UNIVERSITI PUTRA MALAYSIA

EFFECTS OF CUTTING SIZE AND ORGANIC ACID ON QUALITY AND ENZYME ACTIVITIES OF FRESH-CUT WAX APPLE (Syzygium samarangense (BLUME) MERILL & PERRY)

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By

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Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

May 2015

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia on fulfilment of the requirement for the degree of Master of Science

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May 2015

Chair: Associate Professor Yahya Awang, PhD

Faculty: Agriculture

Wax apple seems to be one of the potential fruits for fresh-cut market. The knowledge on fresh-cut wax apple is still lacking especially on their enzymes activity with respect to cell wall softening and tissue browning and how these enzymes could contribute in maintaining products' quality. Thus, the study was conducted in order to gain more knowledge on the changes that occurred during the processing of fresh-cut wax apples that might be affected by cutting sizes and dipping treatment while remaining or maintaining the quality almost as good as intact fruits.

In the first experiment, wax apples were stored as whole (control), halves, quartered, and wedged in domestic refrigerator (~5^0C) for nine (9) days and observed at 0, 3, 6, and 9 day. Water loss was observed to be increasing from day zero to day nine and also significantly related with the cutting sizes in which the whole wax apples lost the least amount of water compared to other cutting sizes. Firmness, total soluble solid, and ascorbic acid of wax apples were reduced significantly throughout the nine days of storage meanwhile the titratable acidity and pH value was observed to increase throughout the storage period. Since cutting sizes did not showed much significant differences on post-harvest qualities except for weight loss and titratable acidity, it is recommended to process wax apple into wedged (1/8) since they have the ability to retain their moisture by absorbing back more water from the condensation that could prevent weight loss. In conclusion, it is possible to use *Syzygium samarangense* as fresh-cut products as the changes in the qualities of fresh-cut wax apples was not critical in a way that they could reduce the market value of wax apples.

For the second experiment, the wedged fresh-cut wax apples were dipped into three types of organic acids; ascorbic acid (AA), citric acid (CA), and oxalic acid (OA) at five different concentrations (0, 0.5, 1.0, 1.5 and 2.0%) and stored for nine days. The type of acids did not significantly affect water loss of the samples but the parameter was markedly varied under varying levels of acid concentration ($P \leq 0.01$) and storage period ($P \leq 0.0001$). The effect of acid concentration was apparently interacted significantly with period of storage ($P \leq 0.01$). The titratable acidity of fresh-cut wax apples was significantly affected by different type of acids but their effects on TA varied depending on their concentration. At a lower concentration of organic acids, the TA measured were similar to each other for AA, CA, and OA but the TA in the OA-dipped fresh-cut wax apples started to increase significantly as the concentration of organic acids increased from 1.0 to 2.0%. In comparison to CA and OA, the concentration of AA dipping treatment caused the increased of the ascorbic acid content in fresh-cut wax apples without decreasing the pH that indicates sourness which can be an added value to fresh-cut wax apple in terms of nutrition. OA treated wax apples was recorded with the highest antioxidant activity which is 90.64% followed by CA (86.15%) and AA (81.17%) with the significant increased throughout nine days of storage period. Fresh-cut wax apples treated with OA (33.84 mg/100g) and CA (33.64 mg/100g) resulted in a significantly higher TPC in comparison to those dipped in AA (30.43 mg/100g) with the increased in TPC over nine days of storage period. As for enzyme activities, only pectin methylesterase and polyphenol oxidase activities were only affected by storage period whereas polygalacturonase activity was not affected by the treatment given.

Overall, it can be concluded that the treatment with the 2.0% of ascorbic acid was proven to be beneficial for fresh-cut wax stored up to 9 days since it was recorded with the highest amount of ascorbic acid content or better known as vitamin C compared to other concentrations but at the same time, the pH remains similar to others that may suggest the retention of the flavours for the fresh-cut wax apples.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

KESAN SAIZ POTONGAN DAN ASID ORGANIK KE ATAS KUALITI DAN AKTIVITI ENZIM BUAH JAMBU AIR (*Syzygium samarangense* (BLUME) MERILL & PERRY)

Oleh

NUR IZZAH BINTI KADIR

Mei 2015

Pengerusi : Professor Madya Yahya Awang, PhD

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Jambu air merupakan salah satu buah yang berpotensi untuk menjadi produk potongan segar. Pengetahuan tentang jambu air potong ini masih lagi kurang terutamanya berkaitan rawatan celupan serta enzim yang mempengaruhi kekerasan serta pemerangan sel tisu jambu serta bagaimana enzim boleh memberi kesan dalam usaha mengekalkan kualiti produk. Oleh itu, kajian ini dilakukan untuk medapatkan lebih pengetahuan tentang perubahan yang berlaku semasa pemprosesan buah jambu air potong yang mungkin dipengaruhi oleh saiz potongan dan rawatan celupan dalam mengekalkan kualitinya sebaik buah yang tidak diproses.

