Crop Protection 49 (2013) 8–20

Contents lists available at SciVerse ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Review

A review of the management alternatives for controlling fungi on papaya fruit during the postharvest supply chain

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ARTICLE INFO

Article history:
Received 14 August 2012
Received in revised form
18 January 2013
Accepted 19 February 2013

Keywords:
Chemical control
Physical control
Non-traditional alternatives
Postharvest pathogens

ABSTRACT

Due to their flavor and nutritional characteristics, papaya fruit are consumed worldwide. As a tropical commodity, storage has serious limitations that result in their rapid deterioration and high incidence of rots during handling and storage. Postharvest handling of papaya differs according to destination. For export markets, there are well-defined postharvest steps established that include technologies that generally avoid disease incidence. For national markets, the postharvest chain is short but characterized by poor handling practices that can result in serious losses due to microorganisms. Anthracnose is considered the main postharvest disease, but development of other rots may also limit good fruit quality, as is the case with, among others, stem-end rots. Control of papaya rots for export markets are applied in accordance with import–export regulations, while for the national market it has typically relied on synthetic fungicides; however, due to their already known 'side-effects' on humans and the environment, other alternatives alone or combined should be tested in integrated technologies. We reviewed the available literature on different control methods to reduce postharvest diseases during papaya storage, including those that reported on their effects on fruit quality. Wax combined with fungicides and heat is currently in use. Other methods, such as the application of irradiation, antagonistic microorganisms and natural compounds [e.g. chitosan and plant derivatives (extracts, essential oils and isothiocynates)], are still under evaluation, but have yielded promising initial results. The application of various organic salts and minerals and modified and controlled atmosphere technologies using ozone and volatiles such as 1-methycyclopropane are also under experimentation. We believe that research areas that include pre-harvest experimentation aimed at reducing postharvest diseases on papaya fruit should be taken into account. Finally, the integration of more than one control method will reduce the incidence of rots, and therefore improve and extend the storage life of this important commodity.

1. Introduction

Papaya (*Carica papaya* L.) belongs to the Caricaceae family. It is believed to be native to southern Mexico and Central America, mainly in Guatemala. According to Morton (1987), papaya cultivation spread through other continents after Spanish colonization of the Americas. Currently, papaya is grown in most subtropical and tropical regions of the world. Since 2000, the leading papaya-producing countries have been Brazil, Mexico, Nigeria, India and Indonesia (www.faostat/fao.org/site/339/default.aspx). The Food and Agriculture Organization reported worldwide papaya production of approximately 11.2 million tons in 2010. Papaya fruit are mainly consumed fresh; however, due to their high nutritional value, there is increasing interest in finding other alternatives for their consumption, for example in juices, nectars, puree, concentrates and fresh-cut and dehydrated cubes (Salunkhe and Desai, 1984; Paull and Chen, 1997; Díaz, 2003; González-Aguilar et al., 2008). Papaya losses are due to various factors such as mechanical damage, chilling injury, diseases and fruit overipeness. Alvarez and Nishijima (1987) mentioned that losses in surface and air shipments may reach 40% and 30% respectively, and losses due to diseases account for almost 93% of the losses. Salunkhe and Desai (1984) reported that estimated papaya postharvest losses range from 40 to 100% depending on the production zone. In a study

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http://dx.doi.org/10.1016/j.cropro.2013.02.011

carried out from 1972 to 1985 in the New York City markets, it was reported that in 62% of the surveyed shipments, the main damage on papayas was due to different fungi (Capellini et al., 1988). According to Ventura et al. (2004), postharvest rots may be divided into three types: superficial, peduncular and internal rots accounting in some cases for 100% of the total losses. Other postharvest losses were due to overipeness (47.4%), soft fruit (16.7%) and bruise damage (14.8%). Additional surveys carried out by Paull et al. (1997) reported that in 73.3% of the inspected cartons, molds and rots were found, while mechanical injuries such as 'sunken areas on skin', 'scarring on the skin' and 'bruising of flesh' were also responsible for a high percentage of losses of this fruit. However, there is a general agreement that postharvest diseases caused by fungi are the most important problem during handling and storage of this fruit (Singh, 2010).

