# Near Infrared Spectroscopy: a Novel Non-Destructive Tool for Rapid Detection of Artificially Ripened Mango (*Mangifera indica*)

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**Abstract**

Indiscriminate use of Calcium Carbide and other fruit ripening enhancers like Ethephon has created a situation where many local fresh fruit products do not satisfy the consumer quality expectations. Therefore, introducing appropriate tools for rapid detection of artificially ripened fruits has become vitally important to secure the industry while preventing the consumers from health hazards. An attempt was made to use the Near Infrared Spectroscopy (NIRS) for the detection of artificially ripened mango by Calcium Carbide and Ethephon. Unripe mangoes were treated separately with Calcium Carbide and Ethephon. The treatments were replicated three times consisting five fruits per each replicate. Untreated mango was used as controls. The fruits were arranged in plastic crates padding with polyurethane foam lining with 36 mm of thickness. Near infrared spectra of all mango fruits were taken daily at the rate of 10 spectra per fruit until the fruits were overripe. Soft Independent Modelling of Class Analogy (SIMCA) calibration models were developed to identify the artificially ripened fruits from the controls. Partial Least Square (PLS) models were also developed to predict the Brix & Firmness values of fruits at ripening. The SIMCA classification was accurate as 98.5% and 97.8% for Calcium Carbide and Ethephon respectively. PLS regressions for Brix and firmness were achieved with Correlation coefficients of 0.85 and 0.86, respectively. The results revealed that high potential possibility exists with NIR technology to serve as a nondestructive evaluation tool for artificially ripened mango fruits using $CaC_2$ and Ethephon.

***Keywords:*** Calcium carbide, Ethephon, Mango, NIRS, SIMCA

## Introduction

While the trade in fresh horticultural products has become increasingly global, there is much more concern about misuse of chemicals in artificial ripening of fruits. Mango, (*Mangifera indica*) is one among the higher demanding fruits in Sri Lanka. It's popularly known as the king of fruit, belongs to family *Anacardeaceae*. Post-harvest losses and poor ripening measures: misuse of Calcium Carbide and Ethephon, have directly influenced the mango fruit quality resulting lack of competency in the export market. On the other hand, indiscriminate use of such chemicals to hasten the ripening process leads health hazards to the consumers. For instance, the calcium carbide contains traces of arsenic and phosphorus, which affect the neurological system resulting in headache, dizziness, mental confusion on a short term basis and can cause cancers or memory loss in the long run. As such chemical contaminants have become a significant authenticity issue focus worldwide (Chace, 1994).

Therefore, adopting novel techniques for quality evaluation of fruits has become vitally important for fruit producers as well as for consumers. Although there are destructive fruit quality evaluation methods available, they are inappropriate for real fruit quality



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detection in market as they destruct the fruits. Over the last three decades NIRS technology has been adapted enthusiastically by many agricultural industries worldwide (Tsenkova, 2006). It is fast, chemical free, environment friendly, no or little sample preparation is needed but also with similar accuracy to their reference chemical methods (Williams, 2006). Considering the advantages of the tool, it will be immensely important to introduce NIRS calibrations into food quality and safety applications. The countries that have fast and nondestructive screening facilities, Near-infrared spectroscopy has been extensively employed for grading fruits such as apple, orange, pear, melon but yet to introduce to Sri Lankan Mango. Therefore, the objective of this study was to assess the Near-infrared spectroscopy as a non-destructive tool for fast selection of artificially ripened Mango by Calcium carbide and Ethephon from naturally ripened fruits.

