Food Research International 44 (2011) 1254–1263

Contents lists available at ScienceDirect

Food Research International

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

Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain

Dharini Sivakumar [a,*], Yuming Jiang [b], Elhadi M. Yahia [c]

[a] Department of Crop Sciences, Tshwane University of Technology, Pretoria (West Campus), Pretoria, South Africa
[b] Agriculture, Food and Photochemistry, South China Botanical Garden, Chinese Academy of Sciences, China
[c] Autonomous University of Queretaro, Avenida de las Ciencias S/N, Juriquilla, Queretaro, 76230, Qro., Mexico

ARTICLE INFO

Article history:
Received 30 August 2010
Accepted 11 November 2010

Keywords:
Postharvest management practices
Fruit quality
Postharvest diseases
Invasive pests
Chilling injury

ABSTRACT

Mangoes are tropical/sub tropical fruit with a highly significant economic importance. Preferable quality attributes include freedom from external damages such as bruises, latex or sap injury and decay, uniform weight, colour, aroma, firmness (with little give away, not soft), shape and size. The fruit is rich in antioxidants and recommended to be included in the daily diet due to its health benefits such as reduced risk of cardiac disease, anti cancer, and anti viral activities. Maintenance of mango fruit quality during the supply chain depends on many aspects including adequate orchard management practices, harvesting practices, packing operation, postharvest treatments, temperature management, transportation and storage conditions, and ripening at destination. Postharvest losses are high during the supply chain due to harvesting fruit at improper maturity, mechanical damage during the whole chain, sap burn, spongy tissue, lenticels discolouration, fruit softening, decay, chilling injury, and disease and pest damage. The aim of postharvest treatments and management practices in the supply chain is to create suitable conditions or environments to extend the storage life and retain the quality attributes, nutritional and functional compositions. This review summarises the available research findings to retain the overall mango fruit quality and to reduce postharvest losses during supply chain by adopting suitable postharvest novel technologies.

1. Introduction

The mango, *Magifera Indica* L. is well known for its excellent exotic flavour and usually referred to as the king of fruit (Fig. 1). It is a dicotyledonous plant belonging to the order sapindales in the family *Anacardiaceae*. It is a popular and economically important fruit, widely cultivated in the tropics and subtropics. Mango was originated in the Indo-Burmese region (Subramanyam, Krishnamurthy, & Parpia, 1975; Tjiptono, Lam, & Mendoza, 1984). The fruit is eaten fresh and in several other by-products, including juices, nectars, purees (Ploetz, Zentmyer, Nishijima, Rohrbach, & Ohr, 1994). Commercial mango production is reported in more than 87 countries. The prominent mango producing countries are India, China, Thailand, Indonesia, Philippines, Pakistan and Mexico (Tharanathan, Yashoda, & Prabha, 2006). Mango production is increasing outside the traditional geographical regions of mango cultivations such as in Central and South America, Australia, South-east Asia, Hawaii, Egypt, Israel and South Africa, especially for export markets (Tharanathan et al., 2006). The most important exporting countries are Mexico (41% of the world market) followed by the Philippines (7.6%) and Pakistan (7.8%) (Sauco, 2004). Some mango fruit cultivars, such as from the Indian and the Sri Lankan regions, show strong aroma, intense peel colouration, delicious taste, and high nutritional value (Thanaraj, Terry, & Bessant, 2009). 'Alphonso' mango is considered as one of the best rated mango cultivar in the world, and some other cultivars (such as Ataulfo from Mexico) are becoming important in the markets. According to Lebrun, Plotto, Goodner, Ducamp, and Baldwin (2008), there are 49 species and thousands of mango cultivars. The popularity of the fruit in the international market is due to its excellent flavour, attractive fragrance, beautiful colour, taste and nutritional properties (Arauz, 2000). In addition, mangoes are good source of ascorbic acid, carotenoids and phenolic compounds, and other dietary antioxidants (bioactive compounds) (Talcott, Moore, Lounds-Singleton, & Percival, 2005). The cv. Nam Dok Mai No.4 contains total phenols ~3.42 mg (GAEg-1 DW) and reveals DPPH antioxidant capacity ranging from 10.94 to 28.16 μMTE/g (Gorinstein et al., 2010).

Consumption of mangoes can provide significant amounts of bioactive compounds with antioxidant activity.

Unfortunately, the consumers are experiencing inconsistent fruit maturity and ripening variability, sometimes even in a single consignment. Mango fruits have a short production season and storage life, and therefore fruit prices after seasonal peak can be very high and therefore may not be affordable by many consumers. The storage life of mangoes is limited to 2–3 weeks in air at 10 °C—15 °C (Yahia, 1998a). Variability in mango fruit quality is detected in the supply chain with respect to taste, flavour, colour, aroma, weight, size and shape, influenced by the production management practices. According to Kader (2002), quality performance of mangoes depends

* Corresponding author. Tel.: +27 21 382 5053; fax: + 27 21 382 5869.
E-mail addresses: dharinisivakumar@yahoo.co.uk (D. Sivakumar), ymjiang@scib.ac.cn (Y. Jiang), Yahia@uaq.mx, elhadiyahia@hotmail.com (E.M. Yahia).

