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# Feasibility on using NIR spectroscopy for the measurement of the textural parameters in mango

To cite this article: S Sharma and P Sirisoomboon 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **301** 012064

# Feasibility on using NIR spectroscopy for the measurement of the textural parameters in mango

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**Abstract.** Texture analysis of different type of mango has been done using several destructive and nondestructive techniques. Puncture test was used for measuring different textural parameters such as initial firmness, average firmness, toughness, rupture force, rupture distance, penetration force in pulp, penetration energy in pulp of mango C.V Namdokmai Sithong. Fourier transform NIR spectroscopy has been used in order to correlate the textural parameters with NIR spectra using partial least square (PLS) regression. Correlation coefficient (r) was obtained for parameters such as average firmness, rupture force of peel, penetration force in pulp, penetration energy in pulp are 0.70, 0.75, 0.71, 0.71 with RMSEP of 0.561 N/mm, 2.37 N, 0.497 N, 1.980 Nmm.

## 1. Introduction

Mango is the fruit well known for its good appearance and taste. The preference of consumer slightly leans towards the fruit by its physical parameters such as shape, color, size and texture. Texture perception is an important factor for quality evaluation of fruit and vegetable products [1]. Abbott [2], describes textural attributes of raw fruits and vegetables are determined by structural, physiological, and biochemical characteristics of living cells and their changes over time through the stages of development, maturation, and senescence.

As one of a famous fruit the textural quality of mango should be well known during the maturity stage. The method that has been used is destructive instrumental methods for measuring the textural properties of fruits and vegetables [3-6]. For some rapid analysis, the destructive method that has been used might not be feasible for evaluation of textural properties of the peel as well as the pulp of the fruit. Sirisoomboon et al., [7] reported the technique based on the measurement of firmness of mango by a compression test. Valente et al., [8] reported the instrumental and sensory characterization of mango fruit texture such as firmness, juiciness, meltiness and also proposed the PLS regression technique to develop the model for texture analysis using Vis-NIR spectroscopy. Softening of the flesh, total soluble solids content and acidity of the mango has been studied using NIR spectroscopic technique by Schmilovitch et al., [9]. Though many researches based on the texture analysis are focused on the nondestructive techniques, the appropriate method to analyze the texture of fruit peel as well as pulp is also important. According to Sirisomboon and Pornchaloempong [10], the puncture test indicates the mechanical response of the peel and pulp at the puncture point of the fruit. The test is effective in categorizing most of damage in fruit which can be useful for further design of post-harvest handling /machines as well as conveying equipment's for fruit grading and sorting.

Namdokmai Sithong is one of the important variety of mango, which is highly exported within and to overseas from Thailand. The fruit is more likely preferred by the consumers because of its appealing look. The main objective of this research is mainly focused on the textural analysis of peel and pulp of the mango C.V Namdokmai Sithong using puncture test analysis and correlating different properties such as initial firmness, average firmness, rupture force of peel, rupture distance, penetration energy in the pulp and penetration force in the pulp with the NIR spectra using partial least square regression. This research could be helpful for the mango producers to analyze the texture of peel and pulp to classify during the time of export.

## 2. Material and methods

### *2.1. Samples*
The samples were collected from the Chachaengsao province of Thailand. 85 fruits were collected in total for the experiment. The fully ripen fruits with same maturity were selected for this experiment. Samples were brought in the NIR Spectroscopy research center of agricultural food and products for the test and NIR scanning. Experiment were conducted on laboratory temperature of ±25° C.

### *2.2. Near infrared scanning on sample*
First the sample were scanned in the middle part by NIR Multi-Purpose Analyzer (MPA) Spectrometer (Bruker optics, Germany) with the scanning resolution of 16 $cm^{-1}$ in absorbance mode and there were 64 scans for 1 average spectrum of the sample. The wavelength range of 800-2500 nm (12,500-4,000 $cm^{-1}$) was used. Gold plate was scanned as the reference background scanning before starting the sample scanning.

### *2.3. Puncture Test*
After spectral acquisition the sample was taken for the puncture test. The sample was tested on a Texture Analyzer (Stable Micro System Model TA HD Plus, London, UK). For puncture test, a stainless plunger with a flat end of diameter 2 mm was attached to the load cell. The deformation speed was 2 mm/sec and depth up to 10 mm. The force-deformation profile thus obtained were used to calculate the initial firmness at 2N, average firmness, rupture force, rupture distance, penetration force in the pulp, penetration energy in the flesh and toughness. Texture Exponent 32 version 4,0,3,0 (Stable Micro Systems London, UK) was used to control the texture analyzer and to record and analyze the force-deformation curve.

