On-tree harvesting quality evaluation of mango fruit with a hand-held NIR instrument

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Introduction

Mango fruits are usually harvested at the mature green stage (unripe but physiologically mature). Maturity at harvest is the most important factor that determines final fruit quality. Fully mature fruit can reach superior eating quality when ripe while less mature fruits cannot.[1,2] Thus, estimation of harvesting quality of fruits is important from the viewpoint of marketing.

Starch has been considered as a yardstick for maturity of mangoes.[3-7] Dry matter (DM) which consists mainly of carbohydrate is one of recommended properties to be used as a maturity index.[8,9] However, measuring chemical properties is destructive and can be done only in sampling fashion which will easily allow contamination of less mature fruits. Moreover, chemical analyses are very expensive and time-consuming.

Near infrared spectroscopy (NIRS) has been widely used in quality evaluation of fresh fruits.[10] In our previous works, we have shown the capability of NIRS for evaluating eating quality of mango fruit using both a research type instrument, NIRSystems6500, and a hand-held type instrument, Fruit Tester 20.[11,12] NIRS is a promising technique for measuring Brix value and DM in intact mango. It was reported as a sufficiently precise method for determining starch content in processed foods.[13-15]

In this work, the system to predict harvesting indices [dry matter (DM) and starch content] of mature green mangoes on trees with a hand-held type NIR instrument was developed, and the demonstration of the system developed was carried out.

Experimental scope

The system for measuring NIR spectrum of mango on a tree with a hand-held type NIR instrument "Fruit Tester 20" (FT20) was developed. Effect of sunlight on spectra measured "outdoor" was investigated and compensated. The calibration equations with temperature compensation were developed to solve the problem of sample temperature that could not be controlled in a field. By the NIR measuring system developed, relationship between harvesting and eating qualities using the same mangoes was investigated (Figure 1).

Near Infrared Spectroscopy: Proceedings of the 11th International Conference.

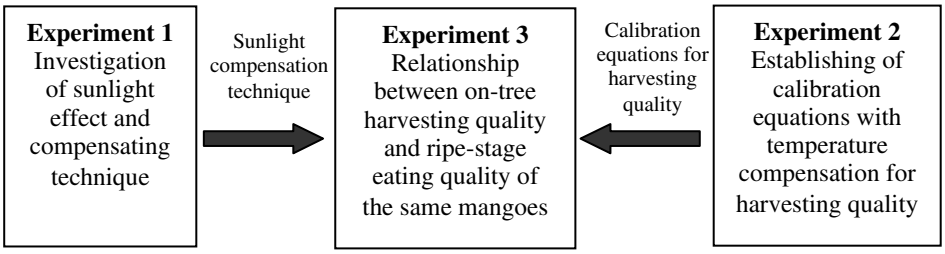


Figure 1. Experimental Scope.

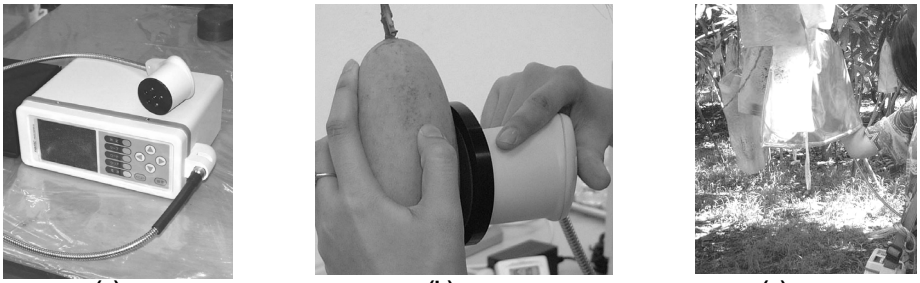
In all experiments, the hand-held type NIR instrument "FT20" (FANTEC, Kosai-city, JAPAN) with an interactance fiber optic probe was used [Figure 2(a)]. The instrument could measure spectra in a short wavelength region from 600 to 1000 nm at 1 nm intervals. The specification of the instrument and the configuration of its probe were shown in our previous report.[12]

Data analyses were carried out with the Unscrambler. The PLS regression was used for making a calibration equation.

Experiment 1: Sunlight effect

Materials and methods

A ripe mangoes (*Mangifera indica* cv. Nam Dork Mai) which were commercially available were used as samples in this experiment. The fruits were purchased at the wholesale market in Chiangmai province, Thailand, transported to our laboratory at Chiang Mai University, and then kept at the cold storage room of 5 °C for the experiment in the following day. Six hours before acquisition of NIR spectra, all fruits were moved from the storage room to the instrument laboratory (25 °C ambient).



