



Environmentally Friendly and
Safe Technologies for Quality
of Fruits and Vegetables

Editor

Carla Nunes, *FCT, Universidade do Algarve, Faro, Portugal*

Editorial Board

Brion Duffy, *Agroscope FAW Wädenswil Bacteriology, Switzerland*

Carla Nunes, *FCT, Universidade do Algarve, Portugal*

Christian Larrigaudiere, *IRTA-Institut de Recerca i Tecnologia Agroalimentàries, Spain*

Josef Streif, *Inst. Sonderkulturen & Produktsphysiologie, Hohenheim, Germany*

Maribela Pestana, *FCT, Universidade do Algarve, Portugal*

Maria Graça Barreiro, *Instituto Nacional de Investigação Agrária, Portugal*

Maria Dulce Antunes, *FCT, Universidade do Algarve, Portugal*

Miguel Salazar, *CICAE, Instituto Universitário Dom Afonso III, Portugal*

Mustafa Erkan, *Akdeniz University, Turkey*

Paolo Bertolini, *Universita de Bologna, Italy*

Pol Tijkskens, *Wageningen University, Netherlands*

Shimshon Ben-Yehoshua, *A.R.O. Volcani Centre, Israel*

Susan Lurie, *A.R.O. Volcani Centre, Israel*

The papers contained in this book report some of the peer reviewed Proceedings of the International Conference “Environmentally friendly and safe technologies for quality of fruit and vegetables”, but also other papers related with the subject were included. The manuscripts were reviewed by the Editor and Editorial Board, and only those papers judged suitable for publication were accepted. The Editor wish to thank to all the reviewers and authors for their contribution.

Authors are responsible for content and accuracy of their papers.

Proceedings of the International Conference “Environmentally friendly and safe technologies for quality of fruit and vegetables”, held in Universidade do Algarve, Faro, Portugal, on January 14-16, 2009. This Conference was a joint activity with COST Action 924.

Convener

Carla Nunes, *Universidade do Algarve, Portugal*

Scientific Committee

Carla Nunes, *Universidade do Algarve, Portugal*

Amílcar Duarte, *Universidade do Algarve, Portugal*

Angelos Kanellis, *Aristotle University of Thessaloniki, Greece*

Bart Nicolai, *Katholieke Universiteit Leuven, Belgium*

Brion Duffy, *Agroscope FAW Wädenswil Bacteriology, Switzerland*

Christian Larrigaudiere, *IRTA-Institut de Recerca i Tecnologia Agroalimentàries, Spain*

Domingos de Almeida, *Universidade do Porto, Portugal*

Josef Streif, *Inst. Sonderkulturen & Produktsphysiologie Hohenheim, Germany*

Krzysztof Rutkowski, *Research Inst. of Pomology and Floriculture, Poland*

Maria Dulce Antunes, *Universidade do Algarve, Portugal*

Maria da Graça Barreiro, *Instituto Nacional de Investigações Agrárias, Portugal*

Mustafa Erkan, *Akdeniz University, Turkey*

Paolo Bertolini, *Universita de Bologna, Italy*

Pol Tijsskens, *Wageningen University, Netherland*

Shimshon Ben-Yehoshua, *A.R.O. Volcani Centre, Israel*

Organizing Committee

Carla Nunes, *Universidade do Algarve, Portugal*

Amílcar Duarte, *Universidade do Algarve, Portugal*

Bart Nicolai, *Katholieke Universiteit Leuven, Belgium*

Maria Dulce Antunes, *Universidade do Algarve, Portugal*

Maria Emília Costa, *Universidade do Algarve, Portugal*

Maribela Pestana, *Universidade do Algarve, Portugal*

Miguel Salazar, *Instituto Universitário Dom Afonso III, Portugal*

Sponsors

COST, European Cooperation in the field of

Scientific and Technical Research

Fundação para a Ciência e a Tecnologia

International Association of Students in Agriculture
and Related Sciences, Faro

Serviço Técnico Pós-colheita do IRTA em Portugal

Algarve.resorts.net

Câmara Municipal de Faro

Câmara Municipal de Albufeira

Câmara Municipal de Aljezur

Câmara Municipal de Lagos

Câmara Municipal de S. Brás de Alportel

Crédito Agrícola, Caixa do Algarve

A Farrobinha

80 g

C.N. Kopke & C^ª

PrimeDrinks, S.A.

