MANGO

Volume 1

Production and Processing Technology

Sudha G Valavi
K Rajmohan
J N Govil
K V Peter
George Thottappilly

38

Application of Postharvest Technology in Mango

SUTRISNO[1], ISMI M. EDRIS[2] AND SUGIYONO[3]

ABSTRACT

The application of postharvest technology in mango has been addressed in developing technology to prevent and eradicate postharvest pest and diseases, to maintain as well as to improve quality and non-destructive techniques to evaluate quality. Technology in pest and disease treatment focuses on disinfestation against fruit flies using heat treatments, irradiation, quick freezing, fumigation and chemical treatments. Maintaining and improving quality are essential to prevent quality deterioration and increase added value of the product by applying technology during postharvest handling. This includes processing through development on material used, modification of micro environment and technique applied. Non-destructive technology that has been developed for mango in these recent years is Near Infra-Red (NIR), image processing, ultrasound method and X-ray.

Keywords: Postharvest technology, Mango, Pest and diseases, Non-destructive quality evaluation, Quality improvement.

[1] Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University, Indonesia, E-mail: kensutrisno@yahoo.com

[2] Agricultural and Food Engineering, Post Graduate School, Bogor Agricultural University, Indonesia.

[3] Agricultural and Food Engineering, Post Graduate School, Bogor Agricultural University, Indonesia.

Corresponding author: kensutrisno@yahoo.com

INTRODUCTION

Mango is one of the popular products from Asia, including Indonesia whi is very popular among others tropical fruits. Indonesia is world's six highest producer of mangoes with 1,621,997 ton or 8.3 ton/ha in 20 (Directorate General of Horticulture, 2008; BPS, 2011). During 1998–200 total national production of mango increased with 2,243,440 ton in 20 (BPS, 2011). Export development also pointed out positive growth of 7.1 during 2002–2006 (Dewandari *et al.*, 2009) which in 2006 was marked 1.182 ton. The largest exports marketed were to United Arab Emirate Saudi Arabia and Singapore (MoA, 2011). Among the many cultivars plante some of the exported mangoes are cv. *Kensington* (Australia); *Irwin*, *Tomn* *Atkins* and *Keitt* (Florida, USA), *Nam Doc Mai* (Thailand), *Gedong Ginc* *Arumanis* and *Golek* (Indonesia). However, mango is a perishable fruit whi needs appropriate postharvest handling in order to meet and to comp consumer and food standard.

Besides quick quality deterioration occurring in perishable fruits, t critical constraints in postharvest handling of mango are pest and diseas attack which in turn fasten quality deterioration. It has become a challenge how to provide technology which enables to minimize deterioration, extendi the shelf life by means of easily accessible technology for producers and safe in the perspective of environmental and food safety. More attention is th addressed for the development of non–destructive techniques to evaluate t quality of fruits and disinfestation of fruit flies and fungus which associate wi postharvest pest and diseases. In order to improve added value of mango d to its perishable characteristic into more stable form, some processi technology has been developed in juicy mango; dehydrated products such crackers and vacuum–puffed mango; spray–dried mango.

POSTHARVEST TECHNOLOGY FOR PESTS AND DISEASE TREATMENTS

The most serious postharvest diseases that are considered reducing econom value and becoming deterrent to mango exports to some countries a anthracnose and stem–end rot which are caused by fungus pest attack fruit fly and seed weevil. At the onset damage symptoms caused by fruit and seed weevil are not visible as there is no external evidence of infestatio Regardless, those pests attack fruit when it is still attached on the tree, t presence of the damage will affect postharvest quality significantly as fung and pests cause fruits' decay which hastens ripening.

Many researches in postharvest sector have been conducted to devel technology for preventing or eradicating their attack especially for fruit disinfestation by applying vapor heat, hot air, hot water, irradiation, qui freezing, fumigation and chemical treatments (Johnson and Hofman, 200 Heat treatment using vapor, air and water has been more popular since t restriction of methyl bromide as fumigants. This substance was consider an environmental issue problem as an ozone–depleting chemical. In the USA, this substance was phased out completely in 2005 but some emergency uses for quarantine applications may be permitted, *e.g.* to destroy a serious quarantine pest in an imported consignment or to meet official requirements of an importing country (EPA, 2008 in Johnson and Hofman, 2006).

Vapor heat treatment (VHT) uses air heated by water vapor at temperature about 40–50°C to heat the fruit in which the air heating circulation can be performed using with or without forced air. The present development of VHT technology on mango has put in several necessary conditions on the application of length of exposure time, fruit waxing and combination with hot water treatment (HWT). HVT held at the fruit centre at 46.5°C for 20–30 min prior to bee waxing at concentration 6% could effectively kill B. *dorsalis* eggs infested in mango cv *Gedong Gincu* and could prolong the shelf life up to 28 days (Hasbullah *et al.*, 2008). During the storage, fungus identified as *Colletotrichum gloeosporioides* and *Pestalotiopsis mangiferae* which cause anthracnose and stem end rot were found in non–HVT while it was not found in fruit exposed to VHT (Marlisa, 2007). Besides those two funguses, *Lasiodiplodia theobromae* and *Cladosporium cladosporoides* are two others fungus that infest in primary Indonesian mango cultivar, *Gedong Gincu*, during storage (Hasbullah, *et al.*, 2008). Jacobi *et al.* (1997) found no diseases either anthracnose nor stem end–rot, in mango cv. *Kenshington* treated with combination of HWT and HVT while untreated fruit experienced severe damage at 10.9% of skin area affected. In the development of heating media, it had been revealed that forced vapor–saturated–air and hot water transferred heat most efficiently to the fruit surface where thermal stress occurred the greatest during heating in vapor–saturated–air (Shellie *et al.*, 2000).

