Banana Peel Physiological Post-Harvest Disorders: A Review

Review Article

Volume 3 Issue 1 - 2016

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Received: July 22, 2016 | **Published:** September 07, 2016

Abbreviations: PPO: Poly Phenol-Oxidase; PAL: Phenylalanine Ammonialyase; PL: Pectate Lyase; CI: Chilling Injury; CWMG: Cell Wall Modifying Genes

Introduction

Banana trees are giant perennial herbs coming from the Southeast Asia and belong to the *Musa* genus [1]. From a botanical point of view, *Musa* genus can be divided into two parts: edible and wild species. Wild species includes wild diploid and seminifar non edible parents, namely *Musa acuminate* (AA) and *Musa balbisiana* (BB), of all consummated bananas [2,3]. The majority of consumed bananas derive from seedless triploid clones [4]. We distinguish three types of edible bananas. First, "dessert" bananas (AAA) characterized by a high sugar content. It represents the majority of cultivated bananas, especially Cavendish, Gros-Michel and Figue-rose sub-groups [5]. These are generally export varieties. Their production requires a high quantity of inputs and is based on a mono specific model without rotation [6]. Second, cooking bananas (AAB) characterized by a high starch content at maturity. This group essentially consists of plantain bananas. Third, ABB triploid group is represented by more hardy bananas which fruits must be eaten cooked [1,3].

Bananas are cultivated in more than 120 countries and on the five continents in tropical and subtropical areas [7]. Bananas production is the fourth most significant of the world in terms of tonnage, after rice, wheat and maize. In 2013, world production was estimated at more than 106 million tons, of which 2 million produced in Caribbean [8]. However, only a small part is produced for commercial purposes. Indeed, not less than 85% is booked to self-subsistence. It's here about basically cooking bananas. Dessert banana is, on the other hand, generally intended to export. In many developing countries, banana, grown in gardens, ensure a fair income [1].

From a nutritional point of view, bananas and plantains cover not less than 25% of energetical needs in developing countries [9]. Its pulp is rich in easily digestible sugars. Chemically, bananas are composed of approximately 70% of water, 27% of sugars, 1.2% of proteins and 0.3% of fatty acids [10].

Bananas cultivation face to several threatens as diseases and pests which are needed to be taken into account for bananas improvement [11]. Among others, we can mention fungal diseases as the black leaf streak disease caused by *Mycosphaerellafijiensis* and the Sigatoka disease due to *M. musicola*, Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*). Others constraints are also induced by bacterial and viral agents as the Moko disease, BBTV (Banana Bunchy Top Virus), CMV (Cucumber Mosaic Virus), BSV (Banana Streak Virus) or BBMV (Banana Bract Mosaic Virus). Finally, concerns are likewise due to insects, as the black weevil (*Cosmopolites sordidus*) and nematodes (*Rodopholussimilis*) [3]. Currently, control methods used are mainly chemical. Unfortunately, these are not available to small bananas farmers in developing countries due to their prohibitive price [12] and have a negative environmental impact. Moreover, chemical control is not always effective either due to appearance of resistant strains or the lack of effective molecules against some diseases. Therefore, thus reinforces the needs of development of resistance varieties to the principal pests and diseases by genetic improvement programs. These programs have taken into account some socio-economic aspects of production, more especially for export bananas. As far as that goes, new hybrids must full fill agronomic, functional and sensorial criteria [3,13].

Genetic improvement of banana is necessary to divert banana's production of parasitical pressure and to respond consumer's demand for more traceability and the perceived negative effects on the environment caused by pesticides [14]. Likewise, small farmers cannot always face to farm inputs costs, and new hybrids could respond to a main issue of the century, which is food security. The main goals of genetic improvement are first developing abiotic and biotic stress tolerant varieties. The second aim is creating new attractive and segmenting varieties, more especially for the export market.

Current challenge of genetic improvement is to obtain a maximum of criterions to help to make choices during selection process. Breeders have to select essentially hybrids which will potentially meet operators and consumers' expectations. Optimal quality is needed throughout all the post-harvest step, in others words during bananas storage, transport, ripening and marketing. Two types of quality must be satisfied: functional and sensorial quality. Functional qualities included both physiological disorders and post-harvest diseases susceptibility. Sensorial quality reflects more consumer's expectation in term of final product.

This mini review will develop more especially post-harvest disorders of banana and the way they could be managed by the banana post-harvest sector.

