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LITERATURE REVIEW FOR SAPBURN DAMAGE IN EXPORTING MANGO

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SUMMARY

One of the main problems in the terminal market is sapburn damage. It is characterized by causing dark brown spots or blackish streaks on mango fruits. The symptoms of contact with sap may not be apparent initially, but can be perfectly distinguished in a few days or as the ripening process occurs. Sapburn damage reduces the quality and shelf life of mango fruits as it promotes a higher incidence of anthracnose and can vary according to the region, season, age of the tree, maturity stage at harvest, and variety. This literature review was carried out with the following objectives: a) To compile the information published in the last 30 years regarding sapburn damage in mango producing areas in the world; b) Identify the factors that affect the incidence and severity of sapburn damage; c) Define the effect of climate and harvest time associated with sapburn damage; d) Show the chemical composition of the sap, as well as the compounds abrasive to the fruit; e) Compile varietal susceptibility to sapburn damage, and f) Technologies to reduce sapburn damage. The information was compiled in the following sections: I. Laticifers and sap chemical composition; II. Factors affecting the severity and incidence of damage, and III. Technologies to reduce sapburn damage. Regarding this last point, the following technologies are listed: sodium chloride (5.0%) and calcium hydroxide (0.5 and 1.0%) for 5 min; alum (0.5 and 1.0%); use of Agral®, Cold Power®, Mango Wash® detergents; sodium hydroxide (2.0%); cut with peduncle > 5 cm and remove peduncle after 24 h; desapping for 20 min up to 4 h; Lemon (0.5%); Sodium bicarbonate (1.0%): Tween 80; Sodium lauryl sulfonate or sodium hypochlorite (0.1%) or dry-decolorized; Commercial or enzymatic detergent (0.1%); Sodium carboxymethyl cellulose and sodium lauryl sulfate; wax coating based on polyethylene; DC Tron (100-1000 µL / L).

BACKGROUND

Mango is one of the favorite fruits in the USA market, where consumption has doubled in the past 10 years. During the last three years (2014-2016) on average, 120 million 10-pound boxes have been imported; mainly from Mexico (67.0 %), Peru (10.0 %), Ecuador (9.0 %), Brazil (7.1 %), Guatemala (4.6 %), and Haiti (2.3%) [USDA-FAS, 2017].

Mexico is one of the top mango exporters to the USA providing 67% of the total exported by producing countries, which represents around 63.6 million boxes per year with a value of 366 million dollars (USDA-FAS, 2017). The main exported varieties for the USA market are Tommy Atkins, Ataulfo, Kent and Keitt compromising 35, 30, 15 and 10% respectively of the exported volume (EMEX, A.C., 2016).

One of the main problems in terminal market is the sapburn damage, which causes dark brown spots or black stripes in mango fruit. Symptoms may be not apparent at the beginning, but they are perfectly distinguished in a few days along to the ripening process. The sapburn damage decreases the quality and shelf life of mango fruit since it promotes higher anthracnose incidence and it may vary according to region, season, tree age, maturity stage at harvest, and variety (Lim and Kuppelweiser, 1993).

Previous results indicated that sap chemical composition consists of two different fractions: one oil fraction and another one derivate from proteins and polysaccharides. The first one causes the more severe sapburn damage. Besides that, it has been demonstrated that this oil fraction constitutes around 50% of the exudate sap flushed after peduncle removal and it decreases to only 3% after 90 min (O'hare y Prassad, 1991). In addition, it is stated that sap flushed from mango fruit contains laccase, terpens, and mucilage (Joel et al., 1978; Joel and Fahn, 1980). In addition, it is specified that the sap exuded in the afternoon (2:00 p.m.) is less than that exudate from fruit harvest at morning (7:00 a.m.). However, sapburn damage is higher for fruit harvested in the afternoon (Brown et al., 1986). The authors conclude the higher damage caused by sap from fruit harvest in the afternoon may be due to a less sap dilution because of less turgor pressure.