During research development before 1999, Hallman (1999) stated that irradiation may be the most broadly applicable quarantine treatment against fruit flies. This could be driven from the performance treatments showed by 46.1°C water immersion quarantine treatment for mangoes ≤ 0.7 kg, which is sometimes detrimental to fruit quality and a treatment > 0.7 kg which cannot currently be treated with hot water due to lack of efficacy and commodity tolerance data for longer treatments. The application of irradiation for fresh fruit is in the range of 250–750 Gy. The range should incorporate the doses for individual pests and commodities due to susceptibility of each fruit.

Quick freezing is held by exposing mango to lower temperature (–17°C) and holding at –6°C or below for 48 h to disinfest mangoes for processing but it is not further approved for importing mangoes with seeds because mango weevil could be presented (Johnson and Hofman, 2006). Chemical treatment was used in examining effect of acidic solutions, hydrochloric acid (HCl), alone or in combination with *prochloraz* on the control of *Alternaria alternata* in mango which cause *alternaria* rot in mango

(Prusky *et al.*, 2006). It was found that application of hot water spraying a brushing for 15–20 s followed by spraying with 50 mM HCl alone combination with *prochloraz* at 45 to 900 mg/ kg could effectively preve *alternaria* rot in stored mango. The enhanced *prochloraz* activity w attributed to its enhanced solubility which resulted in an increase in t fungicide active ingredient in the solution.

TECHNOLOGY FOR QUALITY IMPROVEMENT

Consumers judge fresh mango from its visual appearance *e.g.* color and si which in some cases determine maturity level, injury symptoms on sk surface which is closely related to mechanical damage and physiology as w as chilling injury (CI) indices. Flavor, aroma and texture are other convinc market requirements which correlate with chemical compounds *i.e.* sug volatiles and firm tissues. Consumers, in common, describe directly the qual of mango based on those four quality attributes. Beyond the diversity cultivars, consumers sometimes only put their interest to several cultiva which have attractive flavor and aroma. Those attributes are closely relat as the constituent of aromatic compound will result in different flavor a aroma. Firm tissues generally relate with softening which is sometim undesirable as it is a sign for senescence or internal decay.

Many researches in postharvest have been conducted to identify a look for any necessary technology mainly in method on how to impro quality in extended shelf life either in fresh intact or minimally process mango. For most fresh produce, shelf life is best defined as the period with which the product retains acceptable quality for sale to the processor consumer (Aked, 2002). The researches have been addressed to metho and technique in pre–cooling, packaging, ripening, sortation, grading, stora and transportation using heat treatment, chemical treatment, modified micro environment and material used particularly for packaging or i combination. Identification pays more attention on applied technology effe to physicochemical properties of product.

Pre–Cooling

Pre–cooling can be in the form of water or hydro, air and ice as the cooli medium and also through application of forced circulation. The combinati of water and ice medium for cooler could give better results in maintaini fruits quality (*i.e.* Solid Soluble Content (SSC), acid content, color a firmness which represents texture) rather than used alone applied in man cv. *Cengkir Indramayu* (Nurmawati, 2008).

Packaging

Technology development in *packaging* of fresh mango largely carried out exploring material used while minimally processed is in development micro environment such as modification of atmosphere (O_2 and CO_2) through means of coating on individual fruit. In the development of packaging material, wooden and plastic are being used commonly for domestic market while cartoon is objected for export purpose due to its practical easiness and technology advantages in maintaining fruits quality. In general, the required advantages of packaging *i.e.* increased shelf life, prevention from mechanical damage and hazardous microorganisms, maximize quality, alleviate CI and reduce weight loss.

Edible coating on fresh fruit can provide an alternative to modified atmosphere storage by reducing quality changes and quantity losses through modification and control of the internal atmosphere on the individual fruit (Park, 2002), reduce decay and improve appearance (Baldwin *et al.*, 1999). In mango, different coating materials have different effects on fruit quality. Polysaccharides were found to have ability to provide increased concentrations of flavor volatiles while carnauba wax could significantly reduce water loss (Baldwin *et al.*, 1999). Hoa *et al.* (2008) examined coating using *Xedabio* for mango cv. *Cat Hoa loc* under ambient storage conditions. It was found to be the best material as it retarded ripening by 3 days over other treatments.

Modified atmosphere (~5% CO_2 and ~10% O_2) in 4–kg film–lined cartons using Xtend® film (XF) for mango cvs. *Tommy Atkins* and *Keitt* at 12°C was found to be the most effective in reducing CI than using polyethylene (PE) (Pesis *et al.*, 2000). Other advantage of using XF film was the reduction in the level of sap inside the package due to the lower relative humidity in the XF film (~90%) compared with that of PE packaging (~99%). The thickness also becomes the important parameter which significantly affects the visual appearance and consumers sensory perception (Rujiati, 1991). It was reported that besides the best predefined atmospheric concentration of O_2 and CO_2 at 2.5% and 5%, the thickness of PE at 0.02 and 0.04 mm is the best value for mango cvs. *Arumanis* and *Indramayu* modified atmosphere based on damage level on visual and physical, chemical and sensory acceptance, respectively. Statistically, the thickness of PE significantly influence towards weight loss, firmness, water content, vitamin C content, accumulation of CO_2 inside package and sensory acceptance while weight loss did not influence. Anaerobic respiration should be prevented in modified atmosphere packaging (MAP) by maintaining the composition of O_2 level inside package for not becoming too low (at least 2–3%). Too low O_2 level composition results in the development of pathogenic bacteria *Clostridium botulinum* and accumulation of *ethanol, acetaldehyde* and *organic acids* cause unwanted smell which indicates the deterioration of the quality.

