POSTHARVEST HANDLING OF FRESH CITRUS FRUIT: AN OVERVIEW

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Abstract

Citrus industry in many parts of the world, especially in developing countries, has been facing numerous postharvest problems, leading to both high quantitative as well as qualitative losses and an overall reduction in the profitability of the industry. The improved understanding of citrus physiology, interacting factors, and the latest technological advances has made it possible to reduce theses losses to a great extent and to make it a sustainable and profitable enterprise. The current paper will provide an overview of the postharvest handling of fresh citrus fruit.

Key words: Citrus, postharvest management, shelf life, quality

Citrus production and international trade in fresh citrus fruit has increased manifold during the last decade. World citrus production is around 73.3 million metric tons, with Brazil being largest producer, while European Union being the largest importer of citrus (Anonymous, 2004; FAO, 2003). Although citrus production in many citrus growing countries has increased, however, the overall profitability of the industry in developing countries has been limited by high postharvest losses due to the lack and/ or use of proper postharvest handling system of fresh fruit. From a sustainability and economic perspectives, there will be less investment needed to improve the situation through better postharvest management of the existing produce, compared with investing in increasing the production area to compensate for these losses (Kader, 2002). In order to improve its postharvest handling system, an understanding of the nature of citrus fruit, various factors influencing the postharvest shelflife and quality and the state of postharvest technology will be a pre-requisite.

Citrus is generally charcterised as less perishable fruit in comparison to loquat, lychee, fresh fig (Kader and Arpaia, 2002) and mango. However, in practice, the industry experience substantial postharvest losses due to carelessness and improper handling during its harvesting, storage, transportation and marketing, which cause bruises and injuries to fruit, resulting in various physiological disorders and fruit decay during storage and marketing chain. Being a non-climacteric fruit, citrus do not have the peculiar rise in ethylene production and respiration after harvest, as observed in climacteric fruits like apple and mango during fruit ripening. However, the endogenous ethylene or exogenously applied ethylene may have impacts on fruit shelf life and quality (Porat *et al*., 1999). Likewise, its rate of respiration, which is an important determinant of the fruit shelf life, is influenced by temperature, humidity, movement of air, composition of gases, bruises and microbial infection (Murata, 2001). According to Kader and Arpaia (2002), the most important factors affecting postharvest shelflife and quality include rootstock, cultivar, cultural practices, harvest conditions, and maturity stage, while the postharvest factors involve the operational effeciency, precooling, various fruit treatements (fungicide, waxes etc.) and storage conditions.

Harvest and quality considerations

Fresh citrus fruit needs to meet both internal fruit quality standards as well as the external fruit appearance (fruit colour, size, shape, peel firmness and texture, and free of surface blemish and creasing). Organolaptic taste and flavour of citrus fruit is determined by the levels of total soluble solids, total acidity and presence or absence of different aromatic compounds. The TSS/acid ratio varies between 7-9:1 for oranges and mandarins to 5-7:1 for grapefruit (Davies and Albrigo, 1994). Citrus fruit are generally harvested at full maturity, at which the fruit colour is fully developed. Too early harvesting results in chilling sensitivity, while too late cause fruit deformation puffing, granulation and senescent disorder of rind (Murata, 2001). Manual harvesting is the common practice worldwide. Plucking is used for all fruit except mandarins, which are to be picked by clipping. Improper harvesting techniques often cause damage like stem end bruising and torn skin. In Pakistan, the common practice of harvesting mandarins alongwith pedicels and bunch of leaves is a major source of fruit injuries during transportation. Further, these fruit will have short shelf life due to additional rate of respiration and transpiration (water loss) from the attached leaves. Harvested fruit are to be collected in the canvas baskets. Dropping off the harvested fruit on the ground causes bruises and increases respiration and ethylene production. It has been reported that dropping grapefruit through 1.2-1.8 m on a hard surface, caused increaed respiration and ethylene production (Vines *et al.*, 1968). Postharvest delay in field can cause considerable damge to fruit shelf life and quality.