Several studies have shown that sapburn damage may be alleviate by using calcium hydroxide solutions (1.0%), detergent (0.1%), DC Tron (100-1000 µl/l), or hot water treatment at 51-55 °C for 10 min (O'hare and Prassad, 1991; Lim and Kuppelweiser, 1993).

OBJECTIVES

- To collect information published during the last 30 years about mango sapburn.
- To identify the factors affecting incidence and severity of mango sapburn.
- To define the climatic factors and harvest times associate to mango sapburn.
- To show sap chemical composition and those compounds abrasive to the mango fruit.
- To compile varietal susceptibility to mango sapburn.
- To find technologies to decrease the mango sapburn.

METHODOLOGY

- An exhaustive search will be done in the internet data bases looking especially for some specialized journals such as: Acta Horticulturae, Revista Iberoamericana de Tecnología Postcosecha, HortTechnology, HortScience, REDALYC (Red de Revistas Científicas de América Latina y El Caribe), Revista Fitotecnia Mexicana, Revista Horticultura Mexicana, Revista Chapingo Serie Horticultura, Australian Journal of Plant Physiology, Revista brasileira de Fruticultura, Agronomía Costarricense.
- Bachelor, Master, and Doctoral thesis from different universities will be also explored.
- All the information will be kept in its original format, and it will be analyzed and summarized according to the objectives.

RESULTS

I. LATICIFERS AND SAP CHEMICAL COMPOSITION

Mango tree is characterized by having through its leaves, flowers, stems and fruits, a vast system of ducts called laticifers, which contain resin or sap (Mauseth, 1988; Joel, 1981). There are different opinions about the role of laticifers; however, the most successful is they are a system of plant protection against the attack of herbivores and microorganisms (Fahn, 1990). There are two types of laticifers: the non-articulated ones that develop from a cell that lengthens with the growth of the plant; and articulated laticifers, which consist of linear or branched series of cells that are joined one after the other (Mauseth, 1988; Joel, 1981). The laticifers are heterogeneously distributed throughout the plant, and the sap it contains does not have the same chemical composition in all species and even varies among cultivars (Rojas-Jiménez, 2000). At the base of the fruit, the laticifers have many branches and can be narrow (between 20 and 30 µm) or very wide (1 mm). The basal part of the stem contains narrow laticifers that widen toward the abscission zone. In the abscission zone (region of the stem where the mature fruit is naturally detached from the tree), laticifers are found both in the system of fruit duct and that of the stem, systems that are parallel to each other but do not interconnect. The narrow fruit ducts occupy the peripheral zone of the base of the fruit and end before the abscission zone; and the wider ones end up closed at a short distance after the abscission zone; Stem ducts also cross the abscission zone (Joel, 1981).

When a fruit is harvested before reaching the consumption ripening stage, the sap, which is found in the ducts of the base of the fruit under considerable pressure, is released by draining through the exocarp causing the damage. Sap is a colloidal suspension of small particles that can be white-milky, yellow-brown, yellow-orange or colorless, which flows, mainly after the detachment of the peduncle, causing spots on the mango skin due to its nature acid (pH 4.3) (John et al., 2003; Rojas-Jiménez, 2000; Campbell, 1992). Sapburn injury is characterized by browning and necrosis around the lenticels, causing deterioration in the appearance of the fruit, decreasing its commercial value and storage (Holmes et al., 1993). Sap turns pale yellow when dried and contains resinous acid, mangiferous acid, resinol, mangiferol and mangiferin (Morton, 1987); Sap has a characteristic aroma to that of a ripe fruit, which suggests the spectrum of volatile aromas may be similar in mango pulp and sap (Loveys et al., 1992; McLeod et al., 1988). In general, sap contains a wide variety of chemical compounds, which differ depending on the species and variety (Fahn, 1990).