Uniprofrutal

Frutas Mourinho

07. SHELF-LIFE OF RIPENING 'ROCHA' PEAR: EFFECTS OF THE ORCHARD IRRIGATION REGIME ON QUALITY AND FLUORESCENCE PARAMETERS

Elsa Elias¹, Anabela Bernardes da Silva¹, Rosário Antunes², Jorge Marques da Silva^{1*}

¹Universidade de Lisboa, Faculdade de Ciências, Dep. de Biologia Vegetal and Centro de Biodiversidade, Genómica Integrativa e Funcional, Edifício C2, Campo Grande, 1749-016 Lisboa, Portugal

²FRUTOESTE – Coop. Agrícola de Hortofruticultores do Oeste, CRL, EN 8, Carrascal, 2665-009 Azueira, Portugal

*E-mail: jmsilva@fc.ul.pt

Abstract

The effect of the orchard irrigation regime on the on-shelf ripening of *Pyrus communis* L. var. 'Rocha' fruit was studied and the use of chlorophyll a fluorescence as a tool to assess the maturation of fruit was evaluated. Minimal (F_o) and maximal (F_m) fluorescence and maximal photochemical efficiency of PSII reaction centers (F_v/F_m) were measured in pear grown in irrigated (Ir) and non-irrigated (Nlr) orchards and stored for two months in cold under normal atmospheric conditions, after which fruits were removed from the refrigerated chambers and held at room temperature (approx. 20 °C) for 14 days (d). Measurements were made on the day of removal from refrigerated storage ($t=0$) and after 4, 7, 10 and 14 d at 20 °C. Total chlorophyll content (Chl $a+b$) of pears skin was measured as well as the pulp firmness and the total content of soluble solids (SSC). At 0 d at room temperature, Ir fruit, although with a lower chlorophyll content, was firmer than Nlr fruit but after 14 d at room temperature no differences were observed between them. No significant differences were generally observed in SSC either between Ir and Nlr fruit or during ripening. All fluorescence parameters decreased in Ir and Nlr fruit, with F_o and F_v/F_m lower in Ir fruit after 2 months of cold storage while in F_m no significant differences were observed between the irrigation treatments. The correlation of firmness and chlorophyll content with SSC was always weak in both irrigation regimes. In contrast, the correlation between firmness and chlorophyll content was always strong as well as the relationship between firmness and the fluorescence parameters. The maximal fluorescence (F_m) was the parameter that had the best correlation with fruit firmness. The irrigation regimes applied to 'Rocha' pear orchards seems to influence the ripening of 'Rocha' pear fruit with a more steeply ripening of the fruit grown in irrigated orchards characterized by a greater loss of firmness and chlorophyll fluorescence.

Keywords: Chlorophyll fluorescence, fruit ripening, orchard irrigation regime, shelf-life

Introduction

The adoption of a proper irrigation strategy is crucial for sustainability since it could save water and reduce irrigation costs (Behboudian & Mills 1997). However, post-harvest fruit quality must also be taken into account when defining the irrigation regime. Visual fruit sorting in packing houses do not consider intrinsic characteristics such as fruit firmness and sugar content. On the other hand, the techniques to measure those characteristics are destructive. Special attention has been given to the application of chlorophyll fluorescence as a non-destructive method to evaluate the quality of fruit (Song *et al.* 1997). Although it has been shown that the application of this technique is species and variety dependent, the influence of fruit growth conditions on the relation between fluorescence and fruit quality is unknown. The variety 'Rocha' of *Pyrus communis* L. is a Portuguese pear produced mainly in the western region of Portugal. The aim of this study was to understand how the ripening of 'Rocha' pear fruit is influenced by the orchard irrigation regime and to determine possible relationships between chlorophyll fluorescence parameters and fruit quality.