Packaging material for transportation purpose generally uses wooden crate, corrugated cardboard and additional material for filler. But now, use of wooden crates for packaging is being restricted in international markets on account of quarantine concerns and special disinfestation treatments necessary for international trade (FAO, 2002 in Anwar *et al.*, 2008). As result, corrugated cardboard now becomes the largest alternative found global market including Indonesia to package their products. In order provide efficient distribution in container whether in sea or air freig calculating in pallet optimization becomes the method to obtain the purpo

Distribution efficiency is strongly correlated with pallet use efficien by the seller and the buyer. Both actors should meet the same pallet size optimize the pallet space used in container. Qanytah and Ambarsari (201 stated that various exporters of mango from Indonesia use different sizes pallet. For example, Cirebon and Pemalang use 1200 × 1000 mm wh obtains the most efficient pallet usage if exported to Singapore, Taiwa Germany and the Netherland. Besides the size of pallet, the arrangeme also contributes to efficiency calculation in distribution. The research a reported that among the various numbers of packaging used for exporti mango, package size of 450 × 220 × 180 mm arranged at 1100 × 900 m pallet produced by Cirebon resulted in 100% efficiency. While in Pemala the efficiency was only 82.12%.

Storage and Ripening

Technology in storage is utilized by applying low temperature combin with additional treatment such as $CaCl_2$, waxing, edible coating or modifi atmospheric packaging which is aimed to improve the consumer acceptan towards quality and delay senescence phase. Technology in ripening conducted through artificial ripening by applying ethylene injection particular concentration to provide ripening schedule of the products. So of researches combine storage and ripening treatments so that the resu can provide integration system in order to maintain and improve quality mango during its postharvest growth.

Research in these two stages has relatively been conducted togeth in order to determine the effect of storage condition on quality after ripeni Paramitha (2009) found that storage temperatures of 8 and 13°C significan influenced respiration rate, weight loss, firmness, SSC and color duri storage of mango cv. *Gedong Gincu*. The storage and artificial ripeni temperatures also significantly influenced respiration rate, weight lo firmness, SSC, color and sensory acceptance after ripening using 200 r kg ethylene. Based on sensory acceptance, it was found that the best va acceptance was resulted from storage at 13°C and then followed by ripeni at room temperature (27–30°C). Respiration rate and color change develo during storage (up to measurement at 456 hours or 20 days) and follow by ripening are shown in Figs. 1 and 2. Respiration rate during stora relatively decreased showing the maturity growth process up to 456th h while in ripening changes fluctuate after climacteric peak showi senescence process. The climacteric peak occurred after ethylene inject at the 458th hour. During storage and ripening, there was no increase the value for color indicator *i.e.* "L" and "b" which relatively decreased while "a" showed increase in value.

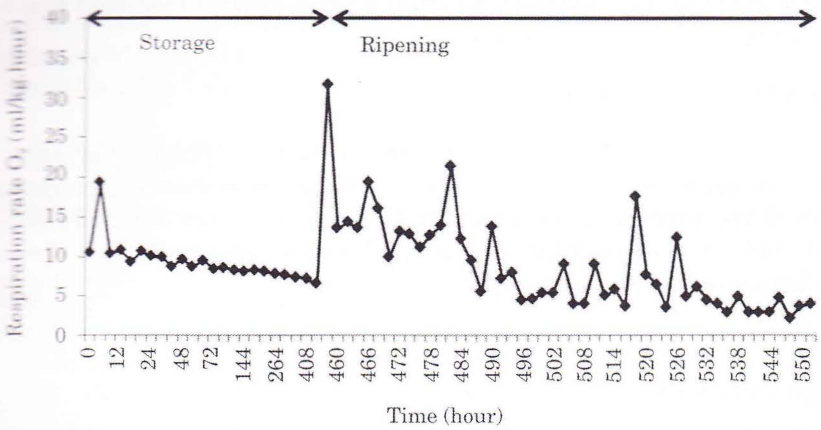
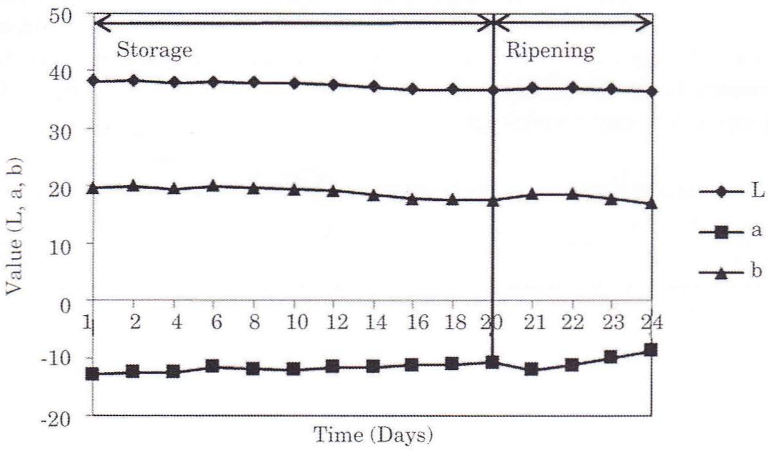


