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Gamma irradiation as a phytosanitary treatment for fresh pome fruits produced in Patagonia

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ABSTRACT

Argentina produces 1.8 million tons/year of apples (*Malus domestica* L.) and pears (*Pyrus communis* L.) in the Patagonia region. *Cydia pomonella*, codling moth, and *Grapholita molesta*, Oriental fruit moth, (*Lepidoptera*: *Tortricidae*) are quarantine pests in pome fruits. Irradiation is a promising phytosanitary treatment because a dose of 200 Gy completely prevents pest adult emergence. A pilot irradiation process of commercially packaged 'Red Delicious' apples and 'Packham's Triumph' pears was performed in an irradiation facility with a Cobalt 60 source. Quality analyses were carried out at 0, 2, 4, 6 and 8 months of storage (1 °C, RH 99%) to evaluate fruit tolerance at 200, 400 and 800 Gy. Irradiation at 200 and 400 Gy had no undesirable effects on fruit quality (pulp firmness, external colour, soluble solids content (SSC), titratable acidity (TA) and sensory evaluations). Irradiation of 'Red Delicious' apples and 'Packham's Triumph' pears can be applied as a commercial quarantine treatment with a minimum absorbed dose of 200 Gy (to control codling moth and Oriental fruit moth) and <800 Gy (according to quality results).

1. Introduction

Argentina produces 1.8 million tons/year of pome fruit in the growing area of Patagonia region (49,200 ha orchards). In 2008, Argentina exported 466,756 tons of fresh pears (*Pyrus communis* L.) and 238,825 tons of fresh apples (*Malus domestica* L.) mainly to Russia, Brazil, the United States and the European Union (*source*: National Service of Agricultural Food Quality and Health-SENASA)

Since 2005, Patagonia region was declared free area of *Ceratitis capitata* (Wiedemann), Mediterranean fruit fly (Diptera: *Tephritidae*) by the United States Animal Plant and Health Inspection Service (APHIS, 7CFR 319.56-5 Revision 20090219003). However, Argentine apples and pears are hosts for *Cydia pomonella*, codling moth, and *Grapholita molesta*, Oriental fruit moth, (*Lepidoptera*: *Tortricidae*). Codling moth is the quarantine pest that inflicts the most severe damage to pome fruit, and hence to the regional economy. The SENASA, jointly with the Plant and Animal Health Commission of the Patagonian Phytosanitary Barrier Foundation (FunBaPa), have developed a pest control program to reduce the pest damage below a threshold level that may ensure competitiveness for trade. However, during 2007–2008, codling moth damage was still 0.67% in apples and 0.22% in pears (*source*: SENASA).

Argentine apples and pears for export to markets that have imposed quarantine treatments for codling moth and/or Oriental fruit moth are certified to be absent of live larvae using a risk mitigation system, cold treatment (0 or 3 °C for 40 or 90 continuous days, respectively) or methyl bromide treatment (2.5 h with 32 gr/m^3 at 21 °C) (*source*: SENASA)

Alternative quarantine treatments are needed because cold treatment requires ⩾40 days, fumigants are being replaced due to fruit damages and health and environmental problems, and codling moth causes around USD 30 million/year losses (*source*: SENASA 2008). The US Department of Agriculture (USDA) approved treatments for Argentine apples and pears are cold treatment (T107-a-1: 1.11 °C or 1.67 °C for 15 or 17 days, respectively) and irradiation (T105-b-2: minimum absorbed dose of 200 Gy). Twenty nine countries approved irradiation of fresh fruits and/or vegetables for disinfestation and/or quarantine control (*source*: Food Irradiation Clearances Database, IAEA). Australia, India, Mexico, Thailand, Vietnam and the US currently apply irradiation for phytosanitary purposes.