Untuk eskperimen pertama, jambu air telah disimpan secara keseluruhan, potongan separuh, potongan 4, dan potongan 8 disimpan di dalam bekas dan diletakkan ke dalam peti ais (~5^0C) untuk 9 hari dan dianalisis pada hari 0, 3, 6, dan 9. Kehilangan air diperhatikan meningkat daripada hari kosong kepada hari ke sembilan dan berkaitan secara signifikan dengan saiz potongan di mana jambu air yang tidak diproses kehilangan sedikit air berbanding dengan saiz potongan yang lain. Kekerasan, jumlah pepejal larut dan asid askorbik berkurang dengan ketara sepanjang 9 hari penyimpanan sementara itu keasidan tertitrat dan nilai pH diperhatikan meningkat sepanjang tempoh penyimpanan. Memandangkan saiz potongan tidak menunjukkan banyak perbezaan dalam kualiti pasca tuai kecuali untuk kehilangan berat dan keasidan tertitrat, ianya dicadangkan untuk memproses buah jambu air pada potongan 1/8 memandangkan mereka mempunyai kebolehan untuk mengekalkan kelembapan dengan menyerap kembali lebih banyak air yang terhasil daripada proses kondensasi yang boleh mengurangkan kehilangan berat. Kesimpulannya, jambu air mempunyai potensi sebagai produk potongan segar kerana perubahan kualiti buah jambu air potong tidak kritikal sehingga mampu mengurankan nilai pasaran jambu air.

Di dalam eksperimen kedua, jambu air potong 1/8 telah dicelup ke dalam tiga jenis asid organik termasuk asid askorbik (AA), asid sitrik (CA), dan asid oksalik (OA) pada 5 kepekatan yang berbeza (0, 0.5, 1.0,1.5, dan 2.0%). Hasil menunjukkan jenis asid tidak mempengaruhi kehilangan air secara signifikan tetapi berbeza di bawah kepekatan asid yang berbeza ($P \leq 0.01$) dan juga tempoh simpanan ($P \leq 0.0001$) yang juga dikesan berinteraksi antara satu sama lain ($P \leq 0.01$). Keasidan tertitrat dipengaruhi secara signifikan oleh jenis asid tetapi berbeza bergantung kepada kepekatannya. Pada kepekatan asid yang rendah, keasidan tertitrat untuk jambu air untuk celupan ke dalam AA, CA, dan OA adalah hampir sama tetapi untuk OA meningkat sebaik sahaja kepekatannya meningkat daripada 1.0% ke 2.0%. Berbanding dengan celupan ke dalam CA dan OA, kepekatan celupan AA telah meningkatkan kandungan asid askorbik di dalam jambu air potong tanpa merendahkan pH yang menunjukkan tahap kemasaman yang boleh dijadikan nilai tambah untuk jambu air potong dari segi nutrisi. Jambu air potong yang dicelup dengan OA juga merekodkan kadar antioksida yang paling tinggi iaitu 90.64% diikuti dengan CA (86.15%) dan AA (81.17%) dengan peningkatan yang signifikan sepanjang sembilan hari penyimpanan. Kandungan fenolik untuk jambu air yang dicelup dengan OA (33.84 mg/100g) dan CA (33.64 mg/100g) adalah lebih tinggi daripada AA (30.43 mg/100g) yang menunjukkan peningkatan sepanjang tempoh penyimpanan. Untuk enzim aktiviti pula, hanya aktiviti pektin metilesterase dan polifenol oksida hanya dipengaruhi oleh jangka waktu simpanan sementara aktiviti polygalakturonase tidak berubah oleh rawatan yang diberikan.

Secara keseluruhannya, rawatan (celupan) ke dalam 2.0% asid askorbik dikenalpasti dapat memberi kelebihan untuk jambu air potong untuk penyimpanan sehigga sembilan hari memandangkan ianya direkodkan dengan jumlah asid askorbik atau lebih dikenali dengan vitamin C berbanding kepekatan yang lain tetapi pada masa yang sama dapat mengekalkan nilai pH sama dengan yang lain.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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%	percent
^{0}C	degree celcius
AA	ascorbic acid
AAS	atomic absorption spectrophotometer
ANOVA	analysis of variance
CA	citric acid
CRD	completely randomized design
FW	fresh weight
LSD	least significant difference
OA	oxalic acid
FAO	Food and Agriculture Organization
TA	titratable acidity
TSS	total soluble solid
TPC	total phenolic content
GRAS	generally recognized as safe
PPO	polyphenol oxidase
PG	Polygalacturonase
PME	pectin methylesterase

CHAPTER 1

INTRODUCTION

Syzygium samarangense or commonly known as wax apple is a species from the Myrtaceae family. The plants of Myrtaceae family can be found abundantly around South East Asia, South America, and Australia (Reynertson et al., 2008). Wax apple, a non-climacteric fruits, is presumed to be native to Philippines, Indonesia, and Malaysia (Rosnah et al., 2012). Khandaker et al., (2011) stated that wax apple is widely cultivated in Malaysia, Thailand, Taiwan, and Indonesia. The tree of wax apple is used to be popular as backyard trees before being cultivated for commercial purposes.

A number of cultivars have been developed and grown all over the tropical and subtropical region of the world (Simirgiotis et al., 2008). Wax apple is glossy and can be found in green to dark red colour depending on the variety (Nakasone and Paull, 1998). As for the shape there are pear-shaped and bell-shaped wax apple according to its variety (Simirgiotis et al., 2008; Rosnah et al., 2012). The length of the fruits may be found within the range of 4 to 5 cm and 5 to 8 cm wide (Rosnah et al., 2012). The fruit is fibrous with white-flesh pulp and sometimes contain 1 to 4 seeds (around 1 to 2 cm in diameter) (Simirgiotis et al., 2008), but can also be seedless (Morton, 1987).