Fig. 1: Respiration rate during storage and ripening



Source: Paramitha (2009)

Fig. 2: Color change during storage and ripening

Ripening process of mango cv *Arumanis* could be delayed by 1–3.6 days through immersing the products into $CaCl_2$ at 4 and 8% concentration for 60, 90 and 120 minutes (Sari *et al.*, 2004). The designed method revealed that calcium infiltration inside the fruits was affected by the length of immersion and not the concentration. Beside the immersion length time, other alternative to infiltrate calcium into the fruits is suggested such as modification in the pressure. Wisnusubroto (1989) reported that application of 145 mmHg could delay 2–4 days ripening rather than infiltration that occurred at normal pressure. To obtain fresher and better visual appearance, waxing could give good solution as waxing can lighten and close the frui pores as well as lower respiration and transpiration. In this regard, Purwok *et al.* (1999) compared application of $CaCl_2$, PE for packaging material an waxing in mango cv. *Arumanis* wherein waxing provided the best result fo visual appearance and freshness.

ARTIFICIAL RIPENING

Artificial ripening is conducted due to various needs and purposes in preparin mango products from farm to fork *i.e.,* scheduling of matured products t optimize the quality of the products to meet consumer demands at eac point of physical distribution along supply chain. This could be in the forr of delaying or fastening the ripening process.

The technology of artificial ripening applied for primary mango (Indonesia *i.e.* cv. *Gedong Gincu* has been conducted in order to study th quality changes as well as developing mathematical modeling of its change during cold storage and after ripening using ethylene 200 mg/kg Rizki (2004) showed that temperature of cold storage and days after ethylen injection interacted which significantly influenced the sensory acceptanc including color, texture, taste and aroma. Mathematical modeling to predi(quality changes (*i.e.* weight loss, SSC and acid) during storage had bee successfully developed using Arrhenius equation with r is higher than 0.ξ The equation and r value are as listed in Table 1.

Table 1: Mathematical modeling to predict quality changes during storage of mango (*Gedong Gincu*

Quality parameter	*Mathematical modeling*	*Storage temperature (°C)*	*r*
Weight loss	$k = 1.53 \times 10^{-14}. e^{-10188.0(1/T)}$	8	0.9(
		13	0.8
Firmness	$k = 1.40 \times 10^{-7}. e^{-5471.7(1/T)}$	8	0.9
		13	0.4
SSC	$k = 2.39 \times 10^{-7}. e^{-5519.51(1/T)}$	8	0.8
		13	0.9
Acid content	$k = 6.80 \times 10^{-1}. e^{-1091.7(1/T)}$	8	0.7
		13	0.9

Source: Rizkia (2004)

Chilling Injury

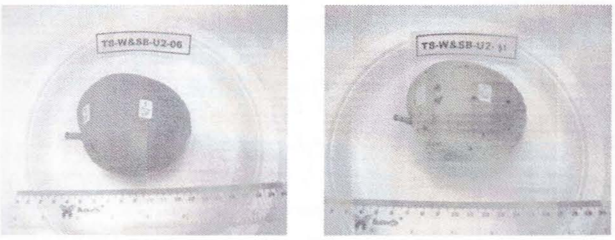
Tropical fruits including mango are susceptible towards low temperatu damage or CI with black spot and cell softening occur. But, at the oth side, cooling is one of the common technologies used for food preservati(through conditioning temperature and relative humidity of its environme which is aimed at minimizing deterioration that can extend the shelf lif The question that emerges is at what condition CI occurs and how to identi the initial symptom non–destructively to maintain the intact shape of the products so it is still saleable.

Sutrisno *et al.* (2010) found that CI occurs at the 4th day storage at temperature below 13°C while at above 13°C it shows at day 4th based on ion leakage parameter. The change of ion leakage from the 0th to 10th days of storage is listed in Table 2. The visual symptom was spot as shown in Fig. 3.

Table 2: The change rate of ion leakage after 20 minutes during 0th to 20th days of storage

Storage (day(s)	*Slope*
0	0.140
2	0.161
4*	0.174
6	0.149
8	0.143
10	0.164

*) CI was occurred
Source: Fikri (2011)



a) Before ethylene injection b) After ethylene injection

Fig. 3: Visual appearance of mango before and after ethylene injection at 12th day storage

PROCESSING

Juicy Mango

Puree is the raw material for nectar, juicy, syrup and jams which are obtained by whisking the pulp of the mango without adding water. Puree of mango can also be mixed with other fruits to enrich the taste or nutrient value content. Puree can be packaged using can which needs to be sealed and pasteurized for preservation. Using polyethylene packaging and storage at –30°C through quick freezing using frozen nitrogen for 70 seconds, puree can be stored for six months (Dewandari *et al.*, 2009).

Dehydrated Mango

Raymundo *et al.* (2009) reported dehydrated products of mango in the form of dried, fruit bar, fruit roll and vacuum–puffed dried mango. The principal purpose of this technology is to remove water content in the food making it less suitable for undesired microbial growth. The technology developmer should be reliable with economical and technical ease for manufacturer which the emerging system now is addressing to sun drying system. Th technique is sometimes unreliable commercially with production schedu and food hygiene so other techniques using mechanical dryer and vacuu need to be explored more. Mango cracker is one of the products using vacuu frying technique. Before it was fried, the slices were immersed into Natriu metabisulfit 1000 mg/kg for 10 minutes (Dewandari *et al.*, 2009). Th temperature and length of time of frying need to be studied further.