### *2.4. Spectrum pre-treatment and NIR spectroscopy model establishment*
Partial least square models for predicting different parameters obtained from the force-deformation curve was developed by using OPUS, v.7.0.129 multivariate analysis software package (Bruker, Ettlingen, Germany). Spectra were pretreated if necessary using different preprocessing such as constant offset elimination, straight line subtraction, vector normalization (SNV), min-max normalization, multiplicative scatter correction (MSC), first derivatives (17 points segment), second derivatives (17 points segment), first derivatives + straight line subtraction, first derivatives + SNV and first derivatives+MSC. Model obtained was later evaluated by comparing different statistical parameters such as correlation coefficient (r), root mean square error of prediction (RMSEP) and RPD.

## 3. Results and Discussion
Figure 1 shows the Force vs Distance graph obtained from puncture test. Figure 2 represents the average raw spectra obtained by NIR scanning using FT-NIR spectrometer. The graph shows the peaks at 10306 $cm^{-1}$, 8400 $cm^{-1}$, 7020 and 5145 $cm^{-1}$. Peaks obtained at 10306 $cm^{-1}$, 6896 $cm^{-1}$ and 5145 $cm^{-1}$ are due to absorption band of the overtones and combination band associated with O-H stretching of $H_2O$ [11]. The number of samples, minimum (Min), maximum (Max), mean and standard deviation (SD) of the textural parameters is shown in table 1. Table 2 shows the results obtained using NIR spectroscopy based PLS regression models to predict each textural parameter derived from mango. For each parameter the most accurate model is shown.