There are several important postharvest fungi, with *Colletotrichum gloeosporioides*, causing anthracnose, being the most common and widespread papaya pathogen worldwide (Chau and Alvarez, 1983a; Yon, 1994; Aires et al., 2004; Casarrubias-Carrillo et al., 2002). Papaya anthracnose is a major limiting factor in storage and transit, and its importance lies in its influence throughout many other tropical regions where papaya is grown (Bolkan et al., 1976). No less important, there are other postharvest fungi associated with papaya that occur on a local level such as *Fusarium* spp, (fusarium fruit rot disease), *Alternaria solani* (alternaria fruit spot), *Rhizopus stolonifer* (rhizopus soft rot), *Penicillium digitatum* (penicillium rot), *Guignardia* spp. (guignardia spot), *Cercospora papayae* (cercospora black spot) and stem-end rot disease that may be caused by various fungi such as *Botryodiplodia theobromae*, *Phomopsis caricae-papayae*, *Mycosphaerella* spp. and *Phytophthota palmivora* (Nishijima et al., 1990; Alvarez and Nishijima, 1987; Guillén-Sánchez, 2001; Hewajulige and Wilson Wijeratnam, 2010) (Fig. 1). Other reports also consider the fungus *Stemphylium lycopersici* (Stemphylium rot) an important postharvest pathogen of papaya (Chau and Alvarez, 1983b; Rahman et al., 2008). Other minor diseases identified have been *Mucor* spp. and *Aspergillus* spp. (Ramos, 2006; Baiyewu et al., 2007). Only two bacteria have been reported during the postharvest storage of papaya and they are *Enterobacter cloacae* (internal yellowing diseases) and *Erwinia herbicola* (purple stain). Disease symptoms of these two bacteria are only observed internally (Nelson and Alvarez, 1980; Nishijima et al., 1987; Ploetz et al., 1998; Hewajulige and Wilson Wijeratnam, 2010); however, with few exceptions, fungal disease symptoms are visible externally and on ripe fruits, thereby reducing the marketability. With respect to papaya disease caused by virus (papaya ringspot virus), it is common in most papaya - producing areas worldwide. However, since symptoms may appear in plants at a very young stage, fruit usually cannot develop. By contrast, when symptoms occur in fruit, they become unsalable. Infection can be due to extended wet periods, lack of an integral hygiene control in the field (removal of fallen fruit and leaves) and mishandling during postharvest operations, thereby facilitating the entrance of the inoculum or hastening disease symptoms.

2. Generalities of papaya

2.1. Fruit morphology and cultivars

Papaya fruit is pear-shaped or round-shaped. Depending on the variety, weight may range from 0.5 to 5 kg. Skin color varies from

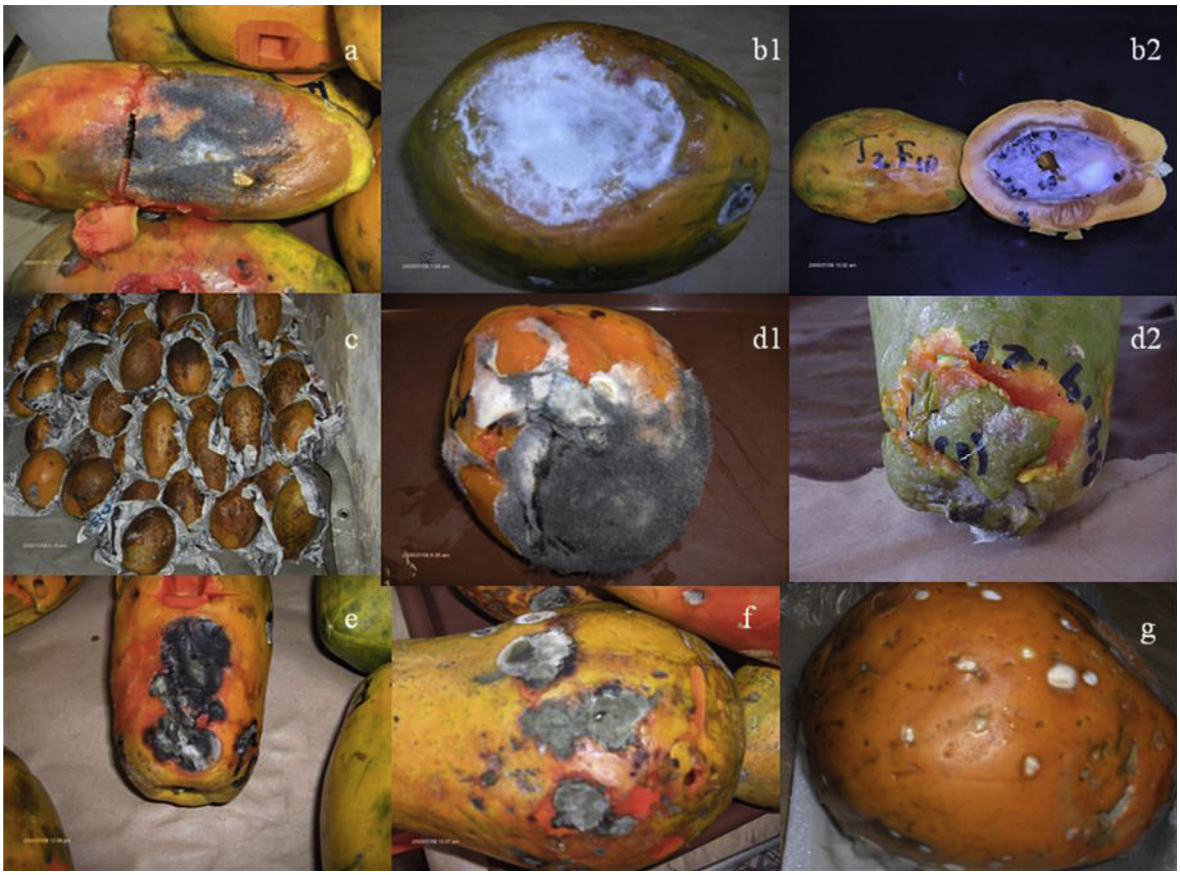

Fig. 1. Postharvest fungi of papaya cv. 'Maradol'. a) *Mucor* sp., b1, b2) *Fusarium oxysporum* c) *Colletotrichum gloeosporioiodes*, d1, d2) *Rhizopus stolonifer*, e) *Alternaria alternata*, f) *Penicillium digitatum*, g) *Aspergillus* sp..