Wax apple's pulp is rich in water and crispy at the same time. Wax apple also produce subtle sweet and low acidic taste that becomes one of the special characteristics of this fruit. According to Food and Agriculture Organization (FAO) (2005), the combinations of the characteristics mentioned above has made wax apple to be favoured in Western countries.

Nowadays, fresh-cut fruits and vegetables has become a trend in order to encourage the consumption of healthy food for a healthier lifestyle. For example, the consumption of fresh-cut produces has been increasing in Asia, Australia, Western countries, and also Europe (Kim, 2007). Fresh-cut or minimally processed fruits and vegetables are defined as fruits and vegetables that are ready for consumption without further processing. In other words, the fruits and vegetables must have been trimmed or peeled or cut, washed, packaged, and maintained with refrigeration as 100% usable products before being sold to consumers.

Another common problem that arises in the fresh-cut industry is the occurrence of enzymatic browning. Enzymatic browning mostly occurs due to the presence of polyphenol oxidase (PPO) on phenolic compounds with the presence of activated enzyme, oxygen, and fibre (Kim and Jung, 2011). Generally, browning in fresh-cut products could reduce the appearance and nutritional values. Ascorbic acid (AA), citric acid (CA), and oxalic acid (OA), the three anti-browning agents that are generally recognized as safe (GRAS), being used as anti-browning agents due to its properties as weak organic acids and widely found in plant tissues. The effectiveness of AA, CA,

and OA on fresh-cut products varied depending on the types of organic acid, concentration being used and type of produces. This is due to the different PPO isozymes and/or phenolic substrates among products types (Suttirak and Manurakchinakorn, 2010).

At the same time, enzymes reactions could also resulted in the reduction of firmness of the fresh-cut products during storage and ripening. This is due to the modifications of the polymers' network causing the loss of the firmness and change the texture of the produces (Brummel et al., 1999). Polygalacaturonase (PG) and pectin methylesterase (PME) are enzymes that play roles in softening of cell wall. In the effort of reducing the firmness loss in fresh-cut produces, it is crucial for us to understand the behavior of cell wall degrading enzymes so that their activities could be controlled in order to lengthen the economical values of the fresh-cut products.

Due to the changes in the qualities of fresh-cut fruits in general, wax apple is not an exception. Hence, it is important to conduct this study so that researchers will be able to gain more knowledge on the changes that might occurred during the processing of fresh-cut wax apples and to figure out the most cutting sizes that allows the trading of fresh-cut wax apples while remaining or maintaining the quality almost as good as intact fruits. Additionally, the treatment with well known anti-browning agents such as AA, CA, and OA that is known to reduce or retard the degradation of the fresh-cut products was might also be beneficial in reducing the quality losses of fresh-cut wax apple as researchers in the fresh-cut field had been working extensively on how to reduce and/or retard the browning problem in fresh-cut products that might also be associated with the enzyme activities revolving inside the wax apple. The appropriate anti-browning agents dipping treatment could effectively delay the browning in fresh-cut wax apples can be determined through this study.

With the justification stated in the paragraph before, hence the objectives of this study were

(1) To evaluate the retention of wax apple qualities throughout storage as whole and also potentially as fresh-cut fruits.
(2) To evaluate the potential use of organic acids such as ascorbic acid, citric acid, and also oxalic acid as they are known to have the potential in retaining or reducing the qualities losses throughout the storage.
(3) To investigate the activities of the cell wall enzymes such as polygalacturonase (PG), pectin methylesterase (PME), and also browning enzyme, polyphenol oxidase activities in affecting the qualities of fresh-cut wax apples.

REFERENCES

Abeles, F. and Takeda, F. (1990). Cellulase activity and ethylene in ripening strawberry and apple fruits. *Scientia Horticulturae*, 42, 269 – 275.

Ahvenainen, R. (1996). New approaches in improving the shelf life of minimally processed fruit and vegetables. *Trends in Food Science and Technology*, 7, 179-187.

Ali, Z. M., Chin, L.-H. and Lazan, H. (2004). A comparative study on wall degrading enzymes, pectin modifications and softening during ripening of selected tropical fruits. *Plant Science*, 167, 317–327.

Altunkaya, A. and Gokmen, V. (2008). Effect of various inhibitors on enzymatic browning, antioxidant activity and total phenol content of fresh lettuce (*Lactuca sativa*). *Food Chemistry*, 107, 1173 – 1179.

Amaro, A. L., Beaulieu, J. C., Grimm, C. C., Stein, R. E. and Almeida, D. P. (2012). Effect of oxygen on aroma volatiles and quality of fresh-cut cantaloupe and honeydew melons. *Food Chemistry*, 130, 49-57.

Anthon, G. E., LeStrange, M. and Barrett, D. M. (2011). Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. *Journal of the Science of Food and Agriculture*, 91, 1175 – 1181.

Antoniolli, L. R., Benedetti, B. C., Sigrist, J. M., Souza Filho, M. D. S. M. and Alves, R. E. (2006). Metabolic activity of fresh-cut 'Pérola' pineapple as affected by cut shape and temperature. *Brazilian Journal of Plant Physiology*, 18, 413-417.

