeks at 2ºC (open circle) and after simulation of shelf-life for 7 days at 20ºC (close circle).

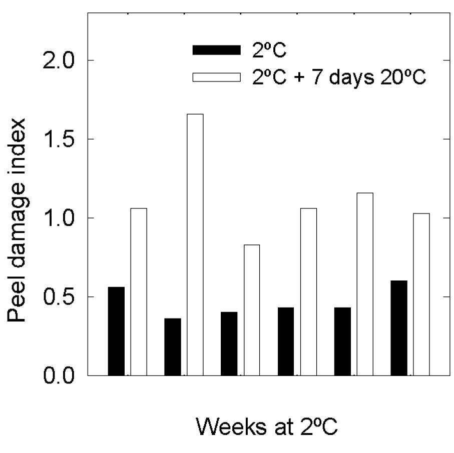

Fig. 7. Index of peel damage in loquat fruit (cv. Algerie) stored at 2ºC and after simulation of shelf-life for 7 days at 20ºC.

From the results reported in this work we can conclude that loquat fruit from Algerie cultivar has a non-climacteric ripening physiology. Different ripening-related changes (peel colour, acidity and soluble solids content) are not coordinated during the ripening process. Storage at 2ºC maintained fruit colour and the content of soluble solids, and delayed the decrease in acidity. After simulation of shelf-life (7 days at 20ºC) the marked reduction in fruit acidity is the main factor affecting fruit quality.

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References

Alique, R., Zamorano, J.P., Calvo, M.L., Merodio, C. and de la Plaza, J.L. (1994). Tolerance of cherimoya (*Annona cherimola* Mill) to cold storage. *J. Amer. Soc. Hort. Sci.*, 119: 524-528.

Ben-Amor, M., Flores, B., Latche, A., Bouzayen, M., Pech, J.C. and Romojaro, F. (1999). Inhibition of ethylene biosynthesis in antisense ACC oxidase mRNA prevents chilling injury in Charentais cantaloupe melons. *Plant Cell Environ.*, 22: 1579-1586.

Biale, J.B. and Young, R.B. (1981). Respiration and ripening in fruit – Retrospect and prospect. In: *Recent Advances in the Biochemistry of Fruits and Vegetables*, Fried, J. and Rhodes, M.J.C. (eds). Academic Press, London, pp. 1-39.

Bleiholder, H., Buhr, L., Feller, C., Hack, H., Hess, M., Klose, R., Meier, U., Stauss, R., van de Boom, T. and Weber, E. (1996). *Compendio para la Tipificación de los Estados Fenológicos de Especies Mono- y Dicotiledóneas, Escala BBCH Extendida*. BASF SG, Germany.

Ding, C.K., Chachin, K., Hamauzu, Y., Ueda, Y. and Imahoti, C.Y. (1998). Effects of storage temperatures on physiology and quality of loquat fruit. *Postharvest Biol. and Technol.*, 14: 309-315.

Ding, C.K., Chachin, K., Ueda, Y., Imahoti, C.Y. and Wang, C.Y (2002). Modified atmosphere packaging maintains postharvest quality of loquat fruit. *Postharvest Biol. and Technol.*, 24: 349-348.

Gariglio, N., Castillo, S., Juan, M., Almela, V. and Agustí, M. (2002). *El Níspero Japonés. Técnicas para Mejorar la Calidad del Fruto*. Generalitat Valenciana, Spain.

Giovannoni, J. (2001). Molecular biology of fruit maturation and ripening. *Ann. Rev. Plant Physiol. and Plant Molec. Biol.,* 52: 725-749.

Hamauzu, Y., Chachin, K., Ding, C.K., and Kurooka, H. (1997). Difference in surface colour, flesh firmess, physiological activity, and some components of loquat fruits picked at various stages of maturity. *J. Jap. Soc. Hort. Sci.*, 65: 859-856.

Hirai, M. (1980). Sugar accumulation and development of loquat fruit. *J. Jap. Soc. Hort. Sci.*, 49: 347-353.

Lafuente, M.T., Zacarías, L., Martínez-Tellez, M.A., Sánchez-Ballesta, M.T. and Dupille, E. (2001). Phenylalanine ammonia-lyase as related to ethylene in the development of chilling symptoms during cold storage in Citrus fruits. *J. Agric. Food. Chem.,* 49: 6020-6025.

Lelievre, J.M., Latche, A., Jones, B., Bouzayen, M. and Pech, J.P. (1997). Ethylene and fruit ripening. *Physiol. Plant.,* 101: 727-732.

Lin, S., Sharpe, R.H. and Janick, J. (1999). Loquat: Botany and horticulture. *Hort. Rev.*, 23: 233-276.

Martinez-Calvo, J., Badenes, M.L. and Llácer, G. (2000). *Descripción de Variedades del Níspero Japonés*. Generalitat Valenciana, Spain.

Martínez-Calvo, J., Badenes, M.L., Llácer, G., Bleiholder, H., Hack, H. and Meier, U. (1999). Phenological growth stages of loquat tree [*Eriobotrya japonica* (Thunb.) Lindl.]. *Ann. Appl. Biol.*, 134: 353-357.

Mc Collum, T.G. (1989). Physiological changes in yellow summer squash at chilling and non-chilling temperature. *Hort. Sci.*, 24: 633-635.

Schirra, M. (1993). Behavior of Star Ruby grapefruit under chilling and non-chilling storage temperature. *Postharvest Biol. and Technol.*, 2: 315-327.

Wang, C.W., Mellenthin, W.M. and Hensen, E. (1971). Effect of temperature on development of premature ripening in Bartlett. *J. Amer. Soc. Hort. Sci.*, 96: 122-126.

Woolf, A.B., Ball, S., Spooner, K.J., Lay-Yee, M. and Ferguson, I.B. (1997). Reduction of chilling injury in the sweet persimmon 'Fuyu' during storage by dry air heat treatments. *Postharvest Biol. and Technol.*, 11: 155-164.

Zhou, H-W., Dong, L., Ben-Arie, R. and Lurie, S. (2001). The role of ethylene in the prevention of chilling injury in nectarines. *J. Plant Physiol.*, 158: 55-61.