Packhouse operations

In most of the packhouse, the operational line is: fruit from field brought into packhouse-blemished/damaged fruit discarded-fruits are washed (detergent and fungicides)-rinsed (fresh water)-waxed-dried-sorted-stamped-sized-packed-and then either temporarily held in cold store or transported to the market. However, there are variations in operational lines and operations may be modified, as under some conditions the process of degreening and colouring may also be needed.

Storage and shipping

Citrus is a wonderful fruit, as it can be stored ontree, even after attaining full maturity. However, the duration of ontree storage varies with the cultivars. In case of postharvest storage, mandarins are kept at 5-8 °C, while oranges at 4-8 °C, with relative humidity of 90-95% (Kader and Arpaia, 2002). Although, fruits could be stored at low O_2 (3-6%) and CO_2 (2.5-4%) concentrations for >5 months (Sun and Sun, 1998), however, controlled atmosphere is not commercially used due to high cost with little advantages. In Pakistan, the potential storage of Kinnow mandarin is yet to be exploited.

Insect pests, diseases and physiological disorders

Among the insect pests, a number of fruit flies e.g Mediterranean (*Ceratitis capitata* Wied.), Caribbean (*Anastrepha suspensa* Loew.), Mexican (*Anastrepha ludens* Loew.) and West indian (*Anastrepha obliqua* Macquart*)* (Murata, 2001), are of major qurantine concern in international trade. The importing countries are imposing strict regulations to save their territory from this pest. As regards Pakistan, Kinnow, being a late cv., is free from this pest. According to a latest survey on the type and prevelance of fruit flies at different locations in Punjab, there was no activity of fruit fly at the time of its maturity and the fruit remained completely free from this pest. However, two species of fruit flies i.e. *Bactrocera dorsalis* and *B. zonata* were present, the later being more active, and the main period of activity was Aug-Nov., especially in locations where the alternate hosts of fruit flies were present (Mahmood *et al*., 2004). Integrated pest management strategy must be used in order to reduce the incidence of fruit fly infestation. Since the fumigation treatment (Ethylene dibromide) is no more used throughout the world, various options to disinfect fruit from fruit flies at postharvest stage including heat (McGuire and Reeder, 1992; Miller and McDonald, 1991) and cold treatments (Underhill *et al*., 1995; Yoav *et al*., 2000), ionizing radiation (Hallman and Martinez, 2001) and combination of heat and controlled atmosphere (Shellie *et al*., 1997) are being explored. Other controlling techniques include Sterile Insect Technique (SIT), population suppression using bait stations, new selective insecticides, entomopathogenic nematodes and the integration of these methods (Yoav *et al*., 2000).

A number of postharvest diseaseses are responsible for fruit losses during storage. Some of them are the result of preharvest infections: Stem-end rot (*Diplodia*), black rot (*Alternaria*), Brown rot (*Phytophthora)* and anthracnose *(Colletotrichum);* while the others are due to postharvest (mainly due to injuries) infections: Green mold (*Penicillium digitatum*), blue mold *(Penicillium italicum)* , sour rot (*Geotrichum*) and trichoderma rot (*Trichoderma*) (Eckert, 1992). Fungicides to control postharvest diseases mainly include benzimidazole (thiabendazole, benomyl and carbendazim) and sterol inhibitors (imazalil, prochloraz and propiconazole) (Eckert, 1990). Experiments conducted locally on the control of postharvest decay in our commercial citrus cultivars including Kinnow, Feutrell's Early, Musambi, and grapefruit concluded that Benlate (300 ppm) and Topsin-M (500 ppm) were the most effective fungicides (Hussain *et al*., 1992). Effective disease mangement is possible through an integrated approach by reviewing the actual cause of infection, minimizing injuries during harvesting and transportation and proper fungicidal treatments.