Asia-Pacific Association of Agricultural Research Institutions (APAARI) (2014). Wax Apple Industry in Taiwan : A Success Story. *Asia Pacific Association of Agricultural Research Institutions*, Bangkok, Thailand. 48 p

Assis, O.B.G., Scramin, J.A., Correa, T.A., De Britto, D., and Forato, L.A. (2012). A Comparative evaluation of integrity and colour preservation of sliced apples protected by chitosan and zein edible coatings. *Revista Iberoamericana de Tecnología Postcosecha* 2012, 13, 76 – 85.

Aydemir, T. (2004). Partial purification and characterization of polyphenol oxidase from artichoke (*Cynara scolymus* L.) heads. *Food Chemistry*,87, 59–67.

Barrelt, D. M. and Gonzalez, C. (1994). Activity of softening enzymes during cherry maturation. *Journal of Food Science*, 59, 574-577.

Beaulieu, J.C and Gorny, J.R. (2004). Fresh-cut fruits, USDA Handbook 66: 17.

Beckles, D. M. (2012). Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. Postharvest Biology and Technology, 63, 129-140.

Brummell, D. A. (2006). Cell wall disassembly in ripening fruit. *Functional Plant Biology*, 33, 103-119.

Brummell, D.A. and Harpster, M.H. (2001). Cell wall metabolism in fruit softening and quality and its manipulation in transgenic plant. *Plants Molecular Biology*, 47, 311 – 339.

Brummell, D.A., Harpster, M.H., Civello, P.M, Palys, J.M., Bennet, A.B. and Dunsmuir, P. (1999). Modification of expansin protein abundance in tomato fruit alters softening and cell wall polymer metabolism during ripening. *The Plant Cell*, 11: 2203-2216

Bsoul, S. A and Terezhalmy, G. T. (2004). Vitamin C in health and disease. *Journal of Contemporary Dental Practice*, 5, 1-13.

Camelo, A.F.L. (2004). Manual for the preparation and sale of fruits and vegetables: From field to market, FAO Agricultural Services Bulletin, 151, Rome.

Chan, S.W., Lee, C.Y., Yap, C.F., Wan Aida, W.M. and Ho, C.W. (2009). Optimisation of extraction condition for phenolic compounds from limau purut (*Citrus hystrix)* peels. *International Food Research*, 16, 203 – 213.

Chen W.H. (2010). Agricultural Statistics Yearbook. *Council of Agriculture*, Executive Yuan, Taipei, Taiwan, Republic of China.

Chuni, S. H., Awang, Y. and Mohamed, M. T. M. (2010). Cell Wall Enzymes Activities and Quality of Calcium Treated Fresh-cut Red Flesh Dragon Fruit (*Hylocereus polyrhizus*). *International Journal of Agriculture and Biology*, 12, 713–718.

Crisosto, C.H., Crisosto, G.M., and Ritenour, M.A. (2002). Testing the reliability of skin color as an indicator of quality for early season 'Brooks' (*Prunus avium* L.) cherry. *Postharvest Biology and Technology*, 24, 147 – 154.

Danyen, M. S., Boodia, N. and Ruggoo, A. (2011). Effects of cutting shapes and thicknesses on the quality of minimally processed pineapple (*Ananas comosus*), cv.'Queen Victoria'. *African Journal of Food, Agriculture, Nutrition and Development*, 11, 5525-5538.

De Tullio, M. C., Jiang, K. and Feldman, L. J. (2010). Redox regulation of root apical meristem organization: connecting root development to its environment. *Plant Physiology and Biochemistry*, 48, 328-336.

Dea, S., Brecht, J., Nunes, C. and Baldwin, E. (2010). Quality of fresh-cut 'Kent' mango slices prepared from hot water or non-hot water-treated fruit. *Postharvest Biology and Technology*, 56, 171-180.

Ding, P., Ahmad, S.H. and Ghazali, H.M. (2007). Changes in selected quality characteristics of minimally processed carambola *(Averrhoa carambola* L.) when treated with ascorbic acid. *Journal of the Science of Food and Agriculture,* 87, 702 – 709.

Dong, X., Wrolstad, R.E. and Sugar, D. (2000). Extending shelf life of fresh-cut pears. *Journal of Food Science.* 65, 181 – 186.

FAO (2005). Growing pains for tropical fruit market. Rome: Food and Agricultural Organization of the United Nations. Available from: www.fao.org/NEWS/1998/980604-E.HTM> Accessed: July 13th, 2011.

Gaffe, J., Tieman, D.M. and Handa, A.K. (1994). Pectin methylesterase isoforms in tomato (*Lycopersicon esculentum*) tissues: effects of expression of a pectin methylesterase antisense gene. *Plant Physiology*, 105**,** 199 – 203.

Gibe, A. and Kim, J. (2013) Influence of cutting size and packaging materials on the quality of fresh-cut winter squash (var. Ajijimang). *Agricultural Sciences*, 4, 477 – 482.

Gil, M. I., Aguayo, E. and Kader, A. (2006). Quality changes and nutrient retention in fresh-cut versus whole fruits during storage. *Journal of agricultural and food chemistry*, 54, 4284–4296.

Gonzalez-Aguilar, G. A., Ruiz-Cruz, S., Soto-Valdez, H., Vazquez-Ortiz, F., Pacheco-Aguilar, R. and Wang, C. Y. (2005). Biochemical changes of fresh-cut pineapple slices treated with antibrowning agents. *International Journal of Food Science and Technology*, 40, 377–383.