Materials & Methods

'Rocha' pear fruits were collected from irrigated (Ir) and non-irrigated (Nir) orchards and stored at 0 °C under normal (0.035% CO₂+21%O₂) atmospheric conditions. In Ir orchards each trees received 600-850 liters of irrigation water per year, while in Nir orchards the trees received only rainfall water. During the 2004 fruit growing season (May to July) Nir orchards received only approximately 3% of the water supplied to the Ir orchards. Fruit chlorophyll *a* (Chl *a*) fluorescence was measured with a pulse amplitude modulation fluorometer (PAM 101 Chlorophyll Fluorometer, Germany). Fruit was adapted to dark at room temperature for one hour before the values of minimal (F_o) and maximal (F_m) fluorescence and maximal photochemical efficiency of PSII reaction centers (F_v/F_m) were determined. Firmness (*F*) and the total soluble solids content (SSC) were respectively determined with a penetrometer FT 327 (TR di Turoni & C.s.n.c., Italy) and a refractometer PR-32 (Atago, USA.). ANOVA, regression and correlation analysis were performed using Origin 7.5 (OriginLab Corporation, USA). Significant correlations were established when $p < 0.05$.

Results

At time 0 no significant differences were observed in the SSC and F_m between Ir and Nir. On the contrary, Ir fruit was slightly firmer and had lower F_o and total chlorophyll content and higher F_v/F_m than Nir fruit (Fig 1,2). During ripening, as expected, firmness decreased in fruit from both irrigation regimes. The decrease of firmness on the first 4 d of ripening was more pronounced in Ir fruit (83%) than in Nir fruit (61%) but no differences were found afterwards (Fig 1A).

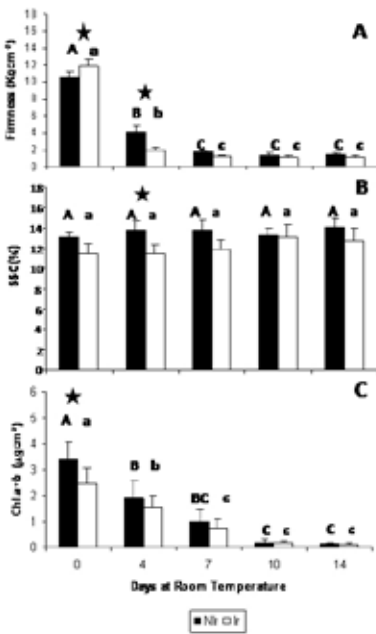


Fig 1. Fruit firmness (1A), total content of soluble solids (SSC) (1B), chlorophyll content (Chl *a*+*b*) (1C) of 'Rocha' pear fruit grown in irrigated (Ir) and non-irrigated (Nir) orchards during 14 d ripening at room temperature after two months of cold storage. Different letters indicate significant differences between d at room temperature in each irrigation regime; differences between Ir and Nir are marked with an asterisk (*) ($p < 0.05$) (mean + sd, n=5).