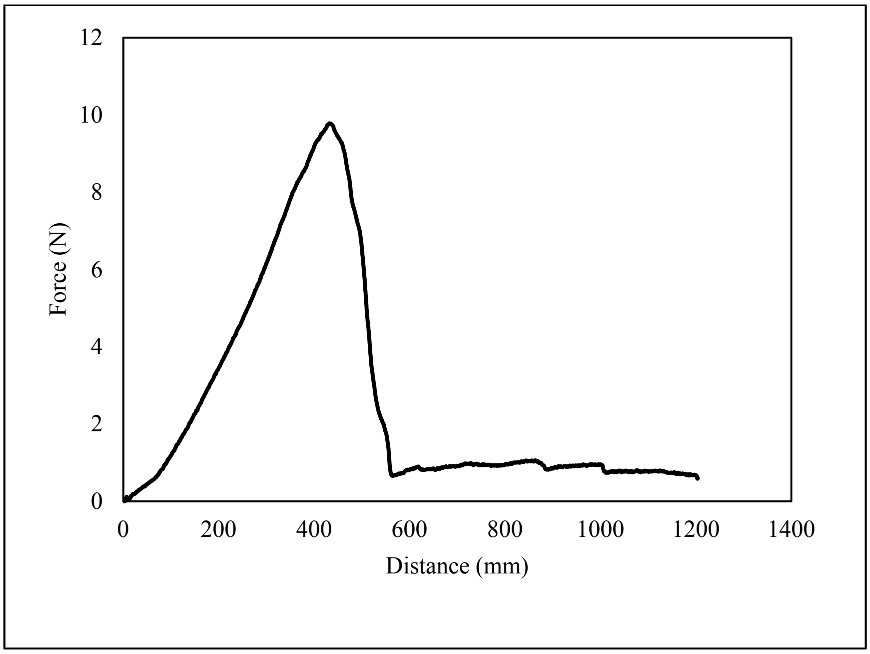


**Figure 1.** Force vs Distance curve obtained from puncture test of mango.

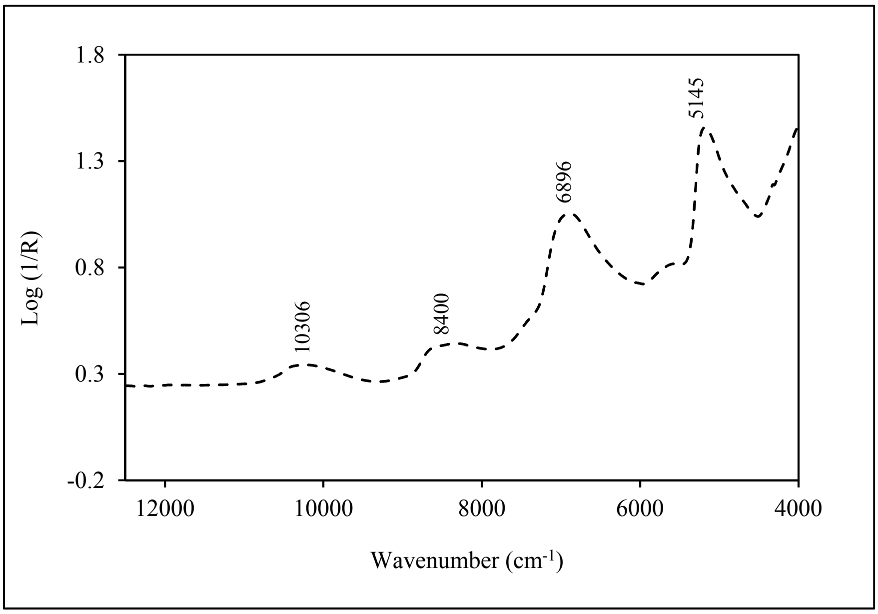


**Figure 2.** Average raw spectra obtained from FT-NIR Spectrometer.

**Table 1.** Statistics of textural parameters obtained by puncture test in Mango.

| Parameter | Calibration Set | | | | | Validation Set | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | Max | Min | SD | N | Mean | Max | Min | SD |
| Initial Firmness (N/mm) | 56 | 2.11 | 3.86 | 1.02 | 0.5 | 23 | 2.09 | 3.61 | 1.08 | 0.62 |
| Average Firmness (N/mm) | 56 | 2.34 | 5.15 | 0.93 | 2.37 | 23 | 2.54 | 4.4 | 1.19 | 0.8 |
| Toughness (Nmm) | 56 | 35.18 | 69.07 | 18.48 | 9.95 | 23 | 41.59 | 65.69 | 20.39 | 12.4 |
| Rupture Force of peel (N) | 56 | 12.64 | 22.42 | 7.39 | 2.72 | 23 | 14.51 | 22.12 | 8.47 | 3.66 |
| Rupture Distance (mm) | 56 | 5.59 | 11.42 | 3.76 | 1.22 | 23 | 5.92 | 8.75 | 4.02 | 1.33 |
| Penetration Force in the pulp (N) | 56 | 1.19 | 3.54 | 0.51 | 0.565 | 23 | 1.52 | 3.32 | 0.53 | 0.72 |
| Penetration Energy in the pulp (N mm) | 56 | 4.76 | 14.12 | 2.05 | 2.26 | 23 | 6.08 | 13.24 | 2.12 | 2.89 |

**Table 2.** Result of PLS regression model obtained for prediction of textural parameters.

| Parameters | Preprocessing | Factor | R | RMSEE | r | RMSEP | RPD |
|---|---|---|---|---|---|---|---|
| Initial Firmness (N/mm) | Vector Normalization (SNV) | 1 | 0.29 | 0.49 | 0.40 | 0.56 | 1.10 |
| Average Firmness (N/mm) | No preprocessing | 4 | 0.55 | 0.63 | 0.70 | 0.56 | 1.41 |
| Toughness (N mm) | Straight Line Subtraction | 7 | 0.71 | 7.49 | 0.53 | 1.03 | 1.19 |
| Rupture Force of peel (N) | No preprocessing | 6 | 0.72 | 1.99 | 0.75 | 2.37 | 1.54 |
| Rupture Distance (mm) | No preprocessing | 7 | 0.59 | 1.05 | 0.26 | 1.25 | 1.05 |
| Penetration Force in the pulp (N) | Straight Line Subtraction | 5 | 0.72 | 1.65 | 0.71 | 1.98 | 1.43 |
| Penetration Energy in the pulp (N mm) | Straight Line Subtraction | 5 | 0.72 | 0.41 | 0.71 | 0.50 | 1.43 |

R= correlation coefficient of calibration set, RMSEE = root mean square error of estimation, r= correlation coefficient of validation set RMSEP= root mean square error of prediction and RPD= residual prediction deviation

From table 2, it was observed that among the parameters measured by puncture test, average firmness, rupture force, penetration energy and penetration force gave the most convincing result with correlation coefficient of validation (r) 0.70, 0.75, 0.71, 0.71. Similarly the result obtained does not presented good correlation for the initial firmness, toughness and rupture distance. Figure 3 shows the correlation plot of measured parameters versus the predicted parameter by NIR spectroscopy for average firmness, rupture force, penetration force and penetration energy. Williams [12], explain the interpretation of the model obtained with respect to r, according to which the value of correlation coefficient from 0.71-0.80 can be used for rough screening. Therefore the parameters such as penetration force in the pulp, rupture force of peel and penetration energy in the pulp can be calculated using NIR spectroscopy for rough screening of mango.