Spray-Dried Mango

Spray-dried mango is designed to produce mango in powder form throug rapid evaporation of H_2O or atomizing using heated air flow materia Raymundo *et al.* (2009) mentioned several advantages in use of th technology *i.e.* efficient and hygienic method for producing cheap but high quality mango fruit powder and instant mango juice if the proper fe formulation and parameters are applied; reduced 85% transportation cos the powder is used for flavoring confectionaries and pharmaceutic preparations; manufacturing baby foods and tropical fruit drinks fortifi with nutrients to replace those portions lost during processing and produ instant juice which can be reconstituted easily.

NON-DESTRUCTIVE TECHNOLOGY FOR QUALITY EVALUATIO

The development of non-destructive technology has been an attracti research for scientists during the growth of robotic technology applied agriculture particularly for automated harvesting, sortation and grading which robot replaces human job. In developed countries, postharve activities have been carried out in automated-integrated handling production line which aim to maintain product quality, inclusive of fo safety, consistency and avoidance of human error during their work *e.* classification on maturity indices and size which involve adjustme prediction capability required from human.

Non-destructive technology applied in prediction quality, pests a diseases of mango is NIR spectroscopy (Schmilovitch *et al.*, 2000, Saranwo *et al.*, 2004, Subedi *et al.*, 2007), image processing (Ahmad *et al.*, 2002, 200 ultrasound method (Mizrach, 2008; Warji *et al.*, 2008) and X-ray (Thom *et al.*, 1995), which in the early development was based on assessment electromagnetic properties corresponding to physical properties of t products. Present researches expands not only include physical but al mechanical and thermal properties.

NIR covers the range of the electromagnetic spectrum between 780 2500 nm. When radiation penetrates the product, the incident radiati may be reflected, absorbed or transmitted where the relative phenomen depends on the chemical constitution and physical parameters of the sampl

Nicolaï *et al.*, 2007). It should be noted that the spectra are clearly very similar and this is the reason why sophisticated multivariate statistical analysis techniques are essential to extract useful information from an NIR spectrum (Nicolaï *et al.*, 2007). NIR has been used widely in evaluating physiochemical properties of mango (Schmilovitch *et al.*, 2000, Saranwong *et al.*, 2004, Subedi *et al.*, 2007), mangosteen (Teerachaichayut *et al.*, 2011) and avocado (Clark *et al.*, 2003). NIR is an expensive technology, so that the application of NIR in Indonesia for fruits quality evaluation has not been widely developed as yet. This technology had been used initially using reflectant spectra. In other countries, experiments employing NIR for mango were carried out by using short wavelength NIR to examine fruit maturity index at harvest and then to determine final eating quality.

A non–destructivel technique using NIRs to predict eating quality of ripe mango fruit in several cultivars from its harvest quality was successfully developed. The experiments were carried out by using short wavelength NIR to examine fruit maturity index at harvest and then to determine final eating quality. NIR absorbance spectra calibration obtained from short wavelength could precisely assess dry matter (DM) and starch content (Saranwong *et al.*, 2004), flesh hunter b and DM content (Subedi *et al.*, 2007) which directly could successfully predict future SSC after ripening stage. Thus prediction was obtained by strong correlation with the ripe–stage eating quality *i.e.* SSC with DM, starch or flesh hunter b. Table 1 shows an overview of applications of NIR in mango. Sutrisno *et al.* (2011) studied NIR spectroscopy of mango cv. *Gedong Gincu* using absorbance spectra which found that the maximum energy is absorbed by starch and it changed every day representing the metabolic process which also changed. The peak energy occurred at 1940 nm as shown in Fig. 4.

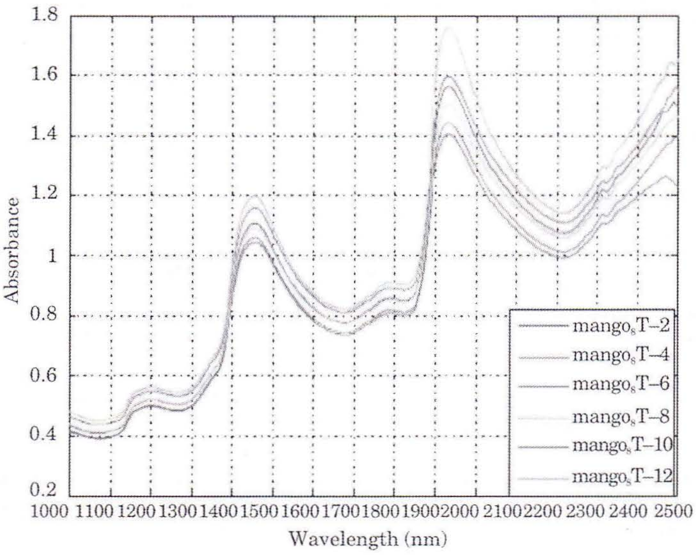


Fig. 3: The absorbance spectra of mango cv. *Gedong Gincu* after 2, 4, 6, 8, 10 and 12 days storage

Besides NIR, ultrasound technology has been used to identify physicochemical properties of mango non–destructively. The wavelength which has been used for industrial and pharmaceutical uses is 0.5–30 MHz, fresh fruits at 0.05–7.5 MHz in which mango is at 0.05 MHz with attenuation coefficient at 4.7–2.16 dB/mm (Mizrach, 2008). Ultrasound also has advantages to identify fruit fly at cv. *Arumanis* using zero moment power (Mo) (Warji *et al.*, 2008). The result shows that Mo could differentiate infested and uninfected sample with value higher than 5.71 and less than 5.49.

