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Hot water treatments combined with cold storage as a tool for *Ectomyelois ceratoniae* mortality and maintenance of Deglet Noor palm date quality

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ABSTRACT

Insect infestation caused by *Ectomyelois ceratoniae* or carob moth is one of the main postharvest disease pests of date fruit and causes serious economic losses during storage and export. Methyl bromide is the most widely used fumigant on stored dates in several countries although it will be withdrawn in 2015 in developing countries. Heat treatment technologies, such as hot water treatment (HWT) are currently a relatively simple, non-chemical alternative that can kill quarantine pests (insects and fungi) in perishable commodities. In this article, the proper HWT treatments (dose and time) that causes *E. ceratoniae* mortality while avoiding quality losses in Deglet Noor fruit when stored for 30 d at 2 °C followed by a retail period of 4 d at 23 °C was studied. The results show that the use of HWT of 50 °C for 10 min, 55 °C for 5 min and 60 °C for 3 min lead to *E. ceratoniae* mortality, also lowering the microbial growth (<1 log cfu g^{-1} for mesophilic and <2 log cfu g^{-1} for yeasts and molds). HWT induced a slight reduction in skin color (luminosity and hue angle), antioxidant activity (10–15% in FRAP and 17–22% in DPPH) and total phenolic compounds (9–14%). Overall quality was slightly reduced using 60 °C for 3 min although all treatments remained above the limit of marketability as there was no heat damage. Storage time also reduced these parameters, as well as monosaccharides (glucose and fructose) and the concentrations of some amino acids such as alanine, aspartic acid and proline. HWT used as an alternative to chemical treatments to control carob moth yielded optimum-quality Deglet Noor date fruit that could be exported to developed countries.

1. Introduction

Date palm fruit (*Phoenix dactylifera* L.) have been a staple food for thousands of years in the Middle East and North Africa. In Tunisia, dates represent the main resource of oases and play a major role in the development of the national economy (Haouel et al., 2010). The Deglet Noor cultivar is the most popular native date variety because of its large size, texture, and particular taste and color. The world's production of dates has increased from 2.8 million in 1985 to 7.2 million tons in 2011 (FAOSTAT, 2013). Nevertheless, dates are subjected to many diseases and pests that decrease their yield and deteriorate their quality around the world. Dates are very often affected by insect infestation from Coleopterans, Lepidopterans and Hymenopterans, as well as by pathogenic bacteria (such as *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus*), and by several mold and yeast genera (Jemni et al., 2014). In North Africa, and especially in Tunisia and Algeria, one of the most economically important pest species is the carob moth (Lepidoptera: Pyralidae), *Ectomyelois ceratoniae* (Zeller), which infests 20% of the harvestable crop annually, causing great economics losses (Dhouibi, 2013). It vastly decreases the marketable quality of dates and compromises exports (Zouba et al., 2009).

Dates destined for export undergo a process of conditioning to preserve and improve their quality (Haouel et al., 2010). Chemical control using fumigation is the most economical postharvest treatment tool for managing stored-product pests; indeed, methyl bromide is the most widely-used fumigant used on stored dates in

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Tunisia and in several other countries (Zare et al., 2002). Nevertheless, the use of this fumigant is being phased out as it is considered harmful to human health as well as for the environment. Due to this the Montreal Protocol of the United Nations Environment Program on ozone-depleting substances (UNEP, 1995), called for its worldwide withdrawal in 2005 in developed countries, and in 2015, its withdrawal in developing countries (MBTOC, 1998) will be a requirement. Because of this, the replacement of this product has become urgent, as its use will not be allowed under any circumstance.

In recent years, several methods have been investigated as alternatives to methyl bromide fumigation in a number of commodities and pests. These include new techniques that are aimed for the avoidance of postharvest pests and diseases, as well as microbial contamination of dates, and to improve the quality of the product during the storage period. Traditional and new postharvest techniques that have been developed for date fruit include irradiation (Azelmat et al., 2006), microwave (Zouba et al., 2009; Abo-El-Saad et al., 2011), essential oils (Haouel et al., 2010), ozone (Abo-El-Saad et al., 2011; Jemni et al., 2014), vacuum and modified atmosphere packaging (Achour et al., 2003), heat treatments (Ben-Lalli et al., 2013), etc. There has been growing interest in the application of postharvest heat treatments for controlling pests, insects and microbial agents, as a secure and non-chemical method to control postharvest diseases (Lurie, 1998; Spadoni et al., 2013; Strano et al., 2014; Zhou et al., 2014). Heat treatments can be applied through hot water dips or treatments (HWT), vapor heat or hot dry air. Heat treatment technologies are currently a relatively simple, non-chemical alternative to methyl bromide that can kill quarantine pests (insects and fungi) in perishable commodities, as well as control some postharvest diseases (U.S. EPA, 1996). Furthermore, heat has been approved as a quarantine treatment by the U.S, Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) against pests for several perishable commodities. HWT by immersion consists of submerging the commodity in a hot-water bath at a specific temperature for a specified period of time, which is based on the commodity being treated and the pests that may be present (APHIS, 1993). This type of HWT is shorter in duration and a more efficient heat transfer medium than hot air, and when properly circulated through a load of fruit, a more uniform temperature profile is established (Shellie and Mangan, 1994). However, there have been problems with heat damage and maintenance of pulp temperatures that make HWT problematic (Mulas and Schirra, 2007).