0963-9969/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodres.2010.11.022

Fig. 1. Mango fruit.

largely on external and internal quality parameters. Consumer acceptance is higher for mangoes free from external damages including bruises, latex or sap injury, decay, uniform weight, colour and shape which are external quality attributes. Internal quality attributes include uniform and intense flesh colour, freedom from damage, and adequate acidity (or pH) and SSC (brix°), depending on cultivar and type of consumer preferences (consumers in different regions have different preferences). Mango flavour quality depends on the type of cultivar, stage of maturity at harvest; postharvest handling methods including the type of treatments, and incidence of mechanical damages or chilling injury, which can also affect fruit flavour (Kader, 2008a, 2008b).

Production and postharvest practices, novel technologies and packhouse management have a great impact on retaining mango fruit quality and on the supply chain. Preharvest and postharvest handling practices and treatments play a major role in ensuring that the fruit reach the consumers with the optimum organoleptic, nutritional and functional quality attributes. Therefore, the objective of this review is to summarise the available information and research findings to retain the overall mango fruit quality and to reduce postharvest losses during the supply chain by adopting suitable postharvest novel technologies.

2. Mango fruit composition and quality attributes

Mango fruit is born in panicle and belongs to the subtype indeliquescent drupe. The fruit is large, fleshy and differs in size, shape, colour, fibre content, aroma, flavour and taste depending on cultivars, and has a characteristic conical projection termed as 'beak'. The fruit can be differentiated into three parts, i.e. exocarp, the part that protects the fruit that is initially green and later changes to yellow or reddish or orangish depending on the cultivar and stage of ripening, and waxy. With advanced stage of maturity and ripening, chlorophyll content declines and carotenoids and/or anthocyanins tend to increase (Tharanathan et al., 2006). The mesocarp is the fleshy edible portion or the pulp, which is always yellow due to the presence of carotenoids (Ornelas-Paz, Yahia, & Gardea, 2008; Ornelas-Paz, Yahia, & Gardea-Bejar, 2007). The endocarp is the thick, tough, and leathery covering of the seed. The fruit has a single seed in the middle of the fruit, which is large, flat, and ovoid-oblong shaped. The edible portion contains mainly glucose, fructose and sucrose and the total sugar content of mangoes can vary from 11.5 to 25% depending on the type of mango and stage of ripeness. Different organic acids such as oxalic, citric, malic, succinic, pyruvic, adipic, galacturonic, glucuronic and mucic acids were reported to be produced by mango fruit, and citric is the major acid (Jain, Krishnamurthy, & Lal, 1959).

Mango fruit contains different classes of phytochemicals such as polyphenols, ascorbic acid and carotenoids, revealing health promoting properties mainly due to their antioxidant properties (Talcott et al., 2005). Polyphenols, gallic acid, gallotannins, mangiferin, quercetin, kaempferol, p-OH-benzioc acid, m-coumaric acid, p-coumaric acid and ferulic acid were reported in mango flesh (Saleh & El-Anasari, 1975; Schieber, Berardini, & Carle, 2003; Schieber, Ullrich, & Carle, 2000). Gallic acid and gallotannins were reported to decline during storage as a result of ripening or in association with loss of astringency which is a descriptive sensory attribute of mango (Lakshminarayanan, Subhadra, & Subramanyam, 1970). Haden and Ataulfo mangoes were reported to contain higher β-carotene content than Kent and Tommy Atkins (Ornelas-Paz et al., 2007).

3. Causes for quality loss

Mango postharvest losses are still very significant, especially considering that almost all the fruit are produced in developing countries. They are primarily due to harvesting fruit at improper maturity, mechanical damage caused during harvesting or improper field handling, sap burn, spongy tissue, lenticels discolouration, fruit softening, decay, chilling injury, and disease and pest damage, among others (Yahia, 1998a). Quality losses often occur due to tight fruit packing, using improper transport and inadequate field handling. Fruit losses during export can vary dramatically depending on postharvest handling and export conditions, especially with regard to rates of decay, pests and physiological breakdown.

4. Maturity and harvesting indices

Traditionally mango is harvested based on judgements by the growers by observing the appearance of the fruit. The selection of suitable maturity indices for harvest is very important. The quality and the postharvest life of mango fruit depend on the maturity stage at harvest. Therefore, the fruit has to be harvested at the suitable stage of maturity in order to develop the optimum sensory quality attributes and extended postharvest life (Yahia, 1998a). Immature fruit are more sensitive to chilling injury during cold storage and may fail to ripen adequately. Fruit harvested at over mature stage is highly susceptible to mechanical damage such as bruising, decay and water loss, resulting in quality deterioration (Yahia, 1998a). Over matured fruit show defects like jelly seeds or jelly pulp after harvest (Yahia, 1998a). Therefore, suitable maturity indices for harvesting are very important in order to minimise the quantitative and qualitative losses.

Generally, physical, physiological and chemical parameters are used to define the maturity stage. Physical methods to determine maturity in mango include softness of the cheek, peel colour, development of shoulder, and specific gravity (Kosiyachinda, Lee, & Poernomo, 1984). These factors are very useful, but their application depends on the type of mango, region of cultivation, and type of market and consumers. Age of the fruit is also considered as a simple method to confirm maturity, calculated from induction, full bloom and fruit set. Generally, harvest maturity in mango is reached about 12 to 16 weeks after fruit set (Yahia, 1998a). However, days from full bloom is most recommended, because they can be implemented as a standardized factor (Yahia, 1998a). The age of fruit (days) at a certain harvest maturity based on full bloom or fruit set varies according to different geographical regions and cultivation conditions. According