Mechanism and Physiological Changes of Lenticel Damage in Mango

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Summary

This paper reviews the mechanism and physiological change of lenticel damage in mango (*Mangifera indica* L.). Lenticel is a porous tissue for gaseous exchange between the internal plant tissue and the environment. The rupturing of stomata during fruit enlargement became to lenticel, which lenticel intensify gradually until fully ripen. The lenticel damage can be caused by several factors such as cultivar, amount of water and air through the lenticel, membrane breakdown, and phenolics accumulation through the activation of polyphenol oxidase (PPO) which cause poor quality of products. Although lenticel damage can not affect the internal quality, but it is a detraction in appearance and reduce the marketable value.

Introduction

Mango (*Mangifera indica* L.) belonging to the Anacadiaceae family, is a tropical fruiting crop (Mukherjee, 1997). Mango is native to India and South East Asia, from where it was distributed to worldwide and became one of the most economically important tropical fruits (Mukherjee, 1997). Taiwan mangoes industry has been developing for several decades, and the production period and cultivation techniques have been improved. In 2013, Taiwan exports 7,798 metric tons mangoes to many countries around the world, including Japan, China, Middle-East, Europe and United States

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(COA Taiwan, 2013). Moreover, consumer preference is an important marketing factor, which including the appearance, regardless of aroma and taste, the first sensory criterion for fresh produce (Pollack, 2001). Therefore, mango fruit quality and appearance are of particular importance for export markets, and any imperfection has financial consequences (Du Plooy *et al.*, 2006).

Skin physiological disorders such as lenticel damage (Curry, 2003), which it is a surface blemish and appearance of darkening around lenticel or dark spots on the mango skin, and it has become one of the serious problems (Tamjinda *et al*., 1992). Although the lenticel damage or the dark spots did not affect to the internal fruit, but it affects visual appearance and it normally be rejected by the consumers (Rymbai *et al.*, 2012). Furthermore, Robinson *et al.* (1993) suggested that the lenticel damage causes the fruits more susceptible to pathogen infection.

Lenticel structure and development

The evolution of the plant anatomical and histological structures are based on their environmental conditions. According to Dubey (1994) researched, the anatomical structure of plant organs such as leaf, fruits, etc. can change when exposed to stress environment. The main function of plant epidermis is to act as a border between plant and environment.

The appearance of the porous tissue on the fruit peel was found in many fruit such as avocado, apple, pear, and mango. However, the porous tissue that works as the gaseous exchange between internal and external plant tissue and was called "lenticel" (Du Plooy *et al*., 2009a). Esau (1977) reported that fruit peel or exocarp is composed of natural wax, cutin, epidermal layer, tissue of sub-epidermal and may including stomata and trichomes. Although, there was no clear evidence about the origination of lenticel in fruit peel, but it has been hypothesized that the lenticel may derived from the change of stomata (stretched and ruptured) during fruit growth and enlargement (Wilson *et al*., 1972; Tamjinda *et al.*, 1992; Bally, 1999). Apples, pears, and cherries have been observed that the stomata was found after fruit set, then it was stretched and ruptured due to the development of fruit and the lenticel formation thereafter (Wilson *et al*., 1972). In mango fruit, it has been reported that under the lenticel, there is a small cell with composed of an intercellular space and situated in the stomata (Tamjinda *et al.*, 1992). Bally (1999) also confirmed that the formation of lenticel in mango caused by the ruptured stomata during fruit growth and development. In addition, the stomata was found on the skin of young avocado fruit, but may disappeared or degenerated, which lead to lenticel formation when the fruit was old (Scora *et al.*, 2002). Therefore, it indicated that the formation of lenticel on mango fruit was derived from the stomata. The intercellular space or pore being delimited by the non-functional of guard cells and packed cells were loosely lined, lead to appear the lenticel on the fruit peel (Rymbai *et al*., 2012). Everett *et al.* (2008) suggested that lenticel acts as a channel for fruit water loss, which cause by the loosely packed cells vary in shape, cell density, and virtual absence of plastid from the normal peel parenchyma cells.