Image processing technology has been used widely to identify visual appearance in sortation and grading activities. In this purpose, automatic grading based on area and texture contrast could be applied in mango cv. *Arumanis* as well as red color index for cv. *Gedong* (Ahmad *et al.*, 2004). An important parameter to define the quality value of mango is color. Unfortunately, color is difficult to be evaluated due to its heterogeneity attached among the fruits. Kang *et al.* (2008) developed color vision system (CVS) technology to evaluate bicolor of mango fruit "B74". Besides visual appearance, use of volatile to determine fruit maturity is also useful as it presents quality attribute such as SSC and acidity in predefined maturity. With regard to the correlation, Lebrun *et al.* (2008) showed that electronic nose and gas chromatography could discriminate fruit maturity of mango cv. 'Cogshall', 'Kent' and 'Keitt' by volatile attribute.

Technology to identify postharvest diseases in mango fruit has also been developed. Thomas *et al.* (1995) developed X–ray imaging to detect damaged fruits caused by seed weevil (*Cryptorynchus (Sternochetus) mangiferae* (F)). X–ray radiographs of infested mango show dark areas in the seed corresponding to disintegrated kernel tissues as a consequence of feeding by developing grubs while non–infested ones show a uniformly light–grey area representing healthy kernel. Mango rot occurrence could also be detected using ultra–fast GC (Li *et al.*, 2009).

Table 3: Overview of NIR spectroscopy application in postharvest technology of mango (*Mangifera indica* L)

Cultivar	*Acquisition mode*	*Spectral range (nm)*	*Attribute*	*SEP*	*Reference(s)*
Tommy Atkins	Reflectance	1200–2400	TSS Acidity Firmness	1.223 0.161 17.140	Schmilovitch *et al.* (2000)
Caraboa	Absorbance	700–1100	Dry matter Starch	0.41 1.71	Saranwong *et al.* (2004)
Collected from different growers in the Darwin and Katherine regions, Australia	Absorbance	300–1150	Dry matter	0.01	Subedi *et al.* (2007)

CONCLUSIONS

Mango is one of the most popular fruits around the world but this fruit is much perishable due to the susceptibility to physiological, mechanical and pest damage. In order to maintain and improve added value of mango, an appropriate postharvest technology must be conducted and complied with quality standard required by consumers. Even many researchers have been found but so many challenges on handling mango still remain to provide premium quality for consumers with appropriate technology application. Besides of its technique concerns, lack awareness of quality control implemented by growers in some countries is a serious constraint in the point of social view to implement technology.

REFERENCES

Ahmad, U. (2002). Pengolahan citra untuk pemeriksaan mutu buah mangga (*Image processing for quality evaluation of mango fruit*). *Buletin Keteknikan Pertanian,* **16(1):** 30–41.

Ahmad, U., Subrata, I.D.M. and Gunayanti. S. (2004). Pemutuan buah mangga berdasarkan penampakannya menggunakan pengolahan citra (*Mango fruit grading based on appearance using image processing*). *Jurnal Keteknikan Pertanian.* **18(1):** 1–8.

Aked, J. (2002). Maintaining the post–harvest quality of fruits. *In:* Fruit and vegetable processing: improving quality. Jongen, W. (*Ed.*). Cambridge: Woodhead Publishing Limited.

Anwar, R., Malik, A.U., Amin, M., Jabbar, A. and Saleem, B.A. (2008). Packaging material and ripening methods affect mango fruit quality. *International Journal of Agriculture and Biology.* **10:** 35–41.

Baldwin, B.E., Burns, J.K., Kazokas, W., Brecht, J.K., Hagenmaier, R.D., Bender, R.J. and Pesis. E. (1999). Effect of two edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. *Postharvest Biology and Technology.* **17(3):** 215–226.

BPS (Badan Pusat Statistik, Statistics Indonesia). Produksi buah–buahan di Indonesia (Fruits production of Indonesia). http://www.bps.go.id/tab_sub/view.php?tabel=1anddaftar=1andid_subyek=55andnotab=3.

Clarck, C.J., McGlone, V.A., Requejo, C., White, A. and Woolf, A.B. (2003). Dry matter determination in 'Hass' avocado by NIR spectroscopy. *Postharvest Biology and Technology.* **29(3):** 301–308.

Directorate General of Horticulture. (2008). Workshop kajian pengembangan mangga dan manggis (*Workshop on the development of mango and mangosteen*).
http://hortikultura.go.id/index.php?option=com_contentandtask=viewandid=121andItemid=214.

Dewandari, K.T., Mulyawanti, I. and Amiarsi, D. (2009). Pembekuan Cepat Puree Mangga Arumanis dan Karakteristiknya selama Penyimpanan (*Quick Freezing of Puree Manggo cv Arumanis and Characteristic during Storage*). J. Pascapanen. **6(1):** 27–33.

Fikri, I. (2011). Deteksi gejala kerusakan dingin pada buah mangga varietas *Gedong Gincu* (*Mangifera indica* L.) yang disimpan pada suhu rendah menggunakan Near infrared (*Detection of chilling injury symptom at mango cv Gedong Gincu stored at low temperature using near infrared*). Undergraduate Thesis. Bogor: Department of Agricultural and Biosystem Engineering. Faculty of Agricultural Engineering. Bogor Agricultural University.