Over the last decade there has been growing concern about food safety especially in fresh produce trade, and the limits of pesticides residues are being defined and restriction being imposed on the basis of MRLs. Biocontrol is being explored as an alternative to chemical control in postharvest pathological research, and developments have been made in controlling citrus green and blue molds (Obagwu and Korsten, 2003; Sun *et al*., 2003; Plaza *et al*., 2003).

A number of pre and postharvest factors contribute to the development of various physilological disoders which influence fruit quality of citrus fruit (Grierson, 1981), including nutritional deficiencies (Cu, B), sunburn, wind blemish, rind staining, puffiness, granulation, oleocellosis, peteca, stylar end breakdown, watery breakdown, chilling and freezing injury etc asc detailed by Murata (2001).

Use of edible coatings

Edible coating of fruits can result in the creation of a modified internal atmosphere, probably due to an effective blockage of the pores within the fruit, reducing respiration rate and improving postharvest quality. However, care should be taken to avoid anaerobic conditions (Perez Gago *et al*., 2003). The commercial waxes like carnauba and shellac are generally used, while resin and composite waxes eg. polysaccharide and shellac-beeswax, and vegetable oils etc are being researched for their effects on shelflife and fruit quality. In Fallglo tangerines (mandarins), resin and shellac solutions substantially reduced pitting compared with shellac waxes, and the surfactant or vegetable oil addition to a commercial shellac wax showed less pitting than those treated with commercial waxes (Dou *et al*., 2000). In India (Punjab), Kinnow (*Citrus reticulata*) fruits harvested on 30th January and 25th March 2000 were treated as unwaxed (fresh fruits), waxed and unwaxed (stored fruits) to determine the losses during transportation. Fruit weight loss due to physiological disorder was lesser in waxed compared to unwaxed fruits. However, fruit rot (4.44%) was less in unwaxed (fresh fruits) and maximum (14.97%) in waxed fruits, which were stored for 75 days under cold storage (4-5°C and 85-90% RH) (Dinesh *et al*., 2002). Research on composite coatings, consisting of polysaccharide and shellac-beeswax indicated that the coated mandarin fruits had delayed dehydration and presented higher internal CO_2 and ethanol concentration than uncoated ones. However, a ratio of 14:1 provided better sensory scores and brittleness for coated fruits than control (Perez Gago *et al*., 2003).