The appearance of lenticel on the fruit peel gradually increase in color with the fruit maturity. Bally (1999) studied in 'Kensington Pride' mango about the surface morphology and the cuticle development during fruit growth and observed that the cuticle surface was smooth and unbroken, but there was no sign of stomata and epicuticular wax at anthesis. At fruit set, a layer of flattened polygonal epicuticular wax scales was clear on the surface and the stomata can be found on this stage. At fruit diameter of 30-120 mm, the epicuticular wax scales had developed a series of slightly flattened and radiating wax rodlets began to fragment. At fruit of 36 mm diameter, lenticel was found at this stage. The surface is covered with stomata in small fruit, but when fruit reaches approximately 36 mm diameter the stomata rupture and become lenticels, almost no stomata are seen on the fruit after this stage of development (Bally, 1999). In addition, the lenticel appears on the fruit peel with fully at 60 days after fruit set and an average of 3,167 lenticels per fruit, which lenticels were distributed 2-3 fold higher in the apical than in the middle and shoulder areas (Khader *et al*., 1992). However, the mount of lenticel is not static and will change during the development of fruit (Rosner and Kartusch, 2003; Kalachanis and Psaras, 2007; Rymbai *et al*., 2012).

Lenticel damage mechanism

Although the mechanism of lenticel damage on the mango fruit surface is poorly understood, but some studies (Tamjinda *et al.*, 1992; Du Plooy *et al*., 2006) have managed to set the relation between lenticel damage with entry of air, phenolic compound, enzyme etc.

Tamjinda *et al.* (1992) studied in lenticel damage of mango cv. 'Namdokmai' and 'Falan' and found that lenticel became darken or damaged when air and water entered through the lenticel. In 'Tommy Atkins' and 'Keitt' mango, the increasing in the darkening tissues around lenticel cause by the endomembrane collapse, then the polyphenol oxidase (PPO) was released, and lead to the phenolics accumulation thereafter (Beckman, 2000; Grassmann *et al*., 2002; Du Plooy *et al.*, 2004;

Bezuidenhout *et al*., 2005). The release of PPO is a signal of plant response to stress and associated with the development of lenticel damage (Dixon and Paiva, 1995).

Du Plooy *et al*. (2006) has been explained the lenticel damage by the phenolic status that phenolic compounds transport was limited in the vicinity of the lenticel cavity. Furthermore, other literatures showed that cell wall deposition might through the resin duct and secrete near the lenticel (Diaz *et al*., 1997; Benzuidenhout *et al*., 2005). Moreover, several studies suggested that the red color of lenticel on fruit was caused by the accumulation of anthocyanin, flavonoid and phenylpropanoid (Kangtharalingam *et al.*, 2002; Dixon and Paiva, 1995; Du Plooy *et al.*, 2009b). Dixon and Paiva (1995) considered that the increasing of red lenticel was a plant response to biotic and abiotic stress and subsequence of the release of PPO within the lenticel.

Lenticel damage and changes in phenolics

The lenticel damage or enhanced prominence on the skin may affect the visual appearance. Phenolics can be (usefully) thought into two classes: 1) those that are synthesized during the normal development of plant tissues, and 2) those that are synthesized by plants in response to physical injury, infection or other stress (Harborne, 1982; Nicholson and Hammerschmidt, 1992; Beckman, 2000). There has been investigated that the accumulation of phenolics presents a rapid and efficient protection against pathogen infections (Wink, 1997). The cell around the lenticels will be darken and form a red or green hollow with or without brown or black spot (Bezuidenhout *et al.*, 2005; Self *et al*., 2006). Du Plooy *et al*. (2006) suggested that the lenticel damage is rather caused by the deposition of phenolic compounds in cell wall than the loss of cellular function. It is possible that precursors (elicitors) leakage through the resin canal near the lenticels caused the pigment formation (Johson and Hofman, 2009). Lenticel damage may be one of the plant defence mechanism against foreign subjects entering through the lenticels (Bezuidenhout *et al.*, 2005; Du Plooy *et al.*, 2006). Similarly, Du Plooy *et al.* (2006) investigated the phenolic profiles of discolored lenticels in mango fruit cv. 'Tommy Atkins' and 'Keitt' by using cytologically and illustrated chronologically. This study showed that non-discolored lenticels had the lowest concentration of phenolic fraction followed by red discoloring and lastly, dark discolored lenticel. This result suggested that the accumulation of phenolic compound around the lenticel create a barrier between the environment and mesophyll (Du Plooy *et al.*, 2006).