Physiological Post-Harvest Disorders of Banana

Physiological disorders are defined as plant or fruit tissue damages caused by neither by an infection nor a mechanical agent [13]. It's developed as a plant response to environmental conditions [15]. Generally, they affect a very discrete tissue area. They can be superficial, i.e. affecting only the fruit skin (e.g. peel splitting) and leave the pulp intact or affecting also the flesh (e.g. bruising) [16]. They affect both shelf life and marketability [17]. Among these, we can cite peel browning and cracking, finger drop or even chilling injury. These disorders affect fruit quality and reduce market value. Post-harvest conditions are the main drivers affecting the quality and post-harvest physiological disorders incidence. Application of the most appropriate temperature and humidity as well the most suitable packaging and handling methods are prerequisites for the bananas reaching consumers in the right condition with optimal quality [18].

Peel Browning

Occurrence: Peel browning is a physiological disorder occurring during maturation process when the fruit is handled. Some varieties seem to be more sensitive than others. Peel browning is caused by a stress related at low temperature or relative humidity [19-21]. Peel browning can be assessed by storing ripened bananas in a room at ambient temperature (20 °C) and low relative humidity (50%). Fruit handling will promote browning if the variety is sensitive.

Importance: Browning limits shelf-life of the banana and reduces its commercial value [22]. Thus, browning is easily detectable by sellers and consumers but is not attractive, curbing act of purchase.

Symptoms: Bananas peel browning is reflected in a brown discoloration of the peel triggered by a peel handling. Browning intensity increases day after day when bananas are stored in dry conditions. Symptoms develop the entire banana surface.

Physiology: This disorder result from an enzymatic and non-enzymatic oxidation of phenolic compounds [23]. It involves the activities of poly phenol-oxidase (PPO), phenylalanine ammonialyase (PAL) and peroxidase (POD). Histologically, PPOs are localized in the chloroplasts [23] or in the cytoplasm and in vesicles between the plasma lemma and cell wall [20] whereas phenolic compounds are synthesized in the cytoplasm and are present in vacuoles. Thus, a membrane damage is needed to put into contact these components in order to induce catalyze reaction. Banana peel browning would result of pre-existing free phenolic compounds release [24]. It's correlated with an increase in the production of phenyl-ammonia-lyase (PAL) and poly phenol-oxidase (PPO) and a decrease of both the total free phenolic compounds and anthocyanins [25]. Polyphenol-oxidase is the enzyme considered as responsible of fruit and vegetables browning [26].

Control: Storing fruit at high relative humidity (95%) can delayed peel browning [27]. Post-harvest browning seems to be correlated with a peel desiccation [28]. In practice, atmosphere relative humidity during shipping and maturation could be managed by a maturation chamber ventilation, air extraction system and use of macro perfored polyethylene bags.

Peel Bruising

Occurrence: Banana bruise damages appear essentially during bananas commercialization, on the market stalls during the handling of fruits [13]. Bruises damages results of a mechanical contact of the fruit with other bodies [29]. Peel bruising can be assessed by impacting ripened bananas, harvested at optimal thermal sum, with a small steel ball (19 mm) down a guiding tube from a range of standard heights at several energies. The weaker impact energy to produce bruising is, the more sensitive banana is [30].

Importance: Peel bruising has been identified as a major cause of quality loss, resulting in a decreasing commercial value [31]. Peel bruising is superficial, thus damages are perceptible from the outside and can prevent potentially the act of purchase [32]. Moreover, damaged tissues area key factor to pathogen invasion [33].

Symptoms: Bruise susceptibility is not exactly a physiological disorder since that it results from a mechanical damage [34], more especially an impact which could be paired with a skin rupture. Bruising leads to the appearance of a brown to black impact on the fruit surface. That occurs rapidly after the damage and spreads on all the impact area. Symptoms are observable on the banana peel but do not impact necessary the fruit pulp [34].

Physiology: It seems that browning linked to bruising would be triggered by enzymatic reaction [35]. For a same variety, sensitivity varies according to the fruit maturity stage at harvest [36]. Susceptibility is also impacted by the fruit turgidity [37] and flesh firmness at time of injury [36]. The severity of bruising depends on the energy and number of impact, the type of impact surface [38]. Bruising susceptibility relies on several factors as temperature, fruit size and fruit shape or tissue and cellular factors as cell wall strength and elasticity, cell shape and internal structure [38-40]. However, temperature and humidity affects remain controversial [41,42]. Mechanical damages also stimulate respiratory process and ethylene biosynthesis [43,35]. Damaging the peel decreases its resistance and provokes loss of cell and membrane integrity [34]. Thus, phenolic compounds stored in vacuolesenters into contact with enzyme [44]. This induces oxidation of phenolic compounds to quinones, which polymerize then to brown pigments [41,35,45].