(a) (b) (c)

Figure 2. The NIR measurement, (a) the FT20 instrument, (b) "indoor" spectra acquisition, and (c) "outdoor" spectral acquisition with a light-tight bag.

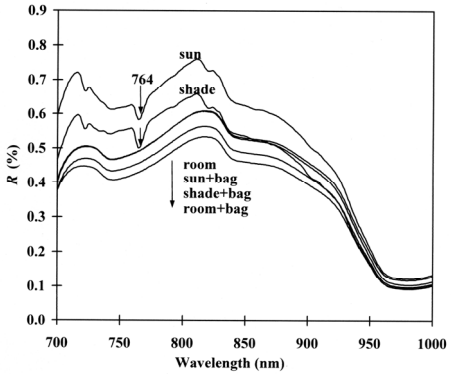


Figure 3. Diffuse reflectance (*R*) spectra of a typical mango measured under the various sunlight conditions.

Effect of sunlight on NIR spectra was studied by compared spectra measured "outdoor" without a light-tight bag (sun, shade), "outdoor" with a light-tight bag (sun+bag, shade+bag) and "indoor" with and without light-tight bag (room, room+bag). Figure 2(b) and 2(c) show the spectral acquisitions "indoor" and "outdoor" with a light-tight bag, respectively.

Results and discussion

Diffuse reflectance (*R*) spectra of a typical mango measured under the various conditions are shown in Figure 3. Sunlight could affect NIR spectra as the "sun" and "shade" spectra show clearly distinguished pattern from the rest. The downward peak at 764 nm was due to the absorption of oxygen molecules in atmosphere.[16] This sunlight effect could be compensated by covering the fruit and the NIR measuring head with a light-tight bag since there were no differences in the spectra between the "outdoor+bag" spectra (sun+bag, shade+bag) and the indoor ones (room, room+bag).

Experiment 2: Calibration equation with temperature compensation

Materials and methods

A total of 196 mature green mangoes (cv. Mahajanaka) cultivated in Lumpang, Thailand were used to derive calibrations, with temperature compensation, for DM and starch content, which were important indices of harvesting quality. After harvesting by hand, the fruits were transported to our laboratory by an air-conditioning car, and then the fruits were kept in the instrument laboratory at least for 1 hr before spectral acquisition.

The "indoor" NIR measurements of samples harvested were conducted at temperatures of 25, 32 and 39 °C. Sample temperature was controlled using the procedure described in a previous study.[11]

DM was measured by drying sample portion at 70 °C for 48 hours. Starch content was measured by the amylolase-amyloglucosidase method.[17,18]

Results and discussions

The mean, range and standard deviation of the DM and starch values used for NIR calibration and validation are shown in Table 1.

Table 1. Characteristics of calibration and validation sample sets of mango used to develop calibration equations with temperature compensation.

Items	Dry matter		Starch	
	Calibration set	Validation set	Calibration set	Validation set
N*	103	89	103	92
Range	16.22-23.53	17.06-22.84	32.97-52.81	35.86-52.45
Mean	19.57	19.44	43.01	42.86
SD+	1.48	1.25	4.48	3.98
Unit	% w/w		% w/w dry base	

* N is the number of samples for one temperature.
+ SD calculated from a set of sample with single temperature. The difference between SD from single temperature set and three-temperature set was negligible.

Original [log (1/R)] and second derivative [d^2log (1/R)] spectra of a typical mature green mango having temperature of 25, 32 and 39 °C are shown in Figure 4. The differences in both original and second derivative spectra around the water band at 842 nm could be noticed because the hydrogen-bonding was affected by temperature.[19] Strong absorption bands due to water were observed at 842 nm and 962 nm. Flat portions at both edges of second derivative spectra were caused by calculation algorithm of NSAS software.

The calibration equations developed were sufficiently precise. The *SEP*s were 0.52 % w/w for DM, and 2.04 % w/w dry base for starch. Scatter plots for validation set of actual values vs. NIR values of DM and starch contents are shown in Figure 5(a) and 5(b), respectively.

Experiment 3: Relationship between harvesting and eating qualities of the same mangoes

Materials and methods

A total of 141 mature green mangoes (cv. Mahajanaka) obtained from the same trees in the same orchard as Experiment 2 were used as samples in this experiment.