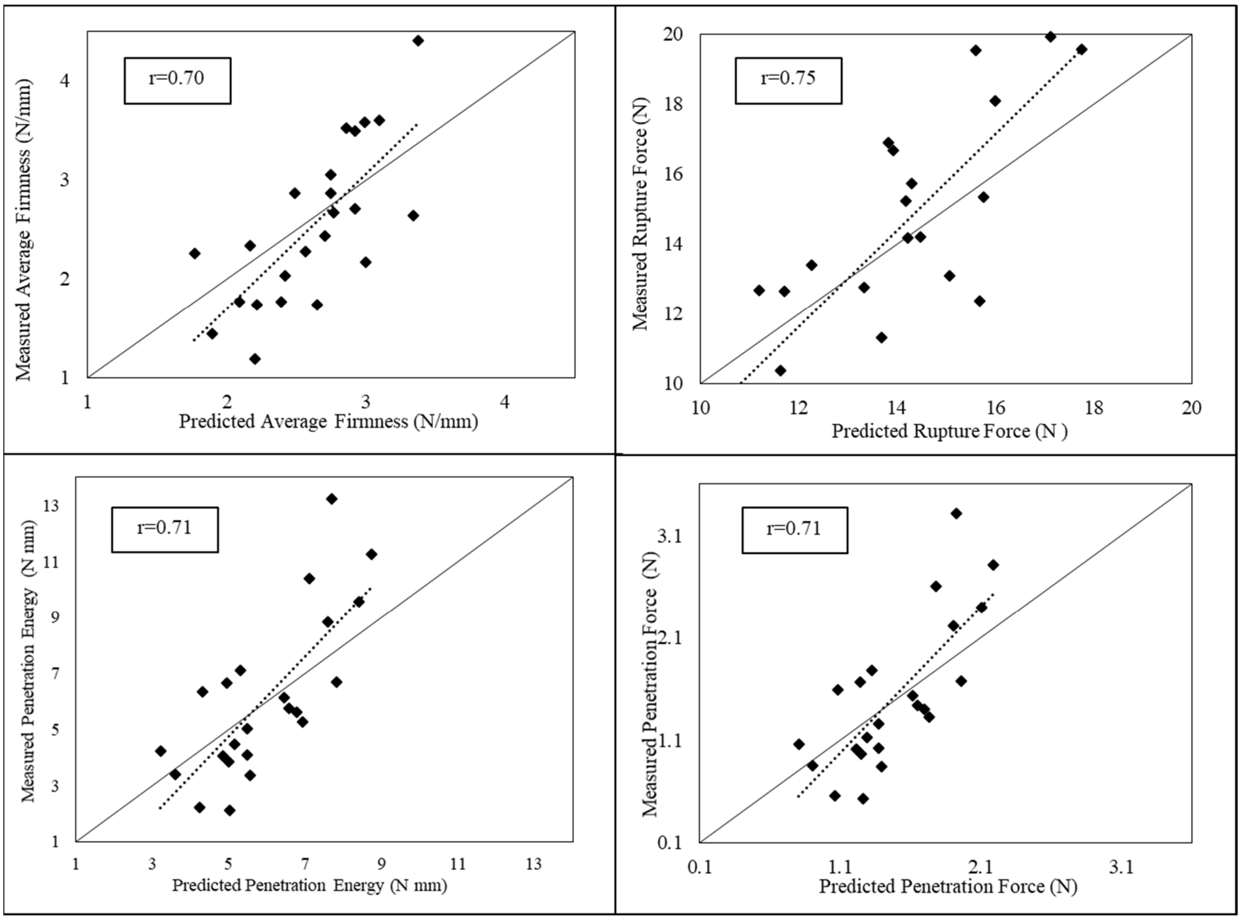


**Figure 3.** Scatter plot showing predicted textural parameters by NIR spectroscopy versus measured textural parameters using puncture test.

In the previous research by Sirisomboon and Pornchaloempong, 2011 the textural properties of mango has been evaluated by using the puncture test and compression test to analyze the response of force applied on different size of mango. The result was impressive and could be used for grading the mango according to the size. But, the way of analysis is the destructive, which is not feasible if the product has to be exported. From the PLS regression model developed in this research, average firmness can indicate the resistance of peel under the pressure applied until sudden fracture, rupture force indicate the penetration force in the skin of mango and penetration force and energy indicates the force/energy required to penetrate through the pulp of mango [10]. These textural parameters will be affected by the maturity, the storage time, or the processing stages. As the peel and pulp of the mango changes significantly during the ripening stages so there characteristics can indicate the stage of mango. So the result obtained in this research could be used as the nondestructive way to evaluate the textural properties of mango in different stages.

## 4. Conclusion

The result obtained from this research, concludes that the rapid NIR spectroscopic technique can be used for the textural evaluation of peel and pulp before sorting or before exporting. Textural parameters such as average firmness, rupture force, penetration force in the pulp and penetration energy in the pulp can be predicted for rough screening of mango. Since the experiment has obtained only satisfactory result, there is always the place for improvement as this method can be implemented for the classification of different maturity of the mango before exporting or sorting. More robust model could be developed in the future by including mango samples in different ripening stages.

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## Acknowledgement

Author would like to acknowledge NIR Spectroscopy Research Centre for Agricultural Food and Products for providing the necessary equipment for conducting the experiment.