The reduction in temperature during ripening reduced susceptibility to impact bruising. Both indicators of the rate of ripening, pulp firmness and soluble solids, showed that the decrease in temperature during ripening delayed fruit maturity by two days, as reported in similar conditions by Omoaka [46]. Membrane permeability, which was found to be the best explanatory parameter for bruise susceptibility, was not significantly impacted by storage treatments. Ratule et al. [47] reported no differences in peel electrolyte leakage in green bananas stored at 10 °C and 15 °C. The decrease in storage temperature was reflected in lower total polyphenolic contents during ripening. In more severe storage conditions i.e.

with chilling temperatures, Nguyen et al. [20] also found that low temperatures decreased total polyphenolic content in pre-climacteric fruit. However, the differences in total polyphenolic content between storage treatments are probably not enough to explain differences in bruise susceptibility, since, as mentioned previously, phenolic compounds were not a factor that limit bruise susceptibility in banana.[NoIcon Annotation]

Control: Varieties differs from each other's by a different sensitivity. Bugaud et al. [34] did not observe visible bruise even under the maximum impact (200 ml) for Grand Naine (AAA, Cavendish subgroup) and Flhorban925 (hybrid produced in Cirad'breeding program; AAA) whatever the maturity while they noticed an increasing bruise susceptibility for Fouganou (ABB; PisangAwak subgroup) or Frech Corne (AAB, Plantain subgroup). Using appropriate commodities conditioning can prevent peel bruising [47]. Because higher turgidity allows to elevate the threshold at which banana peel is sensitive to bruising, it would be better to harvest fruit in the morning and to improve next steps in order to reduce water loss [30]. Reducing temperature during post-harvest chain could reduce damages caused by bruising [22].

Peel Cracking

Occurrence: Genetic, environmental, morphologic and physiologic factors affect peel cracking sensitivity but post-harvest peel splitting is mainly attributable to the environmental conditions of storage [48]. It occurs only between the third and the sixth day after maturation induction (Brat et al., 2016 - unpublished data). Generally, peel cracking is induced by high relative humidity. Some cultivars are more sensitive than others as 'Mas (AA)' [49]. Peel splitting could be assessed by storing green bananas harvested at the optimal thermal sum into a perforated polyethylene film contained in a carton. Ripening is induced by exposure to ethylene. Then, polyethylene film is closed in order to induce splitting by saturate humidity conditions (90-95% RH). The percentage of splitting could be calculated as the number of splitted bananas relative to the total banana number [13].

Importance: Fruit cracking is one of the main physiological disorders limiting post-harvest fruit quality and quantity. Peel splitting results in open wounds promoting rapid moisture loss and opportunistic pathogens infection [49]. Moreover, cracking fruit is not attractive to consumer and also decreases its marketability.

Symptoms: Peel cracking is a physiological disorder reflecting by a longitudinal split of the peel and exposing the pulp. Generally, it begins near the pedicel, and more especially at peel junctions between two flat segments [50]

Physiology: Currently, this disorder is attributed to a peel water content reduction by an inverse water flux from the peel to the flesh [52]. This water movement is induced by osmose due to an increasing sugar content in the pulp [53]. This provokes a turgor pressure increase higher than the pressure corresponding to the expansion capability of the fruit cuticle [54]. Moreover, it was observed a reduction of the peel resistance and a higher water loss by transpiration leading to a peel cracking. Skin characteristics are tightly linked to crack resistance as cuticle mechanical proprieties and thickness [55,56] or tissues and cells architecture [57]. Peel cracking is associated to a boost of respiration, an increase of the oxidative stress markers and a high oxidative stress damage [50].

The thin cuticle and low wax content, and consequently the specific epicuticular wax/cutin thickness ratio could act as mechanical structure regulator and directly impact fruit transpiration. For cultivars prone to peel cracking: the marked rise in fruit respiration under saturating humid conditions linked to higher solute consumption during ripening could hypothetically induce a marked decrease in the osmotic potential in fruit pulp associated with ripening. Peel water loss under saturating relative humidity conditions would therefore cause a reduction in turgor pressure associated with a cellular collapse, as observed through microscopic analysis. This crack-prone cultivar showed a lack of ROS detoxifying enzymes compared to the GN reference. This not well-regulated oxidative stress for this cultivar could be one of the factors associated with peel splitting susceptibility. The much higher increase in hydrogen peroxide production was indeed associated with a boost of MDA production and peel electrolyte leakage markers of cellular damage [50].

