Summary

Mango (*Mangifera indica* Linn) produced in Thailand has been consumed fresh locally and exported, but their economic production has been limited due to a lack of high quality. The relative importance of mango quality depends upon several factors that can be categorized into physiochemicals (maturity at harvest and ripening stage), environmental (low temperature and heat treatment) and edaphic (mineral nutrition of the tree). The results showed that when 'Nam Dok Mai' mangoes at different ripening stages (brought about either by acetylene gas or not) were kept at either 5 or 13 °C for 45 days, the susceptibility of mango fruits to chilling injury (CI) depended on the degree of ripeness; the stage 2 fruit exhibited the longest storage life without CI. Significant differences were found in putrescine levels at different ripening stages. A decrease in level was noted when stage 1 (less-ripened) fruits were stored at 5°C, which was accompanied by chilling injury occurrence.

Both mature and immature fruits were exposed to vapor heat treatment (VHT) as a quarantine treatment, and then kept at 5, 8, 13°C and 25°C. The VHT-treated fruits showed higher polyamine contents, lower electrolyte leakage and lower incidence of disease compared to non-treated fruit. During storage at 8°C for 14-21 days, followed by 25°C for 4 days for ripening, the mature fruits still had a

good general appearance with low incidence of chilling injury and internal breakdown (IB) compared to the immature fruits.

Moreover, the observation of ultrastructural changes in the cells of the VHT-treated fruits, low temperature stored fruits showed considerable cell wall degradation and abundant starch grains present in parenchyma cells of mesocarp tissue.

Fruits were harvested from two different sites where soil mineral composition was different. Fruits harvested from the site of higher Ca/N and (Ca+Mg)/K ratios in the soil kept firmness, showed less decay and increased storage life. Ca content and (Ca+Mg)/K ratio in the fruit were very positively related with storage life. Therefore, these parameters could be good indicators for storage life. X-ray microanalysis of the distribution of mineral elements in mango fruit revealed that K element accumulated mainly in parenchyma cells of the mesocarp, while Ca was lowest in the inner mesocarp. Low Ca in the inner mesocarp in fruit could be involved in the occurrence of jelly seed. To overcome the problem of absorption of Ca by the tree from the soil and distribution of Ca within the tree, in particular, in fruits, further research is needed to find the techniques to improve availability and better distribution of Ca to these tissues.

These findings could be applied to commercial preharvest practices to maintain the high ratio of Ca/N and (Ca+Mg)/K in soil for careful postharvest management. The fully matured and more-ripened mango fruits would minimize chilling injury and

physiological disorders associated with VHT in combination with low temperature storage and enable the expansion of export of the Thai mango to long distance markets.

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Literature Cited

1. Arthachinta, C. 2000. Mango research in Thailand. Acta Hortic. 509:33-36.

2. Autio,W.R. and W.J. Bramlage. 1986. Chilling sensitivity of tomato fruit in relation to ripening and senescence. J. Amer. Soc.Hort. Sci. 111:201-204.

3. Bouchereau, A., A. Aziz, F. Larher and J. Martin-Tanquy. 1999. Polyamines and environmental challenges: recent development. Plant Science 140:103-125.

4. Bower, J. P. and J. E. M. Cutting. 1988. Avocado fruit development and ripening physiology. Hort. Reviews 10: 229-72.

5. Boyer, J.S. 1985. Water transport. Annu. Rev. Plant Physiol. 36:473-516.

6. Burdon, J. N., K. G. Moore and H. Wainright. 1991. Mineral distribution in mango fruit susceptible to the physiological disorder 'soft nose'. Scientia Hortic. 48:329-336.

7. Burmeister, D., S. Ball, S. Green and A.B. Woolf. 1997. Interaction of hot water treatment and controlled atmosphere storage on quality of 'Fuyu' persimmons. Postharvest Biol. Technol. 12:71-82.

8. Chan, H.T. and E. Linse.1989. Conditioning cucumbers for quarantine heat treatments. HortScience 24:985-989.

9. Chan, H.T., S.Y.T. Tam and S.T. Seo. 1981. Papaya polygalacturonase and its role in thermally injured ripening fruit. J. Food Sci. 46:190-197.

10. Chaplin, G. R., R.B.H. Wills and D.Graham. 1983. Induction of chilling injury in stored avocados with exogenous ethylene. HortScience 18: 952-953.

11. Cojocaru, M., S. Droby, E. Glotter, A. Goldman, H.E. Gottlieb, B. Jacoby and D. Prusky. 1986. 5- (1,2-heptadecenyl)-resorcinol, the major component of the antifungal activity in the peel of mango fruit. Phytochemistry 25:1093-1095.

12. Coleman, L.W. and C.F. Hodges. 1991. Interference with the determination of 1-aminocyclopropane-1-carboxylic acid by various plant proteins. J.Plant Physiol. 138:7-11.