The "outdoor" NIR measurements with a light-tight bag were done on mangoes on trees before harvesting. After the NIR measurement, the fruits were harvested and kept for 5 days for eating quality evaluation. The calibration equations with temperature compensation mentioned in

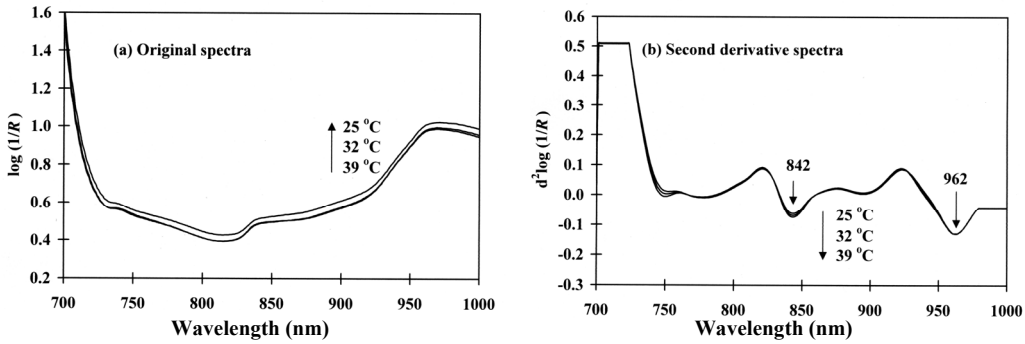


Figure 4. Original (a) and second derivative spectra (b) of a typical mango measured "indoor" with the sample temperature of 25, 32 and 39 °C.

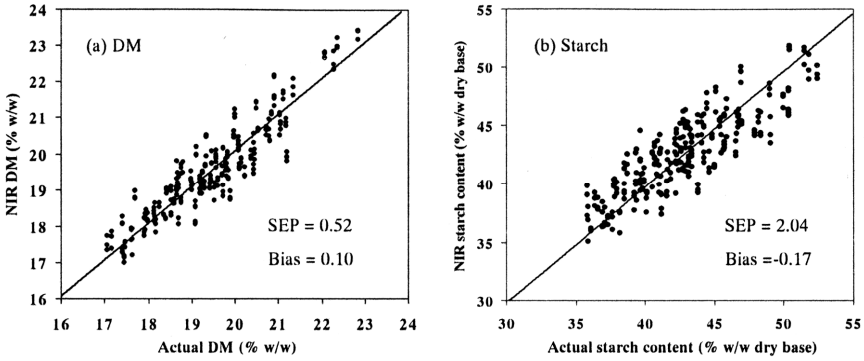


Figure 5. Scatter plots for validation sets of actual chemical values vs. NIR chemical values predicted by calibration equations with temperature compensation. (a) DM, and (b) starch.

Experiment 2 were applied to the "outdoor" spectra to predict the harvesting quality (DM and starch contents) of the on-tree mangoes. Bias corrections were carried out to remove the error between different sample presentation.

Results and discussions

Scatter plots of NIR-predicted harvesting indices of DM and starch contents with a function of sensory-evaluated eating quality. The dotted lines at 19.60 %DM and 44.52 %starch represent boundaries between samples with excellent and unacceptable eating quality. These lines were fixed by subtracting SD of DM or starch content of the excellent samples from their averages. Mangoes

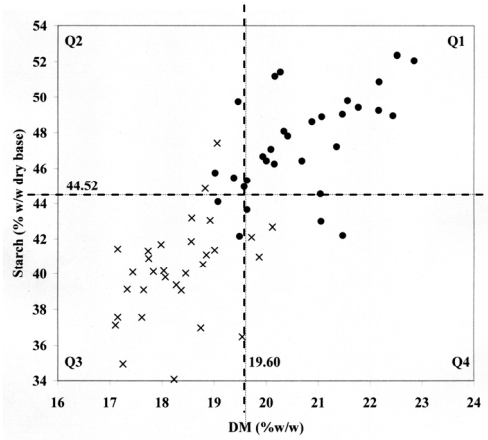


Figure 6. Scatter plots of NIR-predicted harvesting indices of DM and starch contents with a function of sensory-evaluated eating quality. Samples with cross mark (x) were the fruits with unacceptable eating quality while the ones with circle mark (•) were the fruits with excellent eating quality. Dotted lines are the 1SD-Lines at the 1SD values, average of DM or starch content of excellent eating quality group minus standard deviation of DM or starch content of the same groups.

with excellent eating quality when ripe had higher DM and starch contents at hard green stage than those with unacceptable eating quality. Using only one criterion either DM or starch was not sufficient to separate the excellent eating quality mangoes from the unacceptable ones.

Conclusion

By the NIR measuring system developed, it became possible to predict DM and starch contents of mature green mangoes on trees. Thus, by the DM and starch content predicted, eating quality of mangoes at ripe stage could be estimated in advance prior to harvest.

Acknowledgement

This research was supported by the Royal Golden Jubilee Ph.D. Program under the Thailand Research Fund (TRF), Postharvest Technology Institute of Chiang Mai University and the Association of International Education, Japan (AIEJ). The authors would like to acknowledge Ms. Sagee Sirisan for her continuing support and contributions in mango samples. We are grateful to Dr. Johanness Orphal for his support with information about solar radiation.

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