Gorny, J. R., Cifuentes, R. A., Hess-Pierce, B. and Kader, A. A. (2000). Quality changes in fresh-cut pear slices as affected by cultivar, ripeness stage, fruit size, and storage regime. *Journal of Food Science*, 65, 541-544.

Gorny, J.R. (2003). A summary of CA and MA requirements and recommendations for fresh-cut (minimally processed) fruits and vegetables. *Acta Horticulturae (ISHS)*, 600, 609-614.

Han, J.H. and Gennadios, A. (2005). Edible films and coatings: Overviews. In J.H. Han (Ed). *Innovations in food packaging.* pp. 138 -155. Oxford, U.K: Elsevier Academic Press,.

Henick-Kling, T. (1995). Control of malolactic fermentation in wine: Energetics, flavor modification and methods of starter culture preparation. *Journal of Applied Bacteriology Symposium*, 79 (Suppl.), 29S – 37S.

International Fresh-cut Produce Association (IFPA) (2001). Fresh-cut produce: get the facts! <http://www.fresh-cuts.org>. Accessed March 2011

Jiang, Y., Pen, L. and Li, J. (2004). Use of citric acid for shelf life and quality maintenance of fresh-cut Chinese water chestnut. *Journal of Food Engineering*, 63, 325-328.

Kader, A. A. (2003). A Perspective on Postharvest Horticulture (1978 – 2003). *HortScience*, 38, 1004–1008.

Kader, A. A. (2008). Flavor quality of fruits and vegetables. *Journal of the Science of Food and Agriculture*, 88, 1863-1868.

Kader, A. A., and Rolle, R. S. (2004). The role of post-harvest management in assuring the quality and safety of horticultural produce. FAO. Available from ≤http://www.fao.org/3/a-y5431e.pdf> Accessed January 10th, 2012.

Kähkönen, M.P, Hopia, A.I. and Heinonen, M. (2001). Berry phenolics and their antioxidant activity. *Journal of Agricultural Food Chemistry*, 49, 4076-4082.

Karakurt, Y. and Huber, D. J. (2003). Activities of several membrane and cell-wall hydrolases, ethylene biosynthetic enzymes, and cell wall polyuronide degradation during low-temperature storage of intact and fresh-cut papaya (*Carica papaya*) fruit. *Postharvest Biology and Technology*, 28, 219-229.

Kato-Naguchi, H. and Watada, A. E. (1997). citric acid reduces the respration of fresh cut carrot. *American Society for Horticultural Science*, 32, 136.

Kayashima, T. and Katayama, T. (2002). Oxalic acid is available as a natural antioxidant in sme systems. *Biochimica et Biophysica Acta*, 1573, 1 – 3.

Kays, S. J. (1999). Preharvest factors affecting appearance. *Postharvest Biology and Technology*, 15, 233–247.

Kevers, C., Falkowski, M., Tabart, J., Defraigne, J.O., Dommes, J., and Pincemail, J. (2007). Evolution of antioxidant capacity during storage of selected fruits and vegetables. *Journal of Agricultural and Food Chemistry*, 21, 8596 – 8603.

Khandaker, M.M., Al-Saif, A.M., Alebidi, A.I., Hossain, A.B.M.S, Normaniza, O. and Boyce, A.N. (2011). An evaluation of the nutritional quality evaluation of three cultivars of *Syzygium samarangense* under Malaysian conditions, *African Journal of Agriculture Research*, 6, 545 – 554.

Kim, J.G. (2007)., Fresh-cut market potential and challenges in Far-East Asia. *Internation Conference on Quality Management of Fresh Cut Produce*, 746, 33 – 38.

Kim, S. J., and Jung, K. M. (2011). Effects of the PPO (Polyphenol oxidase) Activity and Total Phenolic Contents on Browning and Quality of Dried-Persimmon According to Maturity Degree of Astringent Persimmon (*Diospyros kaki* Thunb .). 2nd International Conference on Biotechnology and Food Science.*Proceedings of International Conference on Biotechnology and Food Science*, 7, 115 – 118.

Kohlmann, F. J. (2003). *What is pH, and How is it Measured?* A Technical Handbook for Industry. Hatch company : Loveland.

Koslanund, R., Archbold, D. D. and Pomper, K. W. (2005). Pawpaw [*Asimina triloba* (L .) Dunal] Fruit Ripening . II . Activity of Selected Cell-wall Degrading Enzymes. *Journal of the American Society for Horticultural Science*, 130, 643–648.

Lamikanra, O. (Ed.). (2002). *Fresh-Cut Fruits and Vegetables: Science, Technology, and Market*, pp. 1 – 452, U.S.A: CRC Press.

Lazan, H., Ali, Z. M., Liang, K. S. and Yee, K. L. (1989). Polygalacturonase activity and variation in ripening of papaya fruit with tissue depth and heat treatment. *Physiologia Plantarum*, 77, 93–98.

Lee, J.Y., Park, H.J., Lee, C.Y. and Choi, W.Y. (2003). Extending shelf-life of minimally processed apples with edible coatings and antibrowning agents. *Lebens Wissen Technology*, 35, 323 – 329.

Lemamy, G. J., Lebrun, M., Omouessi, S. T., Ndeboko, B. and Mouecoucou, J. (2014). Evolution of biochemical and physical parameters of two fresh-cut fruits over storage at 4^0C. *African Journal of Food Science*, 8, 239-248.