13. Cote, F., J.E. Thompson and C. Willemot. 1993. Limitation to the use of electrolyte leakage for the measurement of chilling injury in tomato fruits. Postharvest Biol. Technol. 3:103-110.

14. Escribano, M.I. and C. Meradio. 1994. The relevance of polyamine levels in cherimoya (*Annona cherimoya* Mill) fruit ripening. J. Plant Physiol. 69:701-706.

15. Esguerra, E.B. and M.C.C. Lizada. 1990. The post harvest behavior and quality of 'Carabao' mangoes subjected to vapor heat treatment. ASEAN Food J. 5:6-11.

16. Faust, M. and S.Y. Wang. 1993. Polyamines in horticultural important plants. Hort. Review 14: 333-356.

17. Ferguson, I.B. and B.K. Drobax. 1988. Calcium and the regulation of plant growth and senescence. HortScience 23:262-266.

18.Ferguson, I.B. and C.B. Watkins. 1992. Crop load affects mineral concentrations and incidence of bitter pit in 'Cox's Orange Pippin' apple fruit. J.Amer.Soc.Hort.Sci. 117:373-376.

19. Forney, C.F., W.J. Lipton. 1990. Influence of controlled atmospheres and packaging on chilling sensitivity. In: Wang,W.C. (Ed.), Chilling Injury in Horticultural Crops. CRC Press, Boca Raton, FL, p. 257-267.

20. Gonzalez-Aguilar, G.A., L. Zacarias, M. Malas and M.T. Lafuente. 1997. Temperature and duration of water dips influence on chilling injury, decay and polyamine content in 'Fortune' mandarins. Postharvest Biol. Technol. 12,61-69.

21. Guye, M.G., L. Vigh and J.M. Wilson. 1987. Polyamine titre in relation to chill-sensitivity in *Phaseolus sp.* J. Exp. Bot. 37:1036-1043.

22. Heather, N.W., R.J. Corcoran, T. Heard, K. Jacobi and L. Coates. 1991. Disinfestation of mangoes againt Queensland fruit fly by vapor heat. A report to AQIS for Japanese Government, 20p.

23. Himelrick, D.G. and R.F. McDuffie. 1983. The calcium cycle: uptake and distribution in apple trees. HortScience 18:147-151.

24. Ho, L.C., R. Belda, M. Brown, J. Andrews and P. Adams. 1993. Uptake and transport of calcium and the possible causes of blossom -end rot in tomato. J. Exp. Bot. 44:509-518.

25. Hofman, P. J., L. G. Smith, R. Holmes, T. P. Campbell and G. Meiburg. 1995. Mango fruit quality at harvest is affected by production condition. In: Mango 2000 marketing seminar and production workshop. p.199-207. Department of Primary Industries, Queensland, Australia.

26. Jacobi, K.K. and D. Gowanlock.1995. Ultrastructural studies of 'Kensington' mango (*Mangifera indica* Linn.) heat injury. HortScience 30:102-103.

27. Jacobi, K.K. and L.S. Wong. 1992. Quality of 'Kensington' mango (*Mangifera indica* Linn.) following hot water and vapor heat treatments. Postharvest Biol. Technol. 1:349-359.

28. Kader, A.A. 1999. Fruit maturity, ripening and quality relationships. Acta Hortic. 485:203-208.

29. Kakkar, R.J. and V.K. Rai. 1993. Plant polyamines in flowering and fruit ripening. Phytochemistry 33:1281-1288.

30. Ketsa, S., S. Chidtagool, J.D. Klein and S. Lurie. 1999. Ethylene synthesis in mango fruit following heat treatment. Postharvest Biol.Technol. 15:65-72.

31. Ketsa, S. and T. Raksrithong. 1992. Effect of PVC film wrapping and temperature on storage life and quality of 'Nam Dok Mai' mango fruits on ripening. Acta Hortic. 321:756-763.

32. Klein, J.D. and S. Lurie. 1990. Prestorage heat treatment as a means of improving poststorage quality of apple. J.Amer.Soc.Hort.Sci. 115:255-259.

33. Koen, T. J., S. F. Du Plessis and J. H. Terblanche. 1990. Nutritional factors involved in physiological post-harvest fruit disorders of avocados (cv.Fuerte). Acta Hortic. 275:543-550.

34. Kramer, G.F. and C.Y. Wang. 1989. Correlation of reduced chilling injury with increased spermine and spermidine levels in zucchini squash. Phyiol. Plant. 76:479-484.

35. Kramer, G.F. and C.Y. Wang. 1990. Effect of chilling and temperature preconditioning on the activity of polyamine biosynthetic enzymes in zucchini squash. J.Plant Physiol. 136:115-122.

