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Research paper

Comparative evaluation of the effect of methyl bromide fumigation and phytosanitary irradiation on the quality of fresh strawberries

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ABSTRACT

Fresh strawberries are highly perishable and have a short shelf-life especially when the cold chain is not maintained. Strawberries exported to Asia are currently fumigated with methyl bromide for phytosanitary purposes, which exposes strawberries to warm temperatures for several hours and air freight without temperature control, resulting in a shelf life of just a few days in the destination country. Irradiation offers an efficacious alternative to fumigation and can be performed on cold fruit. This study was conducted to compare the quality of strawberries subject to methyl bromide fumigation or irradiation followed by simulated commercial air freight shipment of strawberries to Asian markets and ambient temperature retail display. 'Amado' and 'Marquee' strawberries were treated with methyl bromide fumigation or gamma irradiation at 400 Gy. The strawberries were wrapped with insulated foil and ice packs for 24 h to mimic commercial air freight conditions then maintained at ambient temperature for two days to simulate retail display. The strawberries lasted only 2 days at ambient temperature, however berries treated with methyl bromide had the highest severity of decay. Irradiated berries were an average of 20% softer than fumigated strawberries and 23% softer than control fruit, however, consumer sensory panels showed no difference in liking for irradiated, fumigated, or control strawberries. Titratable acidity, soluble solids content, color values, and ascorbic acid content were unchanged due to treatments. The marketability of irradiated strawberries was similar to the control and better than the fumigated berries, thus, irradiation at 400 Gy could serve as a viable alternative to methyl bromide fumigation for export of air freighted strawberries.

1. Introduction

The U.S. is the largest strawberry (*Fragaria x ananassa*) producer in the world accounting for 29% of the global production (Boriss et al., 2014). In 2013, 121,880 metric tons were exported, about 12% of the total production (CSC, 2014). Import permits for certain countries specify phytosanitary treatments for strawberries to mitigate the threat of insects such as two spotted spider mite (*Tetranychus urticae*) and western flower thrip (*Frankliniella occidentalis*) which commonly infest strawberries. Australia, for example, specifies that strawberries from the U.S. be fumigated with methyl bromide (MeBr) at the rate of 48 g/m^3 for 3 h at a pulp temperature of no less than 18 °C (DAFF, 2015). MeBr is the most common phytosanitary treatment used on strawberries, however, it depletes the ozone layer and is scheduled to be phased out under the Montreal Protocol (EPA, 2011).

One promising alternative to MeBr fumigation is irradiation. Low dose irradiation is highly effective in sterilizing insect pests and is increasingly being used worldwide to treat fruit for export (Hallman, 2013). The efficacy of treatment at low doses and lack of heat make irradiation particularly suitable as a phytosanitary treatment for fresh fruit. The United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS, 2015) has approved a generic dose of 400 Gy for sterilization of most insects except *Lepidoptera* pupae and adults, however doses are not to exceed 1000 Gy (USDA APHIS, 2015). Strawberries have high tolerance to irradiation, however the beneficial impacts on shelf-life have been observed at dose levels far exceeding the 400 Gy generic dose for phytosanitary purposes. Hussain et al. (2007) observed that irradiation at 1500 and 2000 Gy significantly delayed mold growth and extended the storage shelf life by up to 8 days. Cheour and Mahjoub (2003) observed delays in decay with doses of 1000 and 2000 Gy, and complete inhibition of gray mold development with a dose of 4000 Gy.

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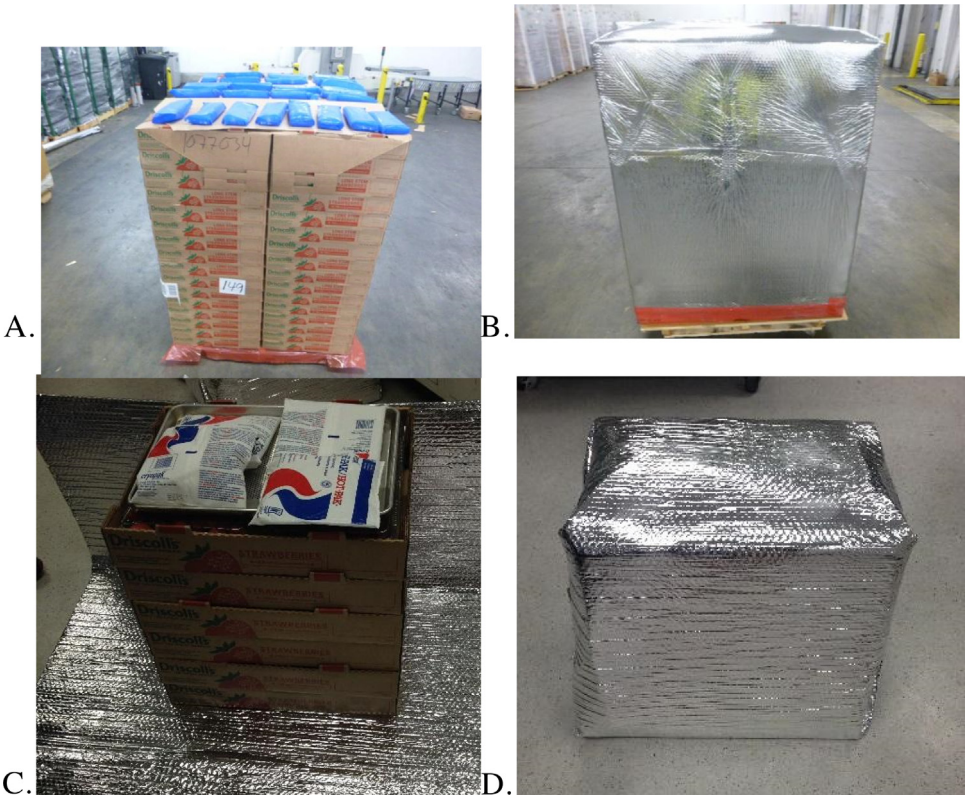