HWT have been effective in controlling *Epiphyas postvittana* and *Pseudococcus longispinus* on Fuyu persimmons (Lester et al., 1995; Lay-Yee et al., 1997), *Ceratitis capitata* in mango fruit (Jacobi et al., 2001) and *Cydia pomonella* in sweet cherries, maintaining overall acceptable fruit quality (Feng et al., 2004). The mean lethal time (LT) values (estimated treatment × mortality) was dependent on the type of insect and fruit.

Therefore, the aim of the current work was to find the proper HWT (dose and time) that causes *E. ceratoniae* mortality while avoiding a loss of marketable quality in Deglet Noor palm date fruit, by studying their effect during cold storage and after a retail sale period.

2. Material and methods

2.1. Chemicals

Ultrapure water was obtained from a Milli-Q system (Academic Gradient A10, Millipak™ 40, Millipore, Paris, France). Sodium hydroxide and methanol (HPLC grade) were purchased from Panreac Química S.A. (Castellar del Vallés, Barcelona, Spain). Individual amino acids and sugars, hydrochloric acid (minimum 37%), sodium chloride, methanol, sodium sulfate, DPPH (2,2-diphenyl-1-picrylhydrazyl radical), gallic acid (3,4,5-trihydroxy-benzoic acid), and Folin–Ciocalteu's phenol reagent were purchased from Sigma–Aldrich Química S.A. (Madrid, Spain). Peptone water, plate count and rose bengal were from Scharlau (Barcelona, Spain).

2.2. Experiment 1: E. ceratoniae *mortality under different HWT treatments*

2.2.1. Plant material

Naturally-infested dates (Deglet Noor cv.) of date palm (*P. dactylifera* L.) were collected, at the beginning of November, from an experimental palm orchard (33°55′0″ North, 8°8′0″ East), belonging to the National Institute of Agronomy of Tunisia located in Tozeur (South west, Tunisia). Naturally-infested dates are characterized by the presence of silk closing the calyx. These fruit, at the fully mature 'Tamar' stage, were carefully collected by professional entomologists from the Department of Plant Protection (National Institute of Agronomy of Tunisia).

About 50 kg of infested dates, attached to a small portion of spikelet, were placed in polystyrene boxes and transported about 500 km by car to Tunis, then by plane to Madrid (Spain), and again by car about 400 km to the Pilot Plant of the Technical University of Cartagena. Total transport duration was about 7 d, at 8 °C. After arrival, fruit were maintained at room temperature (22 °C) and infested dates were manually detached from the spikelets and grouped according to heat dipping treatments. The fruit moisture content was found to be 25%. It is important to measure this parameter, as it influences the speed of heat transfer, with the heating being much faster when moisture content is high (Zouba et al., 2009).

These HWT treatments were performed by placing the fruit in a drilled stainless steel container and dipping it into a 50 L thermostatic water bath, with time and temperature control, continuous stirring and water recirculation. To confirm exact temperature, a digital thermometer was used to control water bath temperature and another was inserted in the center of one date fruit (Fig. 1) for the duration of the heating process. The HWT applied were based on previous experiments that were effective in controlling *E. postvittana* and *P. longispinus* on Fuyu persimmons, with LT_{99} mean values (estimated treatment times for 99% insect mortality) ranging from 31.3 to 66.9 min, respectively, when 44 °C were used. However, that time was reduced to 8.1 min for *E. postvittana* and 13.3 min *for P. longispinus* when the temperature increased to 54 °C (Lester et al., 1995; Lay-Yee et al., 1997). In sweet cherries, HWT provided 100% *C. pomonella* larvae mortality using 50 °C for 10 min and 54 °C for 6 min (Feng et al., 2004). According to this information, to study larvae *E. ceratoniae* mortality in date

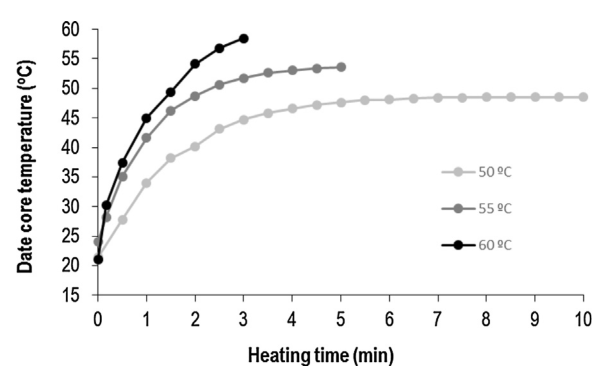

Fig. 1. Temperature mapping of the date core under hot water treatments.