36. Kramer, G.F., C.Y. Wang and W.S. Conway. 1989. Correlation of reduced softening and increased polyamine levels during low oxygen storage and McIntosh apples. J. Amer. Soc. Hort. Sci. 114:942-946.

37. Lartifah, M.N., Z. Sulaiman, O.M. Shamsuddin and J.M.Yunus. 1996. Quality evaluation of Harumanis mango after vapor

heat treatment at different maturity stages. MARDI Research J. 24:147-153.

38. Lin, W.C., J.W. Hall and M.E. Saltveit, Jr. 1993. Ripening stage affects the chilling sensitivity of greenhouse-grown peppers. J. Amer. Soc. Hort. Sci. 118:791-795.

39. Lipton, W.J., Y. Aharoni and E. Elliston. 1979. Rate of CO_2 and ethylene production and of ripening of 'Honey Dew' muskmelons at a chilling temperature after pretreatment with ethylene. J. Amer.Soc.Hort.Sci. 104: 846-849.

40. Lizada, M.C.C. and S.F. Yang. 1979. A simple and sensitive assay for 1-aminocyclopropane-1-carboxylic acid. Anal. Biochem. 100:140-145.

41. Lurie, S. and J.D. Klein. 1991. Acquisition of low temperature tolerance in tomatoes by exposure to high-temperature stress. J.Amer.Soc.Hort.Sci. 116:1007-1012.

42. Marcelle, R. D. 1991. Relationships between mineral content, lipoxygenase activity, levels of 1-amino cyclopropane 1-carboxylic acid and ethylene emission in apple fruit flesh disks (cv.Jonagold) during storage. Postharvest Biol. and Technol. 1:101-109.

43. McCollum, T.G., H. Doostdar, R.T. Mayer and R.E. McDonald. 1995. Immersion of cucumber fruit in heated water alters chilling-induced physiological changes. Postharvest Biol. Technol. 12:71-82.

44. McCollum, T.G., S. D'Aquino and R.E. McDonald. 1993. Heat treatment inhibits mango chilling injury. HortScience 27:1254-1255.

45. Mcdonald, R.E and M.M. Kushad. 1986. Accumulation of putrescine during injury of fruits. Plant Physiol. 82:324-326.

46. Medlicott, A.P., J.M.M. Sigrist and O. Sy. 1990. Ripening of mangos following low temperature storage. J.Amer.Soc.Hort.Sci. 115: 430-434.

47. Mencarelli, F., B. Cecantoni, A. Bolini and G. Anelli. 1993. Influence of heat treatment on the physiological response of sweet pepper kept at chilling temperature. Acta Hortic.343: 238-243.

48. Mendoza, D.B. 1981. Post harvest handling of mango fruits in the Philippines. In: Graham, D., R.B.H Wills, T.H. Lee, and W.B. McGlasson. (eds). Australia Aspects of Post Harvest Horticulture in ASEAN. p.23-32. Australian Development and Assistance Bureau.

49. Mendoza, D.B. and R.B.H Wills. 1984. Mango fruit development, postharvest physiology and marketing in ASEAN. ASEAN Food Handling Bureau, Kuala Lumpur, Malaysia. 111p.

50. Mercado, B.T. 1979. The relationship between nutritional status of the mango plant and its responsiveness of flowering and fruiting research project of mango. In: Flowering and fruiting research project of mango. p.194-216. Annu.Rep.,

Univ.of the Philippines at Los Banos College, Laguna, Philippine Council for Agr. and Resources Res.Proj. 149.

51.Mizuno,N. and M. Minami.1980.Preparation for N, K, Mg, Ca, Fe and Mn analysis in field crops using sulfuric-percholric acid solution. Jpn.J.Soil.Sci.Plant Nutr. 51:418-420 (In Japanese).

52. Nanthachai, P. 1982. Fruit morphology and development in mango (*Mangifera indica* L.). Proc.Workshop on Mango and Rambutan. p92-95. ASEAN Postharvest training and research Center, University of Philippines at Los Banos, College, Laguna, Philippines.

53. Paull, R.E. 1995. Preharvest factors and the heat sensitivity of field grown ripening papaya fruit. Postharvest Biol. Technol.6:167-175.

54. Perring, M. A. 1968. Mineral composition of apple. VIII. Further investigations into the relationship between composition and disorders of the fruits. J.Sci.Food Agri.19: 640-645.

55. Prasad, J. and T.M. Spiers. 1991. The effect of nutrition on the storage quality of kiwifruit (a review). Acta Hortic.297: 579-585.

56. Qiu,Y., M.S. Nishina and R.E. Paull.1995. Papaya fruit growth, calcium uptake and fruit ripening. J.Amer.Soc.Hort.Sci. 120:246-253.