**Methodology**

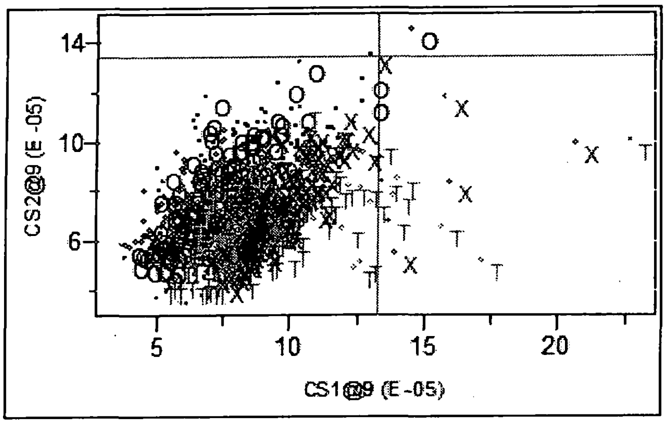
Forty five fruits of moderately grown mangoes from variety Karthakolumban were used in the experiment. The fruits were carefully selected by considering their weight size and shape and kept one day to reduce the transportation stress for uniformity. Total number of 45 fruits were tagged randomly and arranged as five fruits in a single plastic crate 530 × 350 × 300 mm in size. The crates were padded with polyurethane foam lining with 36 mm of thickness to prevent possible mechanical injury to the mango. Each treatment consisting three replicates with five fruits per each replicate. Fifteen mango fruits kept in three crates were treated with Calcium carbide at a rate of 1g/100g fruit weight. Fifteen mango fruits kept in three containers were treated with Ethephon at a rate of 0.5 g/l of distilled water. The fruits in the other three containers were kept as control treatments.

NIR Spectra were taken from all the samples before and after treatments as ten spectra per fruit per day were acquired from the two flat surface orientations of the fruits. The spectra acquisition was continued until the fruits become overripe. The acquired spectra were first evaluated by principal component analysis for removing the possible outliers. The selected spectra were applied in to Soft Independent Modelling of Class Analogy (SIMCA) calibration models for the sample identification. The statistical distance between the treatment and controls were observed over the time to display the discriminating ability.

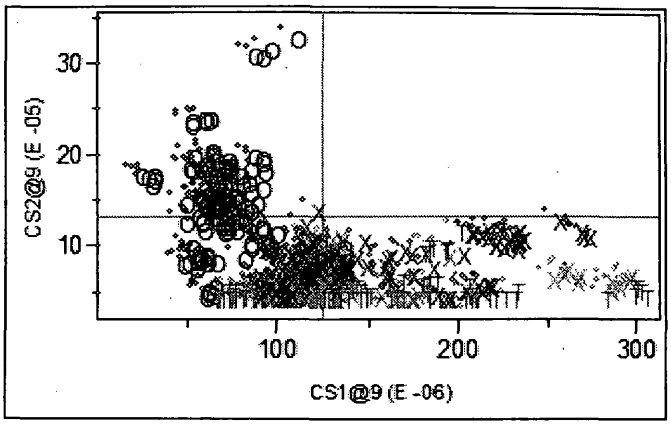
After the spectral data acquisition, the samples were investigated for their Brix and Firmness values. The Brix values were obtained from the Mango juice by using optical refractometer. The fruit firmness values of mango were also taken from the samples by using mechanical penetromater. As this procedure was destructive the Brix & Firmness values of fruits were taken at the end of the experiment. Partial Least Square models (PLS) were developed to predict the Brix and Firmness values at their final stage of ripening.

**Results and Discussion**

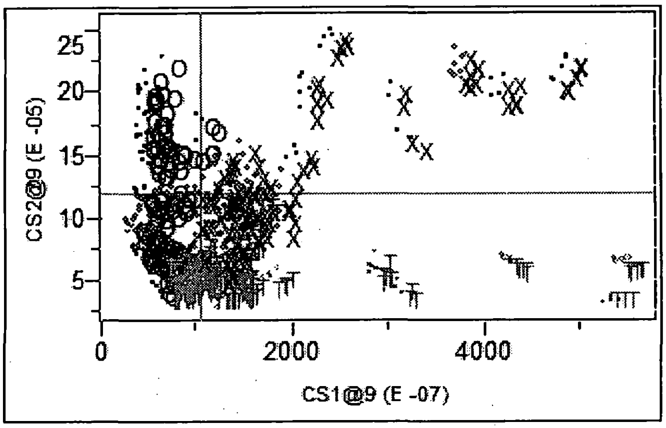
Time series deviation of quality attributes of mango fruits under three different ripening environments are illustrated in Figure 1, in two dimensional principal component space. As shown in the Fig 1a. the statistical distance *i.e* class distance of two treatments to the control were very small. The class distance of control samples (O) to the Ethephon applied samples (T) was 0.27 and to the Calcium carbide applied samples (X) was 0.41. The sample belonging to three groups were observed locating altogether in the same principal component space without clear separation. This indicates that the fruits were having almost similar properties before applying the treatments. After 12 hours, in Fig 1b. the respective statistical distance figures to the control were increased up to 1.4 and 2.3 as Ethephon and Calcium Carbide applied samples, respectively. This indicates that Calcium carbide applied samples were having rapid quality deviation to the control samples when it is compared with the Ethephon applied samples. The results were further consistent as the distances were increased similarly up to 1.9 and 4.9 to the control samples during next 24 hours. After 60 hours, the distance with the Ethephon applied samples were reported declining to 1.6 while Calcium Carbide applied samples were become substantially high as 7.5