The sap is made up of two phases, an aqueous and an oily phase. The oil phase is yellow-brown. This fraction constitutes approximately 50% of the latex immediately after cutting and its proportion decreases to 3 to 10% within 90 seconds of the harvest (Barman et al., 2015). It is the main responsible for quickly staining the mango peel due to the high content of terpenes (3-carene, terpinolene) and 5-resorcinol (Loveys et al., 1992). Terpenes make contact with the skin of the fruit and enter it through lenticels (O'Hare and Prasad, 1991), causing a direct activation of the polyphenol oxidase or indirectly providing contact between the enzyme and its substrate (Robinson et al., 1993). On the other hand, the aqueous phase is essentially composed of proteins and polysaccharides, as well as proteases, peroxidases and polyphenols (Saby et al., 2003), which can also cause spots on the skin, although its effect is much less (Loveys et al. al., 1992).

Bartley and Schwede (1987) found that Kensington mango volatiles, in addition to containing terpinolene, carbohydrates and proteins, contain also phenols and catechols. Likewise, Joel and Fahn (1980) found the sap secreted by the mango fruit contains laccase and mucilaginous substances.

Sandoval et al. (1998) evaluated the content of terpinolene and 3-carene in sap of the varieties Ataulfo, Haden, Tommy Atkins, Kent and Keitt harvested in the states of Michoacán, Nayarit and Sinaloa. They found that in the sap of all varieties there is greater proportion of terpinolene, with Tommy Atkins and Ataulfo having the highest number of terpenes with respect to the varieties Kent, Haden and Keitt, and therefore those most susceptible to sapburn damage. Whereas Díaz de León-Sánchez et al., (2000) differ from Sandoval et al., (1998), since they quantified the terpinolene and 3-carene levels of the sap in Haden and Tommy Atkins varieties of Michoacán, Mexico. They found the levels of 3-carene were higher than the terpinolene, in the two varieties studied. Likewise, Rojas-Jiménez, (2000) quantified the terpinolene and 3-carene levels of the sap in Ataulfo, Tommy

Atkins, Haden, Keitt and Kent, harvested in Michoacán, Nayarit and Sinaloa. It was found that all cultivars contain a higher proportion of 3-carene than of terpinolene, 3-carene being the main compound responsible for sapburn damage, and Haden the most sensitive cultivar to damage. However, previous studies carried out with the cultivars Kensington and Irwin, harvested in Australia, showed that terpinolene is the main component of the oil phase of the sap contained in the fruits of the Kensington cultivar, which is very susceptible to damage. Meanwhile in the cultivar Irwin, which is a variety less susceptible to sapburn damage, the main component was 3-carene. Subsequently, it was shown that the direct application of synthetic terpinolene to the surface of the mangoes produced symptoms similar to those of sapburn damage. These results suggest that terpinolene is the main component of the sap responsible for the damage (Holmes et al., 1993, Loveys et al., 1992). On the other hand, Osuna et al., (2000), analyzed the latex oil phase of four mango varieties Ataulfo, Haden, Tommy Atkins and Kent, finding the main components causing the damage are terpinolene or car-3. ene depending on the cultivar.

II. FACTORS THAT AFFECT THE SEVERITY AND INCIDENCE OF DAMAGE (Effect of climate and harvesting time, varietal susceptibility, among others)

Sapburn damage is a major problem affecting the mango quality. It initially consists in the darkening of the skin around the lenticels; these areas become progressively larger and darker in the 48 hours after cutting, causing a deterioration in the appearance of the fruits, changes in their metabolism (respiration and ethylene production) and an increase in the susceptibility to attack by pathogens. This susceptibility to pathogen attacks is probably due to its high carbohydrate content, increasing the possibilities of mechanical damage to the fruit (Negi et al., 2002), which significantly reduces the acceptability and shelf life of these fruits (Holmes et al., 1993). In the Mexican Pacific region, losses caused by sapburn damage affect approximately 9.9% of export mango production (EMEX, A.C., 1996).

The sap composition is complex and the amount that emanates from the fruit varies depending on factors, such as the weather, the time of day in which the harvest is made, the variety, the time of harvest (beginning, middle or end of the harvest season), age of the trees, fruit maturity, lenticel density, among others (Montero and Molina, 2005, O'Hare et al., 1994, Lim and Kuppelweiser, 1993). Sapburn damage in mango fruits ranges from 5% to 50%, varying in magnitude according to the factors mentioned above (Barman et al., 2015). Some results suggest sapburn damage depends mainly on both the chemical composition of the sap and the sensitivity of the different cultivars to this substance (Díaz de León-Sánchez et al., 2005).