Control: Peel cracking can be controlled by implementation of dry humidity conditions during ripening, i.e. by managing the level of perforation of polyethylene bag or the humidity in the ripening and storage chambers. It seems also that pre-harvest conditions, as calcium deficiency, could impact appearance of peel splitting [54].

Finger drop

Occurrence: Finger drop occurs during banana ripening. Susceptibility varies according to the cultivar [52] and has been reported in the diploid, triploid and tetraploid cultivars [58,59]. However, it seems that tetraploid cultivars were more sensitive than others [58]. Post-harvest environmental conditions impact this physiological disorder intensity. High relative humidity stimulates finger drop [60,61]. However, water content in the peel does not seem to be implicated in this process [52]. High ripening temperature [57] and ethylene promotes weak neck [52]. Hands physiological age influences the sensitivity: more mature they are, more sensitive they are [52]. Weak neck may have three possible causes: genetics, nutrition and post-harvest conditions [16].

Importance: Bananas are generally marketed by 5 or 6 fingers attached together, called cluster. Finger drop is a process leading, during fruit maturation, to a finger break off from the cluster crown. This reduces the market value [60] and increases the potential risk of pathogens contaminations.

Symptoms: Baldry et al. [63] defined finger drop as "physiological softening and weakening of the pedicel which cause the individual fruit of a hand to separate very easily from the crown". This phenomenon is associated to a weakening of the pedicel without the existence of a preferential abscission zone, suggesting a peel weakening [62]. This break up takes place at the pedicel (lignified tissue) – pulp(non-lignified tissue) junction zone [62]. Finger drop assessment could be realized by subjecting a ripened cluster to a 3-5 manual shaking. Recording the number of fingers dislodged allow to calculate the percent of fingers drop per cluster [13].

Another method is to determine the force (N) required to break up the pedicel of the finger [60].

Physiology: It is concluded that finger drop is not due to true abscission but to breaking of the peel at the junction of the fruit and the hand. No evidence was found for a decisive role in this rupture of any of the following factors: fruit weight and thickness, and water content of the peel at the rupture area. A positive correlation was found with the activity of pectate lyase in the peel at the rupture area [62]. Physiologically, fruit ripening is associated with a peel and pulp softening. Currently, this softening is linked to a change in the pectic components of the primary cell walls and middle lamellae [60] due to a de polymerization of the pectic substances [62]. Peel of sensitive bananas to finger drop contains more water-soluble pectin at the rupture area. Moreover, Imsabai et al. [62] showed a lower content of CDTA soluble pectin and insoluble pectin in the sensitive variety peel, suggesting a pectin breakdown and a pectin degradation. This breakdown resulting of an increasing pectate lyase (PL) and pectin methyl esterase (PME) activity [58,61] highlighted a change in the expression of major cell wall modifying genes (CWMG) and ethylene biosynthesis genes [65] occurring in the finger drop area.

Control: Balanced crop nutrition could reinforce cell structure and maintain cell integrity and weak neck could be solved by application of boron, magnesium or silicon [16].

Decreasing residual ethylene concentration in the storage chamber with ethylene absorbers could prevent finger drop. Moreover, using appropriate polyethylene bag (for instance macro-perfored) could help to reduce ambient air moisture.

Chilling injury

Occurrence: Tropical and subtropical plants exhibit a marked physiological dysfunction when exposed to low or nonfreezing temperatures below about 10 to 12 °C. This dysfunction has been of great concern for many years with harvested plant parts because lowered storage temperatures are generally an effective means of extending the post-harvest life of fruits and vegetables [66]. Chilling injury (CI) is the term used to describe physiological damage to fruit tissues resulting from the exposure of chilling-sensitive fruits to temperatures below a critical threshold. In banana (*Musa* spp.), CI can occur in unripe or ripe fruit and may reduce fruit quality and market value [67].

Importance: Chilling injury avoidance represents a key economic step in the banana food chain. Indeed, this physiological problem is only evidenced during fruit maturation and each storage place particularly after ripening induction (e.g. at the market place) must clearly avoid a storage under this critical temperature (i.e. 13 °C for Cavendish). This highly sensitive fruit should be definitely be stored separately to the other non-sensitive fruits stored at very low temperature.

Symptoms: Postharvest losses resulting from CI are probably greater than has been recognized. Quite often, CI symptoms may not be apparent while the produce is still in cold storage; the symptoms show up later, only after the produce has been transferred to market where the temperature is higher [65]. Symptoms of chilling injury become apparent after a few days of storage at the injurious chilling temperature or after transfer of fruits to non-chilling temperatures. When chilling is not severe, which is true in the majority of cases in the conditions used by the banana export industry, the banana green fruit develops surface lesions such as pitting in the first layer of the green epicarp and the color of the peel becomes dull yellow to grayish-yellow or gray during ripening [34].