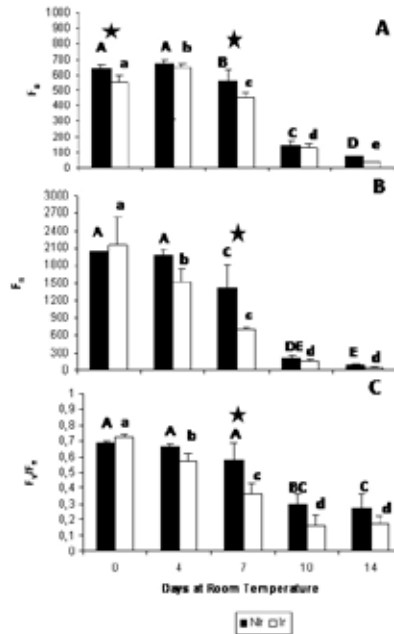


Fig 2. Minimal fluorescence (F_o) (2A), maximal fluorescence (F_m) (2B) and maximal photochemical efficiency of PSII (F_v/F_m) (2C) of 'Rocha' pear fruit grown in irrigated (Ir) and non-irrigated (Nir) orchards during 14 d ripening at room temperature after two months of cold storage. Different letters indicate significant differences between d at room temperature in each irrigation regime; differences between Ir and Nir are marked with an asterisk (*) ($p < 0.05$) (mean + sd, n=5).

No significant trend of SSC variation was found during ripening. Although mean daily values of SSC were slightly higher in Nlr (13.02-14.01%) than in Ir (11.84-12.70%) only at day 4 the difference was significant (Fig 1B). The decrease of chlorophyll content (Fig 1C) along ripening was similar in both irrigation treatments. However, in the first 4 d at room temperature, the decrease of these pigments was more pronounced in Nlr fruit (44%) than in Ir fruit (35%). In both irrigation treatments, the decrease of the total chlorophyll content during ripening seems to follow the softening of the fruit pulp. All fluorescence parameters decreased significantly with the progress of fruit ripening independently of the orchard irrigation regime (Fig 2). The main differences between the irrigation regimes were found after 7 d (d) of ripening, when F_m and F_v/F_m already decreased, respectively, 67% and 49% in Ir fruit but only 31% and 16% in Nlr fruit.

The SSC (Fig 3A) almost did not change as firmness decreased. Chlorophyll content of Ir fruits was relatively unchanged in the firmness range 14 - 4 kg cm⁻² while in Nlr fruits it showed a decreasing trend starting at the highest firmness measured (Fig 3B). Fruit firmness had a non-linear relationship with chlorophyll fluorescence parameters in both orchard irrigation regimes (Fig 4A-C). The maximal fluorescence (F_m) (Fig 4B) was the parameter that had the best correlation with fruit firmness (around 0.86 in Nlr fruit and 0.9 in Ir fruit), followed by F_o (Fig 4A) and F_v/F_m (Fig 4C). The lowest correlation coefficients were found between F_o and firmness of Ir fruit (0.74) and between F_v/F_m and fruit firmness of Nlr fruit (0.78).

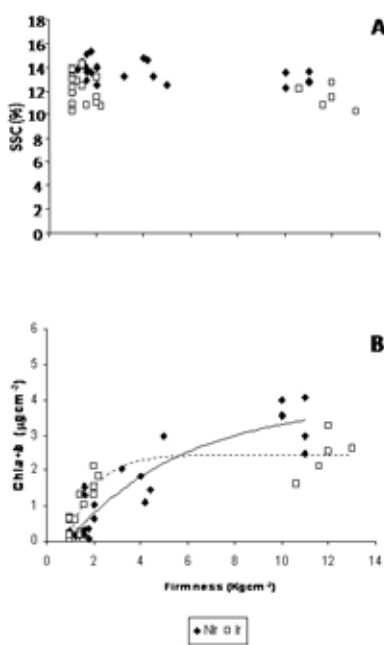


Fig 3. Correlation of total soluble solids content (SSC) (3A) and chlorophyll content (Chla+b) (3B) with firmness (F) of 'Rocha' pear fruit grown in irrigated (Ir) and non-irrigated (Nlr) orchards during ripening at room temperature after two months of cold storage. Points represent measurements taken during 14 d at room temperature (n=25).