Loveys et al. (1992), indicate that the content of the oil phase of the sap (phase responsible for causing stains in the mango) composed of terpenes and 5-resorcinol, varies with the cultivar. Also, Montero and Molina (2005) mention that this phase varies with the time of desapping. Rojas et al. (1999) and Barbosa et al. (1995) indicate that the fruits of Tommy Atkins and Ataulfo have more terpenes than the cultivars Kent, Haden and Keitt.

Hassan et al. (2009), point out that geographic location and crop management are factors that also play an important role in the sap production in fruits. In addition, they indicate the differences of maturity (indicated by the % of dry matter), can contribute to the differences in the characteristics of the sap between the same variety of different growing regions. This effect was very visible in his investigation when observing the varieties "Kensington" and "Nam Doc Mai" of the locality of Ayr of Queensland, Australia had higher percentage of dry matter (more mature). They also showed greater percentage of the oil phase of latex and higher concentrations of 5-n-heptadecenilresorcinol and 5-n-pentadecilresorcinol compared to the fruits of the localities of Nambour or Gin Gin.

Another factor considered important is the time it takes for the sap to emanate. Lim and Kuppelweiser (1993) evaluated the effect of the damage caused by the sap at different emission times; these authors observed that the sap collected from 15 seconds to 15 minutes caused a damage of only 2.5%. While Osuna et al. (2000), point out the sap emitted during the first 30 seconds of the varieties Ataulfo, Haden, Tommy Atkins, and Kent caused the highest damage in the appearance of the fruit. Loveys et al. (1992) obtained similar results in the Kensington variety, where the damage caused by sap emitted during the first seconds was 100%.

The time of the day in which the harvest is carried out is one of the most important factors to consider in sapburn injuries. There is a greater flow of sap during the first hours of the morning than in the afternoon, due to the high-water content or the turgor pressure, which decreases as the temperature of the day increases (Amin et al., 2008). With this increase, the transpiration rate of the fruit surface increases, which ultimately results in the reduction of the water concentration in the latex, and when said reduction occurs, the concentration of the oil phase is higher, which is the main cause of sapburn damage in the fruit (Barman et al., 2011).

On the other hand, Amin et al., (2008) evaluated the harvesting and desapping of the cultivar cv. Samar Bahisht Chaunsa from Pakistan in relation to 3 times (morning 7 a.m., noon 12 p.m., and afternoon 5 p.m.) to observe in which of them there was less damage by sap. They found that harvesting and desapping at 7 a.m. in combination with a subsequent immersion of the fruits in lime (0.5%) was the best treatment to avoid sapburn injuries. Maqbool et al. (2007), agree that the highest sap content occurs in the morning that in the afternoon and found the Chaunsa cultivar of Pakistan had a higher concentration of sap than the Sindhri variety.

With respect to the ripening factor, the onset and severity of the lesion in the fruit increases as it ripens, during storage at room temperature (Barman et al., 2015). In the same way, Maqbool and Ullah (2008) also reported the symptoms of the lesion in the fruit increased as the ripening increased. This is because the activity of the polyphenol oxidase enzyme increases with the onset of ripening (Menezes et al., 1995).