Lenticel damage and pathogen attack

There is little information about pathogen infections in mango fruit lenticel. As known that lenticels are responsible for transpiration and gaseous exchange (Du Plooy *et al*., 2009a) and easily to be infected by pathogen due to the porous tissue (Robinson *et al*., 1993).

Everett *et al*. (2008) showed that lenticel damage in avocado fruit was not caused by fungal. Mechanical damage has closer relationship to lenticel damage rather than pathogen infection. Instead of causal relationship, both lenticels damage and disease will become worse due to mechanical injury (Everett *et al*., 2008). This view is supported by Robinson *et al.* (1993) who suggested that the damaged areas of fruit surface can become sites for secondary disease infections.

Lenticel damage factors and prevention

Quality losses of mango after harvest are caused by harvesting at unsuitable maturity stages, mechanical damage during harvest or through improper field handling, lenticel damage, and disease development (Luria *et al*., 2014). The main factor affecting fruit quality is lenticel damage (Feygenberg *et al*., 2014). Lenticel damage usually appears as one or more round, darken spots, ranging in diameter from 1 to 5 mm after harvest and packing (Duvenhage, 1993). Lenticel damage is a function of many components, including cultural management, growing environment, fruit maturity and postharvest management (i.e. the conditions during storage). However, the appearance of lenticel damage was exacerbated by a range of pre- and postharvest factors, which these factors were discussed below.

I. Cultivar

Lenticel damage is a common problem whose incidence is thought to be affected by many factors, including cultivars. Cultivars showed difference in the expression and the severity of lenticel damage Bally *et al.* (1997). Several studies reported that morphological lenticel characteristics showed that size of lumen or cavity, formation of lenticel and distribution and density of epicuticular wax can affect lenticel damage severity depend on the cultivars (Du Plooy *et al*., 2004; Du Plooy *et al*., 2009a).

Du Plooy *et al*. (2004) investigated the epicuticular morphology and the role it plays in the lenticel damage of the three cultivars ('Tommy Atkins', 'Keitt' and 'Kent') of mango. The comparison of the external appearances of the lenticels of the three cultivars found that 'Tommy

Atkins' had predominantly small lenticel stomata with limited suberization taking place. 'Keitt' had stomata of varying size, but most develops a very large, torn structure with suberisation taking place towards the end of the period of pulp expansion. While 'Kent' lenticels were the most abundant of the three cultivars investigated, appearing predominantly large, with internal wax visible from outside (Du Plooy *et al*., 2004). The studies of lenticel lumen characteristic of three mango cultivars reported that 'Tommy Atkins' had the deepest, most organized lumen and cavernous lenticel, with the smallest lenticel but had more susceptible lenticel damage, followed by 'Keitt' and 'Kent' mango cultivars which had more disorganized lumen and larger lenticels (Bezuidenhout *et al*., 2005; Du Plooy *et al*., 2004; Du Plooy *et al*., 2009a; Oosthuyse, 1998). Other lenticel damage research showed that 'Calypso' is clearer than 'Kensington Pride', 'R_2E_2' and 'Honey Gold' (Joyce *et al.*, 2011). However, the lenticel morphology is characteristic for each cultivars (differ in stomata width, lumen depth, and abundance of epicuticular wax), which associated to lenticel damage.