Physiology: As defined by Asghari & Aghdam [69], cell membrane is the primary structure affected by CI, the transition of the cell membranes from a flexible liquid crystalline phase to a solid gel structure that occurs at chilling temperature increment the risk of cell membrane semi-permeability loss. Taken together, electrolyte leakage measurement or malondialdehyde content, as physiological markers of loss of membrane semi-permeability and membrane lipid per oxidation, were widely used to measure the intensity of this disorder. Membrane damage and reactive oxygen species production are multifarious adverse effects of chilling as oxidative stress in sensitive fruits and vegetables [69].

The physiological changes in green bananas which are very sensitive to chilling injury, were studied during and after exposure to low temperatures (4±1°C, 6±0.5°C) for various periods by Murata [70]. While the fruits injured by chilling did not fail to produce CO2 and ethylene, the pattern of both CO2- and ethylene production in these chilled fruits (9 and 15 days at 6°C) after transfer to 20°C was not normal. The contents of acetaldehyde and ethanol in chilled fruits, both in peels and pulps, increased with the advance of chilling, injury. There was an accumulation of α-keto acids in the peels of chilled fruits. Only half the conversion of 14C (fed as succinic acid-1, 4-14C) to citric acid and isocitric acid was observed in chilled tissues as compared with healthy ones; the activity of citrate synthase in banana peels appears therefore to be inhibited by chilling injury. A histological study of the tissues showed that the browning substances (polyphenols) present in chilled fruits accumulate around the vascular tissues [70].

Control: Postharvest researchers have taken several approaches to lessen chilling-induced injury. These postharvest techniques include temperature conditioning, intermittent warming, controlled-atmosphere storage, chemical treatments, and growth regulator application. The first three techniques involve manipulating and modifying the storage environment, while the other methods involve directly treating the commodities. These techniques reduce CI by either increasing the tolerance of commodities to chilling temperature or retarding the development of CI symptoms [68]. In the Cavendish and Gros Michel groups, chilling injury symptoms develop at temperatures below 12.5 °C. To avoid this problem, bananas are shipped at a controlled temperature of 13-14 °C.

Green life shortening

Banana green life duration corresponds to the potential storage life of banana before the initiation of the climacteric rise [71]. The knowledge of this value is crucial for the export banana because this represents the ability of the fruit transport. Therefore, it is inacceptable to select hybrids with a very short green life duration, except for the local market, since fruits must withstand shipping transport during three or four weeks [72]. Green life duration is measured thanks to the evolution of O_2 and CO_2 concentrations which allows to detect the climacteric peak. Bananas are climacteric fruits meaning they are able to ripen even after the harvesting. Their ripening process is divided into three parts: a pre climacteric stage, the climacteric rise (corresponding to an increasing respiration) and fruit maturation (characterizing by an ethylene production).

Green life duration could be impacted by several factors as environmental conditions or pathogens before and after harvest. It is strongly correlated with the cumulative thermal sum before harvest [73]: the shorter the thermal sum is, the longer the green life duration is [72]. High conservative temperatures reduce green life duration [3]. Pre-harvest disease, as black leaf streak disease [74], or post-harvest, as the crown rot or anthracnoses [75], decrease green life duration.

Conclusion

Physiological disorders impede widely acquisition of new varieties by bananas growers. Indeed, post-harvest quality and yield at harvest for these varieties are not guaranteed systematically contrary to Cavendish bananas. However, a paradigm shift is required because current mono specific model only based on external inputs could not be assumed as sustainable. Growing new varieties with practices more respectful of the environment will necessitate changes and adaptations of the whole banana stakeholders. However, solutions for each physiological disorders exist. Their implementation does not require always important technicalities. Using appropriate maturity stage at harvest, polyethylene bag, and adapt temperature and relative humidity of air ambient from harvest to ripening stage and market can solve in some extent these problems.