Other factors that may affect sapburn damage are temperature and storage time, Maqbool et al. (2007) analyzed three cultivars of commercial mango Chaunsa, Sindhri and Dusehri to observe the susceptibility of these to sap after 24, 48 and 72 hours in two different storage conditions (environment: 25 °C and cold storage: 14 °C, with an RH of 85%), the cultivar Chaunsa was the most susceptible, followed by cv Sindhri and cv Dusehri. The incidence of sapburn damage in cv Chaunsa was more at room temperature (25 ± 1 ° C) than in cold storage (14 ° C, 85% RH). However, in cv Sindhri and Dusehri the damage was almost similar in both temperatures. Maqbool and colleagues also analyzed the severity level by sap with reference to the harvest time of the day. Sapburn damage increased as the day progressed. After 7 days of storage at room temperature, as well as in cold storage (14 °C), the damage caused was medium, the maximum damage occurred when the fruits were harvested at 3 pm, while the minimum damage in fruits harvested at 6 am. In the same way, they analyzed the desapping of the fruits, in trays, for different periods of time, in order to determine the optimal time of desapping to reduce the sapburn damage. The minimum lesion occurred after 15 days of storage (14 °C) in fruits that were desapped for 20 minutes.

A prominent factor is the presence of enzymes polyphenol oxidases and peroxidases, which are present in the skin of the fruit, as well as in the same sap; Several investigations have shown that the blackening due to contact with sap is related to the presence of these enzymes (Saby et al., 2002, Thygensen et al., 1995, Loveys et al., 1992, Joel et al., 1998). The amount and activity of the enzymes vary depending on the mango cultivar. Robinson et al. (1993) suggested when the latex is in contact with the exocarp or skin of the fruit, a breakdown of the superficial tissues is caused, allowing the interaction between these enzymes and their substrates. So, there is a correlation between sapburn damage and the activity of enzymes from the group of polyphenol oxidases, such as catecholase, and laccase. Catecholase catalyzes the oxidation of o-dihydroxyphenols to o-quinones; this enzyme is usually found in the chloroplasts and mitochondria of the exocarp of the fruit. Both enzymes use molecular oxygen and their phenolic substrates are found in vacuoles (Robinson et al., 1993). Regarding the laccase, it catalyzes the hydroxylation of monophenols to o-diphenols present in the sap (Robinson et al., 1993). Díaz de León-Sánchez et al. (2005) mention that several mango studies suggest that terpenes favor sapburn damage through the activation of polyphenol oxidases (PFO's); however, in their research they determined the correlation between sapburn damage and total PFO’s activity of the exocarp and sap in Haden and Tommy Atkins mangoes harvested in April, May and June in Lázaro Cárdenas, Michoacán. They found the activity of the total PFO's of the exocarp was similar in Tommy Atkins and Haden during the first two harvest seasons, increasing in the last season in Tommy Atkins, while the activity of the total PFO's of the sap was greater in Tommy Atkins that in Haden in all seasons of harvest. The authors concluded the susceptibility to sapburn damage showed a contrasting behavior in both cultivars. In Tommy Atkins, it increased throughout the three seasons while in Haden it decreased, so that the total activities of the PFO's in exocarp and latex do not explain the susceptibility to sapburn damage in Mexican mango of Haden and Tommy Atkins varieties.

On the other hand, Saby et al. (2002) point out that the polyphenol oxidase and peroxidase enzymes present in the mango skin are responsible for sapburn damage, and not the polyphenol oxidase and peroxidase present in the sap. That is, when the organic compounds present in the sap come in contact with the mango peel, they can dissolve the waxy layer on the surface and disorganize the susceptible part of the cellular structure. During this process, the polyphenol oxidase and peroxidase present in the peel come into contact with their polyphenol substrates and react in the presence of atmospheric oxygen resulting in the typical brown color, which is characteristic of sapburn damage. The variations in the degree of color observed in the different varieties may be due to variations in the enzymatic activities and the polyphenol content present in the skin.

III. TECHNOLOGIES TO DECREASE SAPBURN DAMAGE

The effect of sap in contact with the surface of the fruit is very variable, sometimes the spot occurs immediately and it is completely irreversible; while other times the sap remains transparent and colorless during storage and transport of fruit and it can be removed, at least partially, without causing permanent damage (Montero and Molina, 2005). These factors make it difficult to search for a consistently effective treatment. However, some of the most effective alternatives are listed below.