The minimum absorbed dose of 200 Gy is required to prevent *C. pomonella* (Mansour, 2003) and *G. molesta* (Hallman, 2004) adult emergence from fifth-instars with Probit-9 efficacy at 95% confidence level. In a commercial-scale irradiation fruit may receive doses 2 or 3 times greater than the minimum absorbed dose. Consequently, fruit must at least tolerate 3 times the minimum absorbed dose required for treatment efficacy.

Drake et al. (1999) found that <900 Gy can be used as a quarantine treatment for 'Fuji', 'Gala', 'Granny Smith' apples and 'Anjou', 'Bosc' pears, and that fruit response to irradiation was cultivar dependant. Olsen et al. (1989) found that <1000 Gy can be used as a quarantine treatment for 'Red Delicious' apples.

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In Argentina, 65% of the apple harvest corresponds to 'Red Delicious' cultivar and 30% of the pear harvest to 'Packham's Triumph'. The objective of this research is to establish the maximum tolerable dose that preserves postharvest quality of 'Red Delicious' apples and 'Packham's Triumph' pears to implement irradiation as a phytosanitary treatment for *C. pomonella* and *G. molesta* in Argentina.

2. Materials and methods

2.1. Fruit material

'Red Delicious' apples (32 boxes with 100 "commercial" grade apples per box) and 'Packham's Triumph' pears (44 boxes with 120 "premium" grade pears per box) were obtained from different production areas of the Río Negro Valley, North Patagonia. Apples were harvested in the third and fourth week of March 2007 and pears in the third and fourth week of February 2007. Fruit was trucked 1000 km to Ezeiza Atomic Centre, Buenos Aires, for irradiation treatment (mimicking normal transport conditions at 1 °C to the Central Market of Buenos Aires). Upon arrival, boxes were stored in cold chamber (1 °C, RH > 99%).

2.2. Irradiation treatments

Gamma radiation treatments with doses of 200, 400 and 800 Gy were carried out in a semi-industrial irradiation facility with a Cobalt 60 source, and an activity of 583.805 Ci (21.62 PBq), at room temperature with a dose rate of 30.15 Gy/min. Silver dichromate and Fricke dosimeter systems were used.

2.3. Apple and pear quality evaluation

Upon irradiation, irradiated and control (0 Gy) fruit boxes were stored in cold chamber (1 °C, RH > 99%).

Apple quality was assessed after 0, 2, 4 and 6 months and pear quality after 0, 2, 4, 6 and 8 months in cold storage. Sixty fruits per treatment divided in 3 replicates (20 each) were used for each storage time and 20 fruits per treatment were also tested after 7 days at 20 °C, to recreate shelf-life under retail conditions. Quality parameters studied were firmness, pH, titratable acidity (TA), total soluble solids content (SSC), SSC/TA maturity index, external colour, visual disorders and decay. Pulp firmness was determined at two opposite points per fruit with an Instron (Instron Corporation, Model 1122) equipped with a probe of 11 mm for apples and 8 mm for pears, and values were reported in Newtons (N). Titratable acidity and total soluble solids content were determined from 2 aliquots of expressed juice of a longitudinal slice from each fruit. SSC (°Brix) was measured with a hand refractometer (Link RHB-32ATC calibrated at 20 °C). TA was determined by titration of 10 mL of juice diluted in 100 mL of d.i. water with 0.1 N NaOH to pH 8.2 and expressed as percentage of malic acid. External colour indexes in the space of even contrast colours were measured at 3 points on each fruit with a colorimeter (Konica Minolta CM-2600D). In the regime of light reflection, parameters L*, a* and b* were measured according to CIE L*a*b* scale (Commission International de l'Eclairage, 1978) and hue angle was calculated as $h^\circ = \arctan(b^*/a^*)$ (McGuire, 1992). Index L* represents lightness from black to white. Index a* indicates redness when positive and greenness when negative, and b* yellowness when positive and blueness when negative. Before each series of measurements the spectrophotometer was calibrated with a standard of white colour.