References

1. Thurston D (1998) Bananas and Plantain in Tropical Plant Disease. (2nd edn), APS Press, USA, pp. 101-105.
2. Lassois L, Busogro JP, Jijakli H (2009) La banane : de son origine a sa commercialisation. Biotechnol Agr Soc Environ 13(4): 575-586.
3. Lassoudière A (2007) Le bananier et sa culture. Quae, France, pp. 383.
4. Bakry F, Haicour R, Hourry JP, Megia R, Rossinol L (1993) Applications of biotechnologies to banana breeding: haplogenesis, plant regeneration from protoplasts, and transformation. Biotechnology Applications for Banana and Plantain Improvement. INIBAP, Montpellier, pp. 52-62.
5. Demol J (2002) Amélioration des plantes. Application aux principales espèces cultivées en région tropicale in Les presses agronomiques de Gembloux, pp. 581.
6. Jenny C, Tomekpe K, Bakry F, Escalant JV (2003) Conventional breeding of bananas in *Mycosphaerella* leaf spot diseases of bananas: present status and outlook. Proceeding of the workshop on *Mycosphaerella* leaf spot diseases held in San José, Costa-Rica on 20-23 May 2002 INIBAP, Montpellier, France.
7. Bakry F, Carreel F, Caruana ML, Côte FX, Jenny C, et al. (1997) Les bananiersin. In: Charrier A, Jacquot M, et al. (Eds.), Lamelioration des plant estropicales. CIRAD/ORSTOM, Montpellier, France, pp.109-139.
8. FAOSTAT (2016).
9. CGIAR (2016) Banana and plantain.
10. Sharrock S, Lusty (2000) Nutritive value of banana. Inibap annual report 1999, Montpellier, France, pp. 28-31.
11. Jones DR (1999) Diseases of banana, abacá, and enset. CABI Publishing, Wallingford, Oxon, UK, pp. 544.
12. Bakry F, Carreel F, Horry JP, Jenny C, Tomekpe K (2005) La diversite genetique des bananiers cultive: situation actuelle et perspectives. Le Sélectionneur Francais 55: 33-41.
13. Dadzie BK, Orchard JE (1997) Routine post-harvest screening of banana/plantain hybrids: criteria and method. Inibap Technical Guidelines p. 75.
14. Turner DV (1897) Needs for plant improvement in the edible *Musa*- an overview in Banana and plantain breeding strategies. Int Work Australia. p. 24-28.
15. Wills RHH, Mc Glasson WB, Graham D, Lee TH, Hall EG (1989) Postharvest: a introduction to the physiology and handling of fruit and vegetables. (3rd edn), Blackwell Scientific Publications, Oxford, UK, pp. 280.
16. Putra E, Zakaria W, Abdullah N, Saleh G (2010) Weak neck of *Musa* sp. cv. Rastali : a review on it's genetic, crop nutrition and post harvest J Agro 9(2): 45 -51.
17. Johnson GI, Sharp JL, Mine DL, Oostluyse SA (1997) Postharvest technology and quarantine treatments *in* The mango: Botany, production and uses. Tropical Research and Education Center, USA, pp. 444-506.
18. Hailu M, Workneh TS, Belew D (2013) Review on postharvest technology of banana fruit. African Journal of Biotechnology 12(7): 635-647.
19. Landrigan M, Morris SC, Gibb KS (1996) Relative humidity influences postharvest browning in rambutan (*Nepheliumlappaceum* L.) HortSci 31(3): 417-418.
20. Nguyen T, Ketsa S, van Doorn W (2003) Relationship between browning and the activities of polyphenol oxidase and phenylalanine ammonia lyase in banana peel during low temperature storage. Post Biol Technol 30(2): 187-193.
21. Jiang YM, Fu JR (1999) Postharvest browning of litchi fruit by water loss and its prevention by controlled atmosphere storage at high relative humidity. Lebensm Wiss u Technol 32(5): 278-283.
22. Yang CP, Fujitan S, Kohno K, Kusubayashi A, Ashrafuzzaman MD, et al. (2001) Partial purification and characterization of polyphenol oxidase from banana (*Musa sapientum*L.) peel. J Agric Food Chem 49(3): 1446-1449.
23. Martinez V, Whithaker J (1995) The biochemistry and control of enzymatic browning. Trends in Food Science & Technology. 6(6): 195-200.
24. Gooding PS, Bird C, Robinson SP (2001) Molecular cloning and characterization of banana fruit poly phenol oxidase. Planta 213(5): 748-757.
25. Jiang Y (2000) Role of anthocyanins, polyphenol oxidase and phenols in lychee pericarp browning. F Sci Food Agric 80: 305-310.
26. Mayer AM, Harel E (1979) Polyphenol oxidases in plants. Phytochem 18: 193-215.

27. Wells I, Bagshaw J (1989) Handling rambutants after harvest. Queensland fruit Veg News 16-17.

28. Underhill SJR, Simons DHL (1993) Lychee (*Litchi chinensisSonn*.) pericarp dessication and the importance of postharvest micro-cracking. Sci Hort 54(4): 287-294.