2016

- Remove peduncles and immerse the fruits in 1% and 5% sodium chloride solutions, as well as in a 0.5% and 1% calcium hydroxide solution, separately for 5 minutes. The detachment and immersion of fruits in 5% sodium chloride and 1% calcium hydroxide were effective in reducing sapburn damage in the "Karuthakolumban" variety. While immersion in 1% sodium chloride and 0.5% calcium hydroxide successfully reduced sapburn damage in the varieties "Willard", "Chembaddan" and "Ambalavi". **Krishnapillai and Wilson (2016)**. Sap burn injury management of mangoes (Mangifera indica L.) in Sri Lanka. Pakistan Journal of Botany, 48 (5): 2147-2152.

- The fruits harvested with a peduncle of 4-5 cm long, and later blended in a lime solution at 0.5% prevent sapburn damage. **Hafeez et al. (2016).** Effect of Modified Atmosphere Packaging on Postharvest Quality of Mango cvs. Sindhri and Sufaid Chanunsa During Storage. Turkish Journal of Agriculture, 4 (12): 1104-1111.

2015

- Application of sodium hydroxide (1%) and alum (0.5 and 1%) (double sulphate of alumina and potassium) showed the best results compared to the use of calcium hydroxide (1%) and control. **Barman et al. (2015).** Influence of different desapping agents on the incidence of sapburn, ripening behavior and quality of mango. Journal of Food Science and Technology, 52 (1): 161-170.
- To reduce sapburn damage, the fruit should be washed in water at room temperature, in one or more disinfectants or soaps such as Agral®, Cold Power® or Mango Wash®. **Guoqin Li. (2015).** Lenticel discolouration on 'B74' mango fruit and under-skin browning on 'honey gold' mango fruit. Doctoral Thesis. The University of Queensland. Australia, 23 p.

2014

- Immersion for 30 seconds in 2% NaOH applied in the orchard before the fruit is transferred to the packing factory. Cultivars of Israel. **Feygenberg et al. (2014).** Improved management of mango fruit though orchard and packinghouse treatments to reduce lenticel discoloration and prevent decay. Postharvest Biology and Technology, 91: 128-133.

2009

- Harvest the mango fruits with a certain length of peduncle (5 cm or more) and accumulate the fruits in the field in boxes. The sap will not drip from fruits that have a long length of attached peduncle. In Brazil, it is a common practice to harvest the mangos with the long peduncle (length> 5 cm), and carefully transport the fruits from the field to the packinghouse where the peduncle of the fruits is trimmed. Approximately 24 hours after harvesting, the sap of the fruits will stop dripping and they will not leak if the peduncles are trimmed later.
- Cut the peduncles at the abscission zone (approximately 1 cm), and immediately afterwards place the fruits with the peduncle trimmed downwards in such a way as to allow the sap to drip without touching the peel of the mango. The duration of the removal varies from 20 minutes to 4 hours depending on the time it takes for the fruit to stop dripping the latex.
- Desap the fruit and wash it with one of the following solutions: lemon (0.5%), sodium bicarbonate (1%), aluminum potassium sulphate - alum (1%), and detergents. **Brecht et al.** (2009). Manual de prácticas para el mejor manejo postcosecha del mango. Universidad de Florida.

2008

- Harvest of the mango fruits (cv. Samar Bahisht Chaunsa) and desapped in the morning (7 a.m.) for its subsequent immersion in lime at 0.5% to control sapburn lesions. The result was to eliminate 100% of the lesions. Cultivars from Pakistan. **Amin et al. (2008).** Mango fruit desapping in relation to time of harvesting. Pakistan Journal of Botany. 40 (4): 1587-1593.
- Immediately after the harvest of Sindhri and Chaunsa cultivars from Pakistan, the following solutions were used separately: calcium hydroxide, Tween-80, sodium carboxymethyl cellulose, sodium lauryl sulfate, detergents and vegetable oil. The fruits after the treatments were dried in the air and packed in cardboard boxes, transported to the laboratory and stored (14 ° C and 85% RH, 25 ° C and 56% RH) for 7 and 14 days in the case of Sindhri cv. and cv Chaunsa, respectively. The fruits

treated with calcium hydroxide presented the best results against sapburn injuries (in addition to improving the total quality of the fruit) followed by Tween-80 in both cultivars. **Maqbool and Ullah (2008).** Anti-Sap Chemicals Reduce Sapburn Injury and Improve Fruit Quality in Commercial Mango Cultivars. International Journal of Agriculture and Biology, 10: 1-8.