57. Quimio, A.J. and T.H. Quimio. 1973. Post harvest control of Philippines mango anthracnose by hot water treatment. Philipp.Agric. 58:138-146.

58. Raymond, L., B. Schaffer, J. K. Breecht and J.H. Crane. 1998. Internal breakdown in mango fruit: symptomology and histology of jelly seed, soft nose and stem-end cavity. Postharvest Biol. and Technol. 13:59-70.

59. Raymond, L., B. Schaffer, J.K. Breecht and E.A. Hanlon. 1998. Internal breakdown, mineral element concentration and weight of mango fruit. J. Plant Nutrition 21:871-889.

60. Rodov, V., S. Ben-Yehoshua, R. Albagli and D.Q.Fang. 1995. Reducting chilling injury and decay of stored citrus fruit by hot water dips. Postharvest Biol. Technol. 5:119-127.

61. Schirra, M. and M. Mulas. 1995. Influence of post harvest hot water dip and imazalil-fungicide treatment on cold-stored 'Di Massa' lemons. Adv.Hort.Sci.1:43-46.

62. Serrano, M., M.C. Martinez-Madrid, G. Martinez, F. Riquelme, M.T. Pretel and F. Romojaro. 1996. Role of polyamines in chilling injury of fruit and vegetables. Food Sci.Technol.Int. 2:195-199.

63. Serrano, M., M.C. Martinez-Madrid, F. Romojaro and F. Riquelme. 1995. Polyamine accumulation in cold stored peppers. Acta Hortic. 312:127-133.

64. Shear, C.B. 1975. Calcium-related disorders of fruit and vegetables. HortScience 10:361-365.

65. Sinclair, W.B. and D.L. Lindgren. 1995. Vapor heat sterilization of California citrus and avocado fruit against fruit fly insects. J. Econ. Entomol. 48:133-138.

66. Tagliavini, M., M. Toselli, B. Marangoni, G. Stampi and F. Pelliconi. 1995. Nutritional status of kiwifruit affects yield and fruit storage. Acta Hort. 383:227-237.

67. Thomas, P. and M.S. Oke. 1983. Improvement in quality and storage of 'Alphonso' mangoes by cold adaptation. Scientia Hortic. 19:257-262.

68. Unahawatti, U., C. Chettanachitara, M. Poomthong, P. Komsom, E. Smitasiri, C. Lapasathukool, W. Worawistthumrong and R. Intarakumheng. 1986. Vapor heat treatment for 'Nang Klangwan' mango, *Mangifera indica* Linn., infested with eggs and larvae of the oriental fruit fly, *Dacus dorsalis* Hendel and the Melon fly, *D. cucurbitae* Coquillette (Diptera:Tephritidae). Agricultural Regulatory Division, Department of Agriculture, Ministry of Agriculture and Co-operatives, Bangkok, pp.108.

69. Valero, D., M. Serrano, M.C. Matinez-Madrid and F. Riquelme. 1997. Polyamines, ethylene and physicochemical changes in

low temperature-stored peach (*Prunus persica* L. cv.Maycrest). J.Agric.Food Chem. 45:3406-3410.

70. Van Lelyvel, L.J. and J.H.E. Smith. 1979. Physiological factors in the maturation and ripening of mango (*Mangifera indica* L.) fruit in relation to the jelly seed physiological disorder. J. Hort.Sci.54: 283-287.

71. Von Mollendorff, L.J., G. Jacobs and O.T. De Villiers. 1992. Postharvest factors involved in the development of chilling injuries in peaches and nectarines. J.S.Afr.Hort.Sci. 2:58-68.

72. Wang, C.Y. 1994. Combined treatment of heat shock and low temperature conditioning reduces chilling injury in zucchini squash. Postharvest Biol. Technol. 4:65-73.

73. Wang, C,Y. and D.O. Adams. 1982. Chilling-induced ethylene production in cucumbers (*Cucumis sativas* L.). Plant Physiol. 69:424-427.

74.Wang, C.Y. and Z.L. Ji. 1989. Effects of low-oxygen storage on chilling injury and polyamine in zucchini squash. Scientia Hortic. 39:1-7.

75. Wild, B.L. 1993. Reduction of chilling injury in grapefruit and oranges stored at 1°C by prestorage hot dip treatments, curing and wax application. Aust.J.Exp.Agric. 33:495-498.

76. Witney, G. W., P. J. Hofman and B. N. Wolstenholme. 1990. Mineral distribution in avocado trees with reference to

calcium cycling and fruit quality. Scientia Hortic. 44:279-291.

77. Woolf, A.B., C.B. Watkins, J.H. Bowen, M.J.H. Lay-Yee, J.H. Maindonald and I.B. Ferguson. 1995. Reducing external chilling injury in stored 'Hass' avocados with dry heat treatment. J.Amer.Soc.Hort.Sci. 120:1050-1056.