Data were analyzed by GLM LS-means procedure using ANOVA and Tukey Test at $P \leqslant 0.05$ (SAS Institute 8.0).

3. Results and discussion

3.1. Dosimetry

The average dose uniformity ratios for the doses of 200, 400 and 800 Gy were 1.27 (212/257 Gy), 1.27 (397/505 Gy) and 1.17 (749/878 Gy) for apples, and 1.27 (200/256 Gy), 1.24 (381/473 Gy) and 1.22 (800/979 Gy) for pears.

3.2. Apple quality

Firmness of 'Red Delicious' apples tended to decrease with dose from 200 to 800 Gy, and with cold and shelf storage (Table 1). Drake et al. (1999) found that firmness loss for 'Fuji' apples occurred at doses > 600 Gy, for 'Gala' apples at doses > 300 Gy and for 'Granny Smith' apples at doses > 150 Gy. Olsen et al. (1989) reported acceptable firmness loss of 'Red Delicious' apples with < 1000 Gy. In a previous study, 'Red Delicious' apples harvested on February 2004 and irradiated with 200 and 400 Gy showed appropriate exportation pulp firmness and acceptable sensory values (above 6 points on a 9-point hedonic scale) in an out-of-panel test for aroma, appearance, flavour, juiciness, texture and general acceptability (Yusef et al., 2004). In this study, firmness loss of 'Red Delicious' apples occurred at 200 Gy presumably due to late harvest (late March). At the beginning of the study control apples were damaged (15% of bitter pit and mechanical damage) and mature (> 90% of starch degradation), and already had the minimum firmness acceptance level for export (*source*: Secretariat of Agriculture, Livestock, Fisheries and Food (SAGPyA) Resolutions 554/83 and 313/88).

Maturity of 'Red Delicious' apples, represented by the coefficient SSC/TA, tended to increase with irradiation and with cold storage (Table 2). Drake et al. (1999) found that TA loss due to storage time in 'Fuji' 'Gala' and 'Granny Smith' apples was not influenced by irradiation. Olsen et al. (1989) reported TA loss of 'Red Delicious' apples due to irradiation.

External colour of 'Red Delicious' apples, represented by index h°, was not influenced by irradiation (Table 3). Index h° tended to increase with cold and shelf storage, indicating a redder and yellower appearance. Correspondently, more positive a* and b* values were observed with cold storage (data not shown).

Decay incidence due to external and internal mould infection increased with storage time and decreased with the incremental doses from 15.8% at 0 Gy to 12.1% at 200 Gy, 8.8% at 400 Gy and 7.1% at 800 Gy.

Table 1
Firmness (N) LS-means of 'Red Delicious' apples as influenced by irradiation dose, cold storage (CS, months at 1 °C) and shelf storage (SS, days at 20 °C).

CS	0	2	4	6	0	2	4	6
SS	0	0	0	0	7	7	7	7
0 Gy	$55.0d^2$	$44.1b^1$	$43.8c^1$	$39.6c^0$	$41.4a^{0*}$	$44.7b^0$	$41.6b^0$	$42.9c^0$
200 Gy	$49.6c^2$	$41.8ab^1$	$43.7c^1$	$35.5b^0$	$42.2a^{1*}$	$39.7a^1$	$42.4b^1$	$29.3ab^{0*}$
400 Gy	$42.6b^2$	$41.1a^2$	$37.8b^1$	$33.8ab^0$	$38.6a^{1*}$	$38.7a^1$	$35.4a^1$	$25.6a^{0*}$
800 Gy	$40.2a^1$	$41.5a^1$	$34.1a^0$	$32.8a^0$	$39.0a^1$	$38.3a^1$	$35.6a^1$	$31.1b^0$

Values within a column followed by the same letter are not significantly different at 95% confidence level. Values within a row followed by the same number are not significantly different at 95% confidence level. Values at SS 7 days for each dose and CS time followed by the symbol * are significantly different at 95% confidence from their correspondent value at SS 0 days.