2005

- Desapping in solution (1% in water) of sodium lauryl sulfonate ether; and / or in sodium hypochlorite solution (100 mg L^{-1}); and / or dry desapped. **Montero M. and Molina M. E. (2005).** Treatments to reduce sapburn damage in mango. Costa Rican Agronomy, 29 (3): 221-229.

2000

- Wash the fruit with commercial detergent (0.1%) or enzymatic (0.1%) to reduce the damage in Haden, Kent and Tommy Atkins, during the first 6 hours of harvesting; For Ataulfo variety during the first 2 hours of harvest and washing with a calcium hydroxide solution (1%) at 2 hours can still reverse the sapburn damage. **Osuna et al. (2000).** Chemical composition, characterization of damage and prevention of burning of mango fruit by sap. Mango Symposium Control of flowering and genetic improvement. Conference report. April 26 and 27, 2000. Apatzingán, Michoacán, México.
- Bósquez et al., (2000) suggested that solutions of sodium carboxymethylcellulose and sodium lauryl sulphate are efficient to control sap injuries in mango fruits of the Haden and Tommy Atkins varieties. **Bósquez et al. (2000).** Sapburn control by the application of different chemical compounds in Mexican mango fruit with exporting quality. International Symposium on Mango. Pattaya, Thailand, February 1, 2000.

1997

- In Australia, release machines are used to remove the sap; later a thin layer of water is sprinkled on the surface of the fruit to remove the sap from the peel. **Brown, B. and J. Bagshaw (1997).** Disorders with external symptoms. Postharvest pest and disorders of mangoes. Queensland Department of Primary Industries Information series, Queensland Department of Primary Industries, Australia.1994

- Application of polyethylene based wax coatings on the mango surface before drying the sap surface; this will help to reduce sapburn damage, without negatively affecting the development of color. **Shorter, A.J. and D.C. Joyce (1994).** Effect of surface coatings on sap burn of Kensington Pride mango fruit. Trop. Agric. (Trinity). 71 (3): 243-246.

1993

- Desap of the fruit in a 0.5% solution of sodium carbonate in water (pH 11). From 77 to 87% of the fruit without damage or with very slight damage. **Fonseca, J. M. (1993).** Reduction of post-harvest losses due to latex spot on mango (Mangifera indica). Bachelor Thesis in Agronomic Engineering. Faculty of Agronomy, University of Costa Rica.
- Desap under a lime solution; use of dips and / or detergent sprays; packing with short stems; pack without stems during the harvest, immersing or spraying detergent on the fruit immediately. **Holmes et al. (1993).** Handling systems to reduce mango sapburn. Acta Horticulturae, 341: 528-532.
- Immersion for 1 min of the fruits in a DC Tron solution (100-1000 µL / L) gave better results against sapburn damage compared to Ethokem, Agral 60, CropLife, Codacide, 1% Chlorsan, and / or calcium hydroxide. **Lim and Kuppelweiser (1993).** Mango sap burn amelioration in the Northern Territory; Acta Horticulturae, 341: 518-527.

1991

- Desap the fruit and then submerge it in a 1% calcium hydroxide solution. **O'Hare, T. and Prasad, A. 1991.** The alleviation of sap-induced mango skin injury by calcium hydroxide.
- Desap the fruit and immerse it in a detergent solution. **Ledger, S. N. (1991).** Effectiveness of detergents in reducing mango sapburn 1990/1991 season. Postharvest Report, Queensland Department of Primary Industries.

- **Landrigan et al., 1991 and Baker, 1991** suggested that to reduce sapburn damage it is necessary to use solutions such as: sodium carbohydrate, sodium lauryl sulfate, calcium hydroxide solutions, varnish with vegetable oil, waxes and dehydration in commercial detergent.

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