Lim, Y.Y., Lim, T.T., and Tee, J.J. (2009). Antioxidant properties of guava fruits: In comparison with some local fruits. *Sunway Academic Journal*, 3, 9 – 20.

Lu, P.L. and Lin, P.H. (2011)., Physiology of fruit cracking in wax apple (*Syzygium samarangense*), *Journal of Plant Science*, 8, 70 – 76.

Mantilla, N., Castell-Perez, M. E., Gomes, C. and Moreira, R. G. (2013). Multilayered antimicrobial edible coating and its effect on quality and shelf-life of fresh-cut pineapple (*Ananas comosus*). *LWT-Food Science and Technology*, 1, 37-43.

Mao, L., Jeong, J., Que, F. and Huber, D.J., (2006). Physiological properties of fresh-cut watermelon (*Citrullus lanatus*) in response to 1-methylcyclopropene and post-processing calcium application. *Journal of Science, Food, and Agriculture*, 86, 46 – 53.

Martin, D., Lewis, T. L. and Cerny, J. (1964). Apple fruit cell numbers in relation to cropping alternation and certain treatments. *Australian Journal of Agricultural Research*, 15, 905–919.

Martinez-Romero, D., Alburquerque, N., Valverde, J.M., Guillen, F., Castillo, S., Valero, D. and Serrano, M. (2006). Postharvest sweet cherry quality and safety maintenance by Aloe Vera treatment: a new edible coating. *Postharvest Biology and Technology*, 39, 93 – 100.

Maskan, M. (2006). Effect of thermal processing on tristimulus colour changes of fruits. *Stewart Postharvest Review*, 2, 1-8.

Mehan, S., Kaur, P., and Singh, M. (2014). Studies on Effect of Storage on Quality of Minimally Processed Babycorn. *Journal of Food Processing and Technology*, 5, 388-396.

Morton, J. F (1987). Loquat. In: Morton, J.F. (Ed.), *Fruits of Warm Climates*. pp. 103-108, Miami, FL: J.F. Morton; Winter vine, NC.

Nakasone, H.Y. and Paull, R.E. (1998). Tropical fruits. p. 445, Oxford: Oxford University Press.

Narain, N., Holschuh, H.J., Bora, P.S., Vasconcelos, M.A. and Da, S. (2001). Physical and chemical composition of carambola fruit at three stages of maturity. *Ciencia Technologia Alimentaria*, 3, 144 – 148.

Nicola, S., Tibaldi, G. and Fontana, E. (2009). Fresh-cut Produce Quality- Implications for a Systems Approach In Florkowski, W.J., Prussia, S.E., Shewfelt, R.L., and Brueckner, B. (Eds), *Postharvest Handling: A Systems Approach*, pp. 247 – 282 Masachussettes, U.S.: Academic Press.

Nicola, S., Tibaldi, G. and Fontana, E. (2009). Fresh-cut Produce Quality- Implications for a Systems Approach In Florkowski, W.J., Prussia, S.E., Shewfelt, R.L., and Brueckner, B. (Eds), *Postharvest Handling: A Systems Approach*, pp. 247 – 282 Masachussettes, U.S.: Academic Press.

Nicolai, B. M., Beullens, K., Bobelyn, E., Peirs, A., Saeys, W., Theron, K. I. and Lammertyn, J. (2007). Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy: A review. *Postharvest Biology and Technology*, 46, 99-118.

Ojeda, G. A., Sgroppo, S. C., and Zaritzky, N. E. (2014). Application of edible coatings in minimally processed sweet potatoes (*Ipomoea batatas* L.) to prevent enzymatic browning. *International Journal of Food Science and Technology*, 49, 876-883.

Oms-Oliu, G., Rojas-Grau, M., Gonzalez, L.A., Varela, P., Soliva-Fortuny, R., Hernando, M., Munuera, I.P., Fiszman, S., and Martin-Belloso, O. (2010). Recent approaches using chemical treatments to preserve quality of fresh-cut fruit: A review. *Postharvest Biology and Technology*, 57, 149 – 148.

Pan, H. and Shü, Z. (2007). Temperature affects color and quality characteristics of "Pink" wax apple fruit discs. *Scientia Horticulturae*, 112, 290–296.

Panggabean, G. (1992). *Syzygium aqueum* (Burm.f.) Alston, *Syzgium malaccense* (L.) Merr. & Perry, *Syzygium samarangense* (Blume) Merr. & Perry In: Comel, R.E. and Verheij, E.W.M. (Eds.): *Plant Resources of South-East Asia 2: Edible fruits and nuts*, pp. 29 -294, Bogor, Indonesia: PROSEA Foundation.

Paul, V., Pandey, R., and Srivastava, G. C. (2012). The fading distinctions between classical patterns of ripening in climacteric and non-climacteric fruit and the ubiquity of ethylene—an overview. *Journal of Food Science and Technology*, 49, 1-21.

Payasi, A., Mishra, N.N., Soares-Cheves, A.L. and Singh, R. (2009). Biochemistry of fruits softening: An overview. *Physiological and Molecular Biology of Plants*, 15, 103 – 113.

Perera, O.C. (2007). *Minimal Processing of Fruits and Vegetables* In Rahman, M.S. (Ed) Handbook of Food Preservation, pp. 137 – 150, London, U.K.: CRC Press.