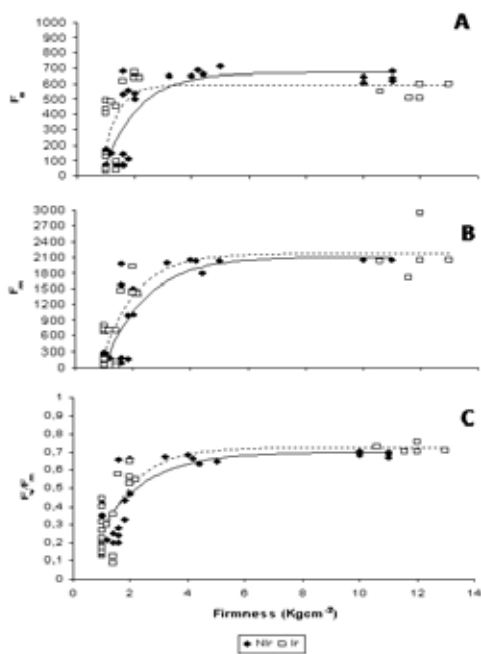


Fig 4. Correlation of minimal fluorescence (F_o) (4A), maximal fluorescence (F_m) (4B) and maximal photochemical efficiency of PSII (F_v/F_m) (4C) with firmness (F) of 'Rocha' pear fruit grown in irrigated (Ir) and non-irrigated (Nlr) orchards during ripening at room temperature after two months of cold storage. Points represent measurements taken during 14 d at room temperature (n=25).

Discussion

In spite of the significant initial decrease of firmness, F/F_m remained relatively constant after 4 d at room temperature, suggesting that it is not related to early changes in the ripening process. However, in pear, SSC (Fig 1B) almost did not change during ripening, suggesting that it is not a good indicator of maturation, which is also supported by the weak correlation of this parameter with firmness (Fig 3A). As expected, the chlorophyll content of pear skin seems also to be related with fruit maturation, as suggested by the strong ($r=0.91$) non-linear correlation observed between this parameter and firmness (Fig 3B). Fruit firmness had a non-linear relationship with chlorophyll fluorescence parameters in both orchard irrigation regimes (Fig 4). Cavaco *et al.* (2009) also found that the correlation between firmness and light reflectance at some wavelength bands was markedly different depending on ripening stage. The maximal fluorescence (F_m) (Fig 4B) was the parameter that had the best correlation with fruit firmness (around 0.86 in Nlr fruit and 0.9 in Ir fruit), followed by F_o (Fig 4A) and F/F_m (Fig 4C). Similar results were obtained by Bron *et al.* (2004) in 'Golden' papaya fruits. The present results indicate that the irrigation regimes applied to 'Rocha' pear orchards influences the shelf-life of 'Rocha' pear fruit, with steeper ripening of the fruit grown in irrigated orchards, characterized by a greater loss of firmness and chlorophyll fluorescence. The chlorophyll fluorescence is a potential tool to assist the quality evaluation and pear fruit maturation. The relationship between chlorophyll fluorescence and quality indexes is cultivar dependent and despite the good results that have been obtained, some problems still remain to be solved. The influence of a large number of environmental parameters during growth and storage, picking time and storage duration can also affect the relationship between chlorophyll fluorescence and quality attributes of fruits.

Acknowledgments

This work was supported by the "Programa Operacional de Agricultura e Desenvolvimento Rural (AGRO)".

References

- Behboudian MH, Mills TM. 1997. Deficit irrigation in deciduous orchards. *Hort Rev* 21:105-31
- Bron IU, Ribeiro RV, Azzolini M, Jacomino AP, Machado EC. 2004. Chlorophyll fluorescence as a tool to evaluate the ripening of 'Golden' papaya fruit. *Postharvest Biol Tec* 33:163-73
- Cavaco A, Pinto P, Antunes MD, Marques da Silva J, Guerra R. 2009. "Rocha" pear firmness predicted by a Vis/NIR segmented model. *Postharvest Biol Tec* 51:311-9
- Lichtenthaler HK. 1987. Chlorophylls and carotenoids: pigments of photosynthetic membranes. *Method Enzymol* 148:350-82
- Song J, Deng WM, Beaudry RM, Armstrong PR. 1997. Changes in chlorophyll fluorescence of apple fruit during maturation, ripening and senescence. *HortScience* 32:891-6