Modified atmosphere packaging and storage

Research is underway for improving fruit shelflife through modified atmosphere techniques using different types of packaging materials i.e. paper as the lining material, bagging, individual paper wrapping, polyethylene sheet lining, individual polyethylene shrink wrapping or seal packing, cardboard boxes covered with high and low density polyethylene etc. (El Mughrabi, 1999; Ismail and El Menshawy, 1997; Jitender *et al*., 2000; Ladaniya, 2001). In an investigation, fruits of mature, green lemon and grapefruit fruits were sealed in low density polyethylene (LDPE) or high density polyethylene (HDPE; less permeable to O_2, CO_2 and water vapour) bags, and stored at 8°C for 3 months. Results showed that sealed packaging significantly reduced the incidence of chilling injury and decay. Weight loss was decreased by sealed packaging, while HDPE was more effective for decay control. Fruit total soluble solids content or acidity was not significantly affected (Ismail and El Menshawy, 1997). Fresh Kinnow fruits washed with chlorinated water (1000 ppm) and shrink-wrapped individually in 60 gauge (0.015 mm) polyolefin films, were stored at ambient conditions (12-20°C, 63-78% RH) along with unwrapped fruits. Samples of fruits tested every week showed that unwrapped fruits became unacceptable (> 20% weight loss) after 2 weeks, whereas shrink-wrapped fruits remained firm and fresh (1.24-2.98% weight loss) during storage. Fruit firmness, appearance, flavour and overall eating quality of wrapped fruits were found to be better than the unwrapped fruits. Under ambient conditions, the shelf life of wrapped fruit was 8 weeks as compared to 2 weeks for unwrapped fruits (Raghav and Gupta, 2000). In another study, 'Mosambi' (*Citrus sinensis*) fruits sprayed (carbendazim 500 ppm) thrice at pre-harvest stage at fortnight interval, degreened, washed (chlorinated water 1000 ppm) and again treated with carbendazim (2000 ppm) and over-wrapped in trays. 'Cryovac' heat-shrinkable films (polyolefin material) and LDPE (linear low density polyethylene) heat-shrinkable and stretchable cling films were wrapped over trays, and stored at 25±5°C and 45±5% RH in vented corrugated fibre-board master boxes. Cryovac film-wrapped (BDF 2001, 30 µm thick; D-955, 15 and 25 µm thick) and stretchable film (15 µm) wrapped fruits had significantly lower weight loss compared with that of non-wrapped fruits. There was no spoilage in any treatment up to 40 days except D-955 (15 µm) film (6.01%) after 20 days. Rind colour development was not affected while, fruit firmness decreased slightly in most of the treatments after 20 and 40 days except in non-wrapped and SM-250 (perforated) film wrapped fruits. Juice contents significantly decreased in non-wrapped fruits due to water loss. Ascorbic acid content also declined, especially in control and SM-250 film wrapped fruits (Ladaniya *et al*., 2001). In a study on Kinnow mandarin, fruits were packed in card board boxes and covered with polyethylene under various storage conditions. Analysis after 77 days of storage showed that fruits stored in polyethylene bags had the lowest physiological weight loss while those packed in paper lining recorded the greatest physiological weight loss. There was no fruit decay up to 28 days of storage. After that, the decay severity increased with extended storage period. The lowest decay loss was observed in fruits packed with paper lining while the highest was in fruits individually packed with polyethylene (Rana *et al*., 2002).

Chilling injury

Most of the citrus develop chilling injury (CI) during low temperature storage, and stage of maturity has been reported to influence the susceptibility to CI (Schirra *et al*., 1998) . Research is underway on the ways to reduce chilling injury using various heat treatments to increase the tolerance of fruit to chilling injury (Holland *et al*., 2002; Rodov *et al*., 1995) or a combination of treatments to protect it. The late-ripening mandarin (*Citrus reticulata*, Blanco, cv. 'Fortune') is also sensitive to chilling injury (CI). In a study, the effect of postharvest hot-water dip (HWD) treatments on its chilling tolerance was investigated. After 45 days storage at 2 °C, fruit dipped for 6 min at 47C or 3 min at 53 °C, had maximum reduction in CI, while those stored at 12 °C did not develop any CI symptoms. The treatments also helped in reducing fruit decay (Gonzalez-Aguilar *et al*., 1997). In another experiment it was found that Washington Navel oranges wrapped in diphenyl-impregnated paper resulted in the lowest percentages of chilling injury and wrapped fruits could be stored for >4 months at 5°C with minimal loss of fruit quality (Erkan *et al*., 2000). In red grapefruit (*Citrus paradisi* cv. Star Ruby), of the various treatments, hot water brushing (HWB) treatment at 60 °C for 30s significantly reduced postharvest decay development. Conditioning and curing significantly increased fruit weight loss, enhanced peel color alteration, and increased the TSS/acid ratio of juice. Overall, postharvest heat treatments for short duration, including either HWD or HWB effectively induce tolerance to cold temperatures in 'Star Ruby' grapefruit without significantly affecting any other quality attributes (Porat *et al*., 2000).

Conclusions

Overtime, there has been significant progress in the areas of postharvest physiology, pathology, entomology and postharvest technology of citrus fruit. By understanding and using these developments, the postharvest handling system can be improved, which will help to improve the profitability of industry. While, many challenges in the area of postharvest are still to be tackled, our current state of postharvest losses can be minimized by application of the principles of postharvest management.

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