29. Blahovec J, Paprstein F (2005) Susceptibility of pear varieties to bruising. Postharvest Biology and Technology 38(3): 231-238.

30. Banks NH, Joseph M (1991) Factors affecting resistance of banana fruit to compression and impact bruising. J Sci Food Agric 56: 265-268.

31. Pang W, Studman CJ, Ward GT (1992) Bruising damage in apple-to-apple impact. Journal of Agricultural Engineering Research 52: 263-277.

32. Menesatti P, Beni C, Paglia G, Marcelli S, Dandrea S (1999) Predictive statistical model for the analysis of drop impact damage on peach. Journal of Agricultural Engineering Research 73(3): 275-282.

33. Bruton BD (1994) Mechanical injury and latent infections leading to postharvest decay. HortScience 29: 747-748.

34. Bugaud C, Ocrisse G, Salmon F, Rinaldo D (2014) Bruise susceptibility of banana peel in relation to genotype and post-climateric storage conditions. Post Biol Technol 87: 113-119.

35. Maia VM, Salomao LCC, Siquiera DL, Puschman R, Filho VJGM, et al. (2011) Physical and metabolic alterations in "PrataAnã" banana induced by mechanical damage at room temperature. Sci Agric (*Piracicaba, Braz*.) 68(1): 31-36.

36. Arpaia M L, Mitchell F G, Katz P M, Mayer M (1987) Susceptibility of avocado fruit to mechanical damage as influenced by variety, maturity and stage of ripeness. South African Avocado Growers 'Association Yearbook 10: 149-151.

37. Garcia JL, Ruiz AltisentM, Barreiro P (1995) Factors influencing mechanical properties and bruise susceptibility of apples and pears. J Agric Eng Res 61: 11-17.

38. Ahmadi E, Ghassmenzadeh H R, Sagehui M, Moghaddam M, Neshat SZ (2010) The effect of impact and fruit properties on the bruising of peach. Journal of Food Engineering 97: 110-117.

39. Van Zeebroek M, Van Linden V, Darius P, De Ketelaere B, Ramon H, et al. (2007) The effect of fruit properties on the bruise susceptibility of tomatoes. *P*ostharvest Biology and Technology *45*: 168-175.

40. Van Linden V, Scheerlinck N, Desmet M, De Baerdemaeker J (2006) Factors that affect tomato bruise development as a result of mechanical impact. Postharvest Biology and Technology 42: 260-270.

41. Klein J D (1987) Relationship of harvest date, storage conditions, and fruit characteristics to bruise susceptibility of apple. J Am Soc Hort Sci 112: 113-118.

42. Akkaravessapong P, Joyce DC, Turner DW (1992) The relative humidity at which bananas are stored does not influence their susceptibility to mechanical damage. Sci Hortic 52: 265-268.

43. Crisosto C H, Garner D, Doyle J, Day K R (1993) Relationship between fruit respiration, bruising susceptibility, and temperature in sweet cherries. Hort Science 28(2): 132-135.

44. Martinez Romero D, Serrano M, Carbonell A, Castillo S, Riquelme F, et al. (2004) Mechanical damage during fruit post-harvest handling: technical and physiological implications *in* Production practices and quality assessment of food crops 3: 233-252.

45. Rinaldo D, Mbeguie A Mbeguie D, Fils Lycaon B (2010) Advances on polyphenols and their metabolism in sub-tropical and tropical fruits. Trends Food Sci. Technol 21(12): 599-606.

46. Omoaka (2000) Postharvest physiology, ripening and quality evaluation in banana (*Musa sp.*) fruits. Thesis. Universitécatholique de Leuven, p.182.

47. Ratule NMT, Osman A, Ahmad SH, Saari N (2006) Development of chilling injury of Berangan banana (*Musa cv*. Berangan (AAA)) during storage at low temperature. J Food Agric Environ 4(1): 128-134.

48. Baritelle A, Hyde G M (2001) Commodity conditioning to reduce impact bruising. Postharvest Biology and Technology 21(3): 331-339

49. Khadivi Khub A (2015) Physiological and genetic factors influencing fruit cracking. Acta Physiol Plant *37*: 1718.

50. Brat P, Lechaudel M, Segret L, Morillon R, Hubert O, et al. (2016) Post-harvest banana peel splitting as a function of relative humidity storage conditions. Acta Physiologiae Plantarum 38: 234.

51. Wo S M, Osman A, Ahmad S H, Saari N (2005) Peel and pulp splitting in Mas banana (Musa cv Mas (AA)). Journal of Food Agriculture & Environment *3*(2): 213-215.