Hallman, G.J. (1999). Ionizing radiation quarantine treatments against *tephritid fruit* flies. *Postharvest Biology and Technology*. **16(2):** 93–106.

Hasbullah, R. and Marlisa, Dadang. E, (2008). Kajian perlakuan panas untuk disinfestasi lalat buah pada mangga gedong gincu (*Study on heat treatment for fruitfly disinfestation of mango cv gedong gincu*). Prosiding: Seminar Nasional Teknik Pertanian 18–19 November, Yogyakarta. Hal, pp. 1–11.

Hoa, T.T. and Ducamp. M.N. (2008). Effects of different coatings on biochemical changes of 'cat Hoa loc' mangoes in storage. *Postharvest Biology and Technology*. **48(1):** 150–152.

Jacobi, K.K. and Giles. J.E. (1997). Quality of 'Kenshington' mango (*Mangifera indica* Linn.) fruit following combined vapour heat disinfestation and hot water disease control treatments. *Postharvest Biology and Technology*. **12:** 285–292.

Johnson, G.I. and Hofman, P.J. (2009). Postharvest technology and quarantine treatments. *In:* The Mango, 2nd Edition: Botany, Production and Uses. Litz, R.E. (*Ed.*). CAB International.

Kang, S.P., East, A.R. and Trujillo, F.J. (2008). Colour vision system evaluation of bicolour fruit: a case study with 'b74' mango. *Postharvest Biology and Technology*. **49:** 77–85.

Lebrun, M., Plotto, A.S., Goodner, K., Ducamp, M.N. and Baldwin. E. (2008). Discrimination of mango fruit maturity by volatiles using the electronic nose and gas chromatography. *Postharvest Biology and Technology*. **48(1):** 122–131.

Li, Z., Wang, N., Raghavan, G.S.V. and Vigneault, C. (2009). Ripeness and rot evaluation of "Tommy Atkins" mango fruit through volatiles detection. *J. of Food Engineering*. **91:** 319–324.

Marlisa, E. (2007). Kajian disinfestasi lalat buah dengan perlakuan uap panas (vapor heat treatment) pada mangga gedong gincu (*A study of fruit fly disinfestation by applying vapor heat treament in mango fruit cv Gedong Gincu*). Graduate Thesis. Bogor: Major of Postharvest Technology, School of Postgraduate, Bogor Agricultural University.

MoA (Ministry of Agriculture). (2011). Ekspor komoditi pertanian berdasarkan negara tujuan (Export of *agriculture commodities based on destination country*). http://database.deptan.go.id/eksim/eksporNegara.asp.

Mizrach, A. (2008). Ultrasonic technology for quality evaluation of fresh fruit and vegetables in pre–and postharvest processes. *Postharvest Biology and Technology*. **48:** 315–330.

Mulyawanti, I. and Dewandari Yulianingsih, K.T. (2008). Pengaruh waktu pembekuan dan penyimpanan terhadap karakterisitik irisan buah mangga arumanis beku (*Effect of freezing time and storage to frozen fresh cut properties of mango fruit cv Arumanis*). *J. Pascapanen*. **5(1):** 51–58.

Nicolaï, 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(2):** 99–118.

Nurmawanti, N.E. (2008). Pengaruh pra–pendinginan dan suhu penyimpanan terhadap mutu buah mangga cengkir indramayu (*The effect of pre–cooling and storage temperature towards quality of mango fruit cv Cengkir Indramayu*). Undergraduate Thesis. Bogor: Department of Agricultural Engineering, Faculty of Agricultural Engineering, Bogor Agricultural University.

Paramitha, N.R. (2009). Kajian perubahan mutu buah mangga gedong gincu selama penyimpanan dan pematangan buatan (*A study of quality changes of mango fruit* *cv Gedong Gincu during storage and artificial ripening*). Undergraduate Thesis. Bogor: Department of Agricultural Engineering, Faculty of Agricultural Engineering, Bogor Agricultural University.

Park, H.J. (2002). Edible coatings for fruits. *In:* Fruit and vegetable processing: improving quality. Jongen, W. (*Ed.*). North America: CRC Press. pp: 331–343.

Pesis, E., Aharoni, D., Aharon, Z., Ben–Arie, R. and Fuchs, N.Y. (2000). Modified atmosphere and modified humidity packaging alleviates chilling injury symptoms in mango fruit. *Postharvest Biology and Technology*. **19(1):** 93–101.

Prusky, I., Kobiler, M. and Miyara Akerman, I. (2006). Effect of acidic solutions and acidic prochloraz on the control of postharvest decay caused by *Alternaria alternata* in mango and persimmon fruit. *Postharvest Biology and Technology*. **42(2):** 134–141.

Purwoko, B.S. and Magdalena. F.S. (1999). Pengaruh perlakuan pasca panen dan suhu simpan terhadap daya simpan dan kualitas buah mangga (*Mangifera indica* L.) varietas arumanis (*The effect of post–harvest treatment and storage temperature towards shelf life and quality of mango fruit cv arumanis*). *Bul. Agron*. **27(1):** 16–24.

Ambarsari Qanytah, I. (2011). Efisiensi penggunaan kemasan kardus distribusi mangga arumanis (*Used efficiency of corrugated cardboard for distribution of mango cv arumanis*). *Jurnal Litbang Pertanian*. **30(1):** 8–15.

Raymundo, L.C., Ombico, M.T. and de Villa, T.M. (2009). Fruit processing. *In:* The Mango, 2nd Edition: Botany, Production and Uses. Litz, R.E. (*Ed.*). CAB International.