Perkins-Veazie, P. and Collins, J.K. (2004). Flesh quality and lycopene stability of fresh-cut watermelon. *Postharvest Biology and Technology*, 31, 159 – 166.

Pilizota, V. and Subaric, D. (1998). Control of Enzymatic Browing of Foods. *Food Technology and Biotechnology*, 36, 219 – 227.

Pitts, M., Drake, S. and Calieri, R. (1997). Apple size and length of storage affects firmness. < http://postharvest.tfrec.wsu.edu/pages/PC97D> Acessed on 13th June 2015

Pizzocaro, F., Torregini, D. and Gilardi, G. (1993). Inhibition of apple polyphenol oxidase by ascorbic acid, citric acid, and sodium chloride. *Food Processing and Protection*, 17, 21-30.

Plotto, A, Narciso, J.A., Rattanapanone, N, and Baldwin, E.A. (2010). Surface treatments and coatings to maintain fresh-cut mango quality in storage. *Journal of Science, Food, and Agriculture*, 13, 2333 – 2341.

Portela, S. I. and Cantwell, M. I. (1998). Quality changes of minimally processed honeydew melons stored in air or controlled atmosphere. *Postharvest Biology and Technology*, *14*, 351–357.

Prasanna, V., Prabha, T.N., and Tharanatha, R.N. (2007). Fruit ripening phenomena – An overview. *Critical Review of Food Science and Nutrition*, 47, 1 – 19.

Priya Sethu, K. M., Prabha, T.N. and Tharanathan, R.N. (1996). Post-harvest biochemical changes associated with the softening phenomenon in *Capsicum annuum* fruits. *Phytochemistry*, 42, 961 – 966.

Rabobank. (2010). Fresh-cut fruit and vegetables doing well despite downturn. Available from:≤http://www.rabobank.com/content/news/news_archive/060-Fresh-cutfruitandvegetablesdoingwelldespitedownturn.jsp> Accessed January 10th, 2012.

Rankine, B.C. (1989) *Making good wine: a manual of winemaking practice for Australia and New Zealand*, Melbourne, Australia: Macmillan.

Rees, D., Farrell, G. and Orchard, J. (2012). Crop Post-Harvest: Science and Technology, Perishables. John Wiley & Sons, 480 pp.

Reynertson, K.A., Yang, H., Jiang, B., Basile, M.J. and Kennelly, E.J. (2008). Quantitative analysis of antiradical phenolic constituents from fourteen edible Myrtaceae fruits. *Food Chemistry*, 109, 883-890.

Riov, J. (1974). A polygalacturonase from citrus leaf explants: role in abscission. *Plant Physiology*, 53, 312 – 316.

Rivera-Lopez, J., Vazquez-Ortiz, F.A., Ayala-Zavala, J.F., Sotelo-Mundo, R.R. and Gonzalez-Aguilar, G.A. (2005). Cutting shape and storage temperature affect overall quality of fresh-cut papaya va. 'Maradol'. *Journal of Food Science*, 70, S482 – S489.

Rocha, A.M.C.N. and Morais, A.M.M.B. (2002). Polyphenoloxidase activity and total phenolic content as related to browning of minimally processed 'Jonagored' apple. *Journal of the Science of Food and Agriculture*, 82, 120 – 126.

Rosnah, S., Wong, W.K., Noraziah, M. and Osman, H. (2012). Chemical composition changes of two water apple (*Syzygium samarangense*). *International Food Research Journal*, 19, 167-174.

Sapers, G. M., Garzarella, L., and Pilizota, V. (1990). Application of browning inhibitors to cut apple and potato by vacuum and pressure infiltration. *Journal of Food Science*, 55, 1049–1053.

Saxena, A., Saxena, T. M., Raju, P. S., and Bawa, A. S. (2013). Effect of controlled atmosphere storage and chitosan coating on quality of fresh-cut jackfruit bulbs. *Food and Bioprocess Technology*, 6, 2182-2189.

Shin, J., Harte, B., Harte, J. and Dolan, K. (2011). The effect of low-dose x-ray irradiation on the quality of fresh-cut asparagus in microwaveable vacuum skin packs. *HortScience*, 46, 64-69.

Shiri, M.A., Ghasemnezhad, M., Bakshi,D. and Saadatian, M. (2011). Effects of ascorbic acid on phenolic compound and antioxidant activity of packaged fresh cut table grapes. *Journal of Environmental, Agricultural, and Food Chemistry*, 10, 2506 – 2515.

Shü, Z., Lin, T., Lai, J., Huang, C., Wang, D. and Pan, H. (2007). The industry and progress review on the cultivation and physiology of wax apple – with special reference to " Pink " variety. *The Asian and Australasian Journal of Plant Science and Biotechnology*, 1, 48–53.

Simirgiotis, M. J., Adachi, S., To, S., Yang, H., Reynertson, K. A, Basile, M. J., Gil, R.R., Weinstein, I.E. and Kennelly, E. J. (2008). Cytotoxic chalcones and antioxidants from the fruits of a *Syzygium samarangense* (Wax Jambu). *Food chemistry*, 107, 813–819.

Simsek, S. and Yemenicioglu, A. (2010). Commercially suitable pectin methylesterase from Valencia orange peels. *Turkish Journal of Agriculture and Forestry*, 34, 109-119.