II. Environmental conditions at harvest

Environmental conditions at harvest is one of the most important factors which affect on the prominent and severity of lenticel damage. Oosthuyse (1998) studied the effect of environmental conditions at harvest on the lenticel damage incidence in mango, which found that cool, humid or wet conditions on the date of harvest strongly favour the postharvest occurrence of lenticel damage. In contrast, dry or hot conditions were indicated to disfavour the postharvest occurrence of lenticel damage (Oosthuyse, 1998). These results indicated that cool, humid and wet conditions during harvest increase the risk of lenticel damage. In Everett *et al*. (2008) investigated that the lenticel damage will become more severe when the fruit was imbibed into the water for 2 h than dehydrate. This result was supported by Duvenhage (1993) observation in which the fruit-picked wet had greater lenticel damage than dry. In addition, increased damage following excess irrigation during the latter stage of fruit growth (Simmons, 1998). Lenticel damage can also be more severe in larger fruit obtained from branches with higher leaf:fruit ratios, possibly because of greater damage to the lenticels during fruit growth (Simmons *et al*., 1998).

Therefore, the management of environmental conditions such as controlling soil moisture may reduce the incidence of lenticel damage. Cronje (2009) reported that the orchard that which has lenticel damage history can be reduced by controlling the soil moisture to reduce fruit turgor and increase tree water potential (Johnson *et al*., 1997). Therefore, Rymbai *et al*. (2012) suggested that the reduction of water content of soil till about -50 kPa can be a good practice to reduce lenticel damage. In addition, fruit bagging during fruit development can reduce the lenticel damage and blemish on fruit (Kitagawa *et al.*, 1992) in 'Tommy Atkins' and 'Keitt' mango fruit (Cronje, 2009).

III. Postharvest management

In general, lenticel damage is most obvious on the fruit surface after exposed to sap flow. This skin disorder has been called pitted spot (Oosthuyse, 1993). In 'Keitt' postharvest treatments by soap washing and hydro-heating increased lenticel damage incidence (Oosthuyse, 1999). In addition, postharvest handling of 'Tommy Atkins' mango fruits increased lenticel damage after washing the fruits with calcium hydroxide solution (Simao de Assis *et al*., 2009). Several studies demonstrated that postharvest treatment such as hot water treatment, hot air treatment or the combination, disinfectant, and cleaning with ambient water can increase the lenticel damage (Bally *et al.*, 1997; Jacobi *et al*., 2001; O'Hare *et al*., 1996). Other postharvest techniques such as calcium infiltration under low pressure and gamma irradiation also can induce lenticel damage (Joyce and Shorter, 1996; McLauchlan *et al*., 1990; Johnson *et al*., 1990; Lonsdale *et al*., 1991; Lonsdale, 1992).

Furthermore, lenticel damage incidence will accelerate when the mango fruits are stored below 10-12°C (Pesis *et al*., 2000). Luria *et al.* (2014) reported that postharvest by hot water brushing at 55°C for 15-20 s enhanced lenticel damage on the fruit peel after storage for 3-4 weeks at 12°C. In addition, lenticel damage was found to increase when the storage period increased (Oosthuyse, 2002).

However, postharvest handling and proper temperature maintenance may reduce the damage of lenticel and prolong the quality of the fresh produce. Several studies have been reported that hot water treatment before cold storage can reduce lenticel damage on mango fruits (Joyce *et al.*, 2001; Simao de Assis *et al.*, 2009). Cronje (2009) reported that mango cv. 'Tommy Atkins' and 'Keitt' stored at low temperature and high humidity condition contributed lower lenticel damage than high temperature and low humidity.

Conclusion

Mango lenticels originates from stomata, and the number of lenticels will gradually increase during fruit enlargement and maturity. The incidence of lenticel damage is the response of biochemical and physiological changes which is caused by several factors during pre- and postharvest. This incidence can affect the appearances, low marketing value and consumer refusal.

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芒果皮孔之損傷：機制與生理變化

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關鍵字: 芒果、皮孔損傷, 機制、生理變化

摘要：本論文探討芒果皮孔開裂之發生機制及生理變化。皮孔是植物內部氣體與外界環境進行氣體交換之主要通道，當果實膨大時會使氣孔開裂而形成皮孔，而後隨果實發育，密度逐漸增加，直到果實成熟。造成皮孔開裂之因素很多，如品種，水氣通過皮孔的總量，膜體之破壞及酚類化合物的累積，活化許多酚氧化酵素，進而造成果實品質下降。雖然，皮孔開裂並不影響果實內部品質，但卻嚴重影響果實外觀，而降低販售價值。

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