Rujiati, S. (1991). Penggunaan atmosfir termodifikasi (modified atmosphere) untuk penyimpanan buan mangga (*Mangifera indica* L.) kultivar arummanis dan indramayu. Skripsi. Bogor: Institut Pertanian Bogor, Fakultas Teknologi Pertanian.

Saranwong, S., Sornsrivichai, J. and Kawano. S. (2004). Prediction of ripe–stage eating quality of mango fruit from its harvest quality measured nondestructively by near infrared spectroscopy. *Postharvest Biology and Technology*. **31(2):** 137–145.

Sari, F.E., Trisnowati, S. and Mitrowihardjo, S. (2004). Pengaruh kadar $CaCl_2$ dan lama perendaman terhadap umur simpan dan pematangan buah mangga arumanis (*The effect of* $CaCl_2$ *and dipping time on shelve life and ripening of arumanis mango*). *Ilmu Pertanian*. **11(1):** 42–50.

Schmilovitch, Z., Mizrach, A., Hoffman, A., Egozi, H. and Fuchs. Y. (2000). Determination of mango physiological indices by near–infrared spectrometry. *Postharvest Biology and Technology*. **19(3):** 245–252.

Subedi, P.P., Walsh, K.B. and Owens, G. (2007). Prediction of mango eating quality at harvest using short–wave near infrared spectrometry. *Postharvest Biology and Technology*. **43(3):** 326–334.

Sutrisno, E., Syaefullah, Y.A. and Darmawati. Purwanto, E. (2010). Deteksi dini perubahan mutu manggis berbasis perubahan kadar air melalui kecerdasan buatan dengan tingkat ketelitian 90% (*Early detection for quality changes of mangosteen fruit based on water content through artificial intelligence with accuracy level at 90%*). Final Report. Bogor: Bogor Agricultural University.

Shellie, K.C. and Mangan, R.L. (2000). Postharvest disinfestation heat treatments: response of fruit and fruit fly larvae to different heating media. *Postharvest Biology and Technology*. **21(1):** 51–60.

Teerachaichayut S., Terdwongworakul., A., Thanapase, W. and Kiji, K. (2011). Non-destructive prediction of hardening pericarp disorder in intact mangosteen by near infrared transmittance spectroscopy. *J. of Food Engineering*. **106(2011):** 201–211.

Thomas, P., Kannan, A. Degwekar, V.H. and Ramamurthy, M.S. (1995). Non–destructive detection of seed weevil–infested mango fruits by x–ray imaging. *Postharvest Biology and Technology*. **5:** 161–165.

Warji, Suroso. and Hasbullah, R. (2008). Pendugaan kerusakan mangga arumanis akibat lalat buah menggunakan ultrasonik:zero moment power (*Prediction of Arumanis Mango Damage Caused by Fruit Fly Using Ultrasonic: Zero Moment Power*). Prosiding: Seminar Nasional Teknik Pertanian 18–19 November, Yogyakarta. Hal. pp. 1–13.

Wisnusubroto. (1989). Menunda kematangan buah mangga arumanis dengan perlakuan $CaCl_2$ (*$CaCl_2$ Treatment for delaying ripeness of mango fruit cv Arumanis*). *Penelitian Hortikultura*. **3(4):** 64–68.

MANGO

Volume 1

Production and Processing Technology

About the Volume

The mango is a fleshy stone fruit belonging to the genus *Mangifera*, consisting of numerous tropical fruiting trees in the flowering plant family Anacardiaceae. The mango is native to India from where it spread all over the world. It is also the most cultivated fruit of the tropical world and its fruit is distributed essentially worldwide.

Mango is basically crop well suited for natural farming. In fact before 1950, mango was grown without use of any chemicals, there used to be enormous variability and superb quality. Use of chemicals was initiated in commercial cultivation of mango after advent of green revolution. As a result, number of pests became alarming and now there is always impression that use of agro chemical is not the ultimate solution for sustainable cultivation of mango.

Looking the excellent taste, wide variability with respect to varieties, nutritive, therapeutic value, organic production in mango will have immense scope in domestic and export market.

Mango is the most important horticultural crops of India. It is rightly titled as **"King of Fruits"** for its wide variability, attractive colours, excellent taste, nutritive, therapeutic values and export potentials. The crop is very well adapted to tropical and subtropical climates. Temperature, rainfall, wind velocity and altitude are the main climatic factors which influence its growth and fruiting. The major constraints in mango cultivation are low productivity, prolonged juvenility, alternate bearing in most of the varieties and incidence of large number of pest and diseases.

The book has two volumes. The volume I deals with Basics, Production, Utilization and Export and volume II with cultivation of mango in different countries. The editors have made sincere efforts to integrate and include modern science such as biotechnology, techniques of mango production, processing, uses, various recipes, marketing and export so that all persons presently concerned or new entrepreneurs can benefit tremendously.

Readership: Students of Agriculture, Horticulture, Biotechnology and Botany at B.Sc., M.Sc and Ph.D. levels, nutrition experts, scientists, administrators, policy makers, farmers, processors, exporters and above all housewives and all those concerned with production, processing and marketing of mango. It should form an excellent reference book in all libraries.

Studium Press LLC
P.O. Box 722200, Houston
TX 77072 - U.S.A.
Tel: (281) 776-8950, Fax: (281) 776-8951
E-mail: studiumpress@gmail.com
Website: http://www.studiumpress.in

SERIES ISBN: 1-933699-92-2
ISBN 1-933699-93-0
9 781933 699936