Fig. 1. Commercially air freighted strawberry pallets maintained cold (A) with ice packs (B) with ice packs and wrapped with insulated foil. Chapman University air freight simulation maintained cold (C) with ice packs (D) with ice packs and wrapped with insulated foil.

Strawberries are highly perishable and should be stored at 0 ± 0.5 °C immediately following harvest to help retain marketability (UCD, 2013). Maintenance of the cold chain and quick shipment is essential for optimizing the shelf life (Zegota, 1988), since the fruit can shrivel, develop fruit rot, and bruising quickly if cooling is delayed (Kader, 1991). During air freight to overseas destinations, however, the cold chain can be significantly compromised, particularly if the fruit is fumigated. Fumigation with MeBr involves exposing strawberries to warm temperatures for several hours (18 °C for 3 h, in the case of Australia) followed by de-gassing, which can take another 2–5 h (USDA APHIS, 2015). During air freight, temperature is generally not controlled in the cargo hold and highly dependent upon the location of the fruit in the airplane, the airline, and the duration of flight. To keep the temperature of the fruit as cool as possible, freight companies wrap pallets of cold fruit with insulation material such as reflective bubble insulation and cold gel packs but product temperatures can increase to 13–16 °C during the flight. Upon arrival in the destination country, the cold chain is often compromised further due to lack of refrigerated warehousing or retail. These breaks in the cold chain and subsequent retail display at ambient temperatures result in just a few days of shelf life in the destination country.

Use of irradiation as a phytosanitary treatment would allow the fruit to be kept cold during the treatment as compared to fumigation which requires exposure of the fruit to warm temperatures for several hours. Thus, the hypothesis of this study is phytosanitary irradiation treatment would be a better treatment than MeBr fumigation in preserving the quality of fresh strawberries. The objective of this study was to determine the effect of phytosanitary irradiation and MeBr fumigation on the shelf-life of strawberries under conditions simulating air transport to Asia followed by retail display.

2. Materials and methods

2.1. Sample procurement

The entire experiment was conducted on two varieties of strawberries at two different times each, for a total of four separate trials. Marquee strawberries were harvested on June 13th and June 27th, 2014 in Santa Maria, CA. Amado strawberries were harvested in October 24th and November 7th 2014 in Oxnard, CA. The strawberries were harvested at 70% ripeness and transported to the packinghouse where they were placed into 454 or 907 g (1 or 2 lb) clamshells and held at ambient temperature for pickup within 2 h.

Strawberries were transported directly to the fumigation facility (Raymond Express, Los Angeles, CA) (257 km from Santa Maria or 97 km from Oxnard) where they were assigned to one of four treatments, refrigerated control (RC), air freight control (AC), irradiation plus air freight (AI), and methyl bromide fumigation plus air freight (AM). A fourth of the berries were fumigated with methyl bromide (AM). The remaining berries were cooled to 1 °C in a forced air cooler. The next day, another fourth of the untreated strawberries were taken to Sterigenics, Inc., a contract irradiation facility in Tustin, CA (~66 km), for irradiation treatment. All the strawberries were then transported to Chapman University (Orange, CA) (~11 km) for air freight and retail display simulation.

2.2. Methyl bromide fumigation of strawberries

The strawberries were allowed to reach a temperature of 21 °C prior to being fumigated with MeBr. The boxes were fumigated using MeBr for 2 h at a concentration of 32 g/m^3 at a temperature of 21 °C as is the procedure for export to South Korea (USDA APHIS, 2015) and left to degas in the fumigation chamber for 4–5 h, and subsequently cooled to 1 °C in a forced air cooler.