52. Paull R (1996) Ethylene, storage and ripening temperatures affect Dwarf Brazilian banana finger drop. Post Biol Technol 8: 65-74.

53. Peet M M (1992) Fruit cracking in tomato. Hort Technol 2 : 216-223.

54. Wang Y, Long LE (2015) Physiological and biochemical changes relating to postharvest splitting of sweet cherries affected by calcium application in hydrocooling water. Food Chemistry 181: 241-247.

55. Demirsoy L, Demirsoy H (2004) The epidermal characteristics of fruit skin of some sweet cherry cultivars in relation to fruit cracking. Pak J Bot 36(4): 725-731.

56. Khanal BP, Grimm E, Knoche M (2011) Fruit growth, cuticle deposition, water uptake, and fruit cracking in jostaberry, gooseberry, and black currant. Scientia Hoticulturae 128(3): 289-296.

57. Sekse L (1995) Fruit cracking in sweet cherries (*Prunusavium L.*) Some physiological aspects-a mini review. Scientia Horticulturae 63(3-4): 135-141.

58. New S, Marriott J (1983) Factors affecting the development of 'finger drop' in bananas after ripening. J Food Technol 18(2): 241-250.

59. Pereira M, Salomao L, de Oliveira S, Cecon P, Puschmann R, et al. (2004) Different banana genotypes in relation to their susceptibility to finger drop and fruit characterization. Rev Bras Frutic 26: 499-502.

60. Semple A, Thompson A (1988) Influence of the ripening environment on the development of finger drop in bananas. J Sci Food Agric 46(2): 139-146.

61. Saengpook C, Ketsa S, van Doorn (2007) Effects of relative humidity on banana fruit drop. Post Biol Technol 45(1): 151-154.

62. Imsabai W, Ketsa S, van Doorn W (2006) Physiological and biochemical changes during banana ripening and finger drop. Post Biol Technol 39(2): 211-216.

63. Baldry J, Coursey DG, Howard GE (1981) The comparative consumer acceptability of triploid and tetraploid banana fruit. Trop Sci 83: 213-218.

64. Mbeguie A Mbeguie D, Hubert O, Baurens FC, Matsumoto T, Chillet M, et al. (2009) Expression patterns of cell wall-modifying genes from banana during fruit ripening and in relationship with finger drop. J Exp Bot 60(7): 2021-2034.

65. Hubert O, Piral G, Galas C, Baurens FC, Mbeguie A Mbeguie D (2014) Changes in ethylene signaling and MADS box gene expression are associated with banana finger drop. Plant Sci 223: 99-108.

66. Lyons J M (1973) Chilling injury in plants. Ann Rev Plant Physiol 24(1): 445-466.

67. Bugaud C, Joannes Dumec C, Louisor J, Tixier P, Salmon F (2015) Preharvest temperature affects chilling injury in dessert bananas during storage. J Sci Food Agric 96(7): 2384-2390.

68. Wang Chien Yi (1994) Chilling injury of tropical horticultural commodities. Hort Sci 29: 986-988.

69. Asghari M, Aghdam MS (2010) Impact of salicylic acid on post-harvest physiology of horticultural crops. Trends Food Sci Technol 21(10): 502-509.

70. Murata (1969) Physiological and biochemical studies of chilling injury in bananas. PhysiologiaPlantarum 22 (2): 401-411.

71. Chillet M, de Lapeyre de Bellaire L, Hubert O, Mbeguie A Mbeguie D (2008) Measurement of banana green life. Fruit 63: 125-127.

72. Umber M, Paget B, Hubert O, Salasb I, Salmon F, et al. (2011) Application of thermal sums concept to estimate the time to harvest new banana hybrids for export. Sci Hort 129(1): 52-57.

73. Jullien A, Chillet M, Malezieux E (2008) Pre-harvest growth and development, measured as accumulated degree days, determine the post-harvest green life of banana fruit. J Hort Sci Biotech 83(4): 506-512.

74. De Lapeyre L, Foure E, Abadie C, Carlier J (2010) Black leaf streak disease is challenging the banana industry. Fruit 65: 327-342.

75. Bugaud C, Lassoudière A (2005) Variabilité de la durée de vie verte des bananas en conditions réelles de production. Fruits 60(4): 227-236.

Citation: Luyckx A, Lechaudel M, Hubert O, Salmon F, Brat P (2016) Banana Peel Physiological Post-Harvest Disorders: A Review. MOJ Food Process Technol 3(1): 00060. DOI: 10.15406/mojfpt.2016.03.00060