Soliva-Fortuny, R.C. and Martin-Belloso, O. (2003). New advances in extending the shelflife of fresh-cut fruits: A review. *Trends in Food Science and Technology*, 14, 341 – 353.

Supapvanich, S. and Tucker, G. A. (2011). Physicochemical changes in fresh-cut Honeydew melon fruit during storage, *African Journal of Agricultural Research*, 6, 2737–2742.

Supapvanich, S., Pimsaga, J., and Srisujan, P. (2011). Physiochemical changes in fresh-cut wax apple (*Syzygium samarangenese* [Blume] Merill& L.M. Perry) during storage. *Food Chemistry*, 127, 912-917.

Suttirak, W. and Manurakchinakorn, S. (2010). Potential application of ascorbic acid , citric acid and oxalic acid for browning inhibition in fresh-cut fruits and vegetables, *Walailak Journal*, 7, 5–14.

Suttirak, W. and Manurakchinakorn, S. (2010). Potential application of ascorbic acid , citric acid and oxalic acid for browning inhibition in fresh-cut fruits and vegetables, *Walailak Journal*, 7, 5–14.

Tareen, M.J. (2011). *Fruit Quality of Peach (Prunus persica L.) cv Flordarking as Affected by Different Rootstocks and Postharvest Treatments*, Doctoral dissertation, Arid Agriculture, University Rawalpindi, Pakistan.

Toivonen, P.M.A. and Brummell, D.A. (2008). Biochemical bases of appearance and texture changes in fresh-cut fruit and vegetables. *Postharvest Biology and Technology*, 48, 1 – 14.

Uddin, M.S., Hawlader, M.N.A., Ding, L. and Mujumdar, A.S. (2002), Degradation of ascorbic acid in dried guava during storage. *Journal Food Engineering*, 51, 21 – 26.

Ullah, H., Ahmad, S., Anwar, R. and Thompson, A. K. (2006). Effect of High Humidity and Water on Storage Life and Quality of Bananas. *International Journal of Agriculture and Biology*, 8, 828–831.

United States Department of Agriculture Economic Research Service, 2015 - Fruit and Vegetable Prices, <http://www.ers.usda.gov/data-products/fruit-and-vegetable-prices.aspx> Accessed on 17th June 2015.

Verma, L. R. and Joshi, V. K. (Eds.). (2000). *Postharvest technology of fruits and vegetables: handling, processing, fermentation, and waste management (Vol. 2)*. Indus Publishing.

Vidal, L., Ares, G., and Giménez, A. (2013). Projective techniques to uncover consumer perception: Application of three methodologies to ready-to-eat salads. *Food Quality and Preference*, 28, 1-7.

Voon, Y. Y., Sheikh Abdul Hamid, N., Rusul, G., Osman, A. and Quek, S. Y. (2007). Volatile flavour compounds and sensory properties of minimally processed durian (*Durio zibethinus* cv. D24) fruit during storage at 4°C. *Postharvest Biology and Technology*, 46, 76–85.

Wang, D., Li, X., Ma, Y., and Zhao, X. Y. (2014). Effect of packaging films on quality of fresh-cut broccoli. *Advanced Materials Research*, 881, 785-788.

Watada A.E, and Qi L. (1999). Quality of fresh-cut produce. *Postharvest Biology and Technology*, 15, 201-205.

Watada, A. E., Ko, N. P. and Minott, D. A. (1996). Factors affecting quality of fresh-cut horticultural products. *Postharvest Biology and Technology*, 9, 115-125.

Whitaker, J. R. (1995). Polyphenol oxidase. In *Food Enzymes*. pp. 271-307, U.S.: Springer.

Willats, W.G., McCartney, L., Mackie, W. and Knox, J.P. (2001). Pectin: cell biology and prospects for functional analysis. In *Plant Cell Walls* , pp. 9-27. Netherlands: Springer

Wills, R.B.H., Lim, J.S.K. and Greenfield, H. (1986). Composition of Australian Foods. *Food Technology Australia*, 38, 118 – 123.

Wills, R.H.H., Lee, T.H., Graham, D., McGlasson, W.B., and Hall, E.G. (1981). Post-harvest – An Introduction to the Physiology and Handling of Fruit and Vegetables. New South Wales University Press Limited. Kensington, England.

Xiao, Y. Y., Chen, J. Y., Kuang, J. F., Shan, W., Xie, H., Jiang, Y. M. and Lu, W. J. (2013). Banana ethylene response factors are involved in fruit ripening through their interactions with ethylene biosynthesis genes. *Journal of Experimental Botany*, 64, 2499-2510.

Yoruk, R., Balaban, M.O., Marshall, M.R. andYoruk, S. (2002). The inhibitory effect of oxalic acid on browning of banana slices. In: Annual Meeting and Food Expo, Anaheim, California, 30G-18, p. 74.

Yoruk, R., Yoruk, S., Balaban, M. O., and Marshall, M. R. (2004). Machine vision analysis of antibrowning potency for oxalic acid: A comparative investigation on banana and apple. *Journal of Food Science*, 69, 281 – 289.

Zhu, Y., Pan, Z. and McHugh, T.H. (2007). Effect of dipping treatments on color stabilization and texture of apple cubes for infrared dry-blanching process. *Journal of Food Processing and Preservation,* 31, 632 – 648.