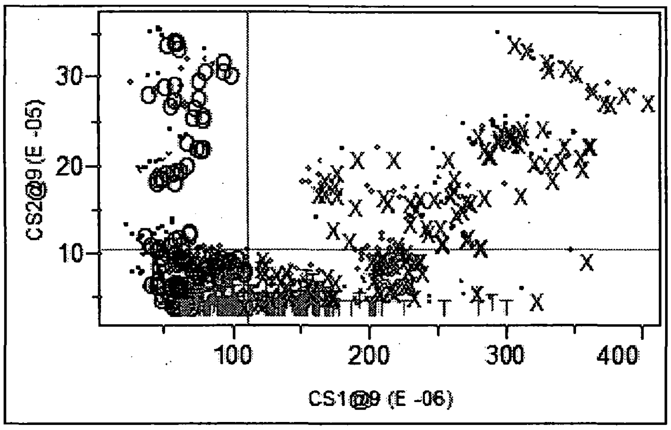

a. before applying the treatments




b. 12 hours after applying the treatments




c. 36 hours after applying the treatments




d. 60 hours after applying the treatments

Table 1, reveals the prediction performance of fruit samples belonging to each category. As it was shown, 53 samples (12+24+18) belonging to three categories were misclassified before applying the treatments. This was however a fairly high rate (over 82%) of correct classification before applying the treatments and seemed to be undesirable as it indicates considerable variation between the mangos between three categories even before applying the treatments. However, this argument has been answered by the small statistical distance reported (0.27) Ethephon treated and (0.41) Calcium Carbide treated before applying the treatments. As a rule of thumb, the class distance should be greater than 3 to consider a sample group as a separate population. The class distances as well as the classification rates were rapidly improved 12 hours after applying the treatments which was accurate as 98.5%, 97.8% and 98.2% in control treatments, $CaC_2$ and Ethephon respectively. PLS regression constructed for Brix and Firmness values were with fairly good correlation coefficients of 0.85 and 0.86, respectively.

**Table 1. SIMCA Prediction performances of fruits at artificial ripening**

| Time | Treatment | Total samples | Correct classification | Error classification | Prediction rate |
|---|---|---|---|---|---|
| Before Treatment | Control | 140 | 128 | 12 | 91.4 |
| | $CaC_2$ | 140 | 116 | 24 | 82.8 |
| | Ethephon | 140 | 122 | 18 | 87.1 |
| 12 hours after treatment | Control | 134 | 132 | 2 | 98.5 |
| | $CaC_2$ | 139 | 136 | 3 | 97.8 |
| | Ethephon | 139 | 138 | 1 | 99.2 |
| 36 hours after treatment | Control | 113 | 109 | 4 | 96.4 |
| | $CaC_2$ | 115 | 111 | 4 | 96.5 |
| | Ethephon | 118 | 114 | 4 | 96.6 |
| 60 hours after treatment | Control | 114 | 110 | 4 | 96.4 |
| | $CaC_2$ | 116 | 108 | 8 | 93.1 |
| | Ethephon | 118 | 116 | 2 | 98.3 |

## Conclusions

The spectral calibration model of Soft Independent Modeling of Class Analogy (SIMCA), classified the artificially ripened mango successfully at the rates of 98.5%, 97.8% & 98.2% as control treatments, $CaC_2$ and Ethephon treated samples, respectively. The deviation of Calcium Carbide treated samples were rapid and substantial at early as 12h compared with the Ethephon treated samples where they accounted maximum 1.90 during the experiment. PLS models constructed for Brix and Firmness values were with fairly good correlation coefficients of 0.85 and 0.86, respectively with their regression. The results revealed that high potential possibility exists with NIR technology to serve as a nondestructive evaluation tool for artificially ripened mango fruits.

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