

Evaluation of Dry Extract System Involving NIR Spectroscopy (DESIR) for Pesticide Residues Detection on Fresh Carabao Mango (*Mangifera indica* L. cv 'Carabao') Fruit

Jula Mae E. Beseos

Agricultural Engineering Department, College of Engineering, Central Mindanao University, Musuan, Bukidnon, Philippines

ABPROD-CEAT, University of the Philippines Los Baños, College, Laguna, Philippines

Email: julamaechalico@yahoo.com

Kevin F. Yaptenco, Elda B. Esguerra, and Engelbert K. Peralta

University of the Philippines Los Baños, College, Laguna, Philippines

Email: kfyaptenco@up.edu.ph, elda_esguerra@yahoo.com and k.peralta@gmail.com

Abstract—Intensive cultivation to meet the growing market demand of mangoes for both domestic and export consumption leads to the presence of possible pesticide residues and other agricultural chemicals on the fruit which may pose health hazards since mangoes are eaten as fresh fruit. The dry-extract system involving near infrared spectroscopy (DESIR) was employed using NIR reflectance spectroscopy for detecting pesticide residues on fresh Carabao mango fruit. Best calibration models were achieved using Partial Least Square Regression analysis. Results of spectra of dry extracts of aqueous solutions were encouraging due to its usability for most applications including research but with caution. Regression models for dry extracts from the recovery of water washes of the sprayed fruit were also inspiring for its model fitness (R^2_{cv} of approximately 0.7-0.81) and RMSECV range of 0.13-1.004 g/L of active ingredient. This result suggested acceptability of NIR as a rapid screening tool for immediate decision making but suspected samples being subjected to the reference GC-MS analysis method.

Index Terms—fresh Carabao mango fruit, near infrared, pesticides, pesticide residues

I. INTRODUCTION

Mango (*Mangifera indica* L.) is regarded as the queen of fruits in tropical areas in the world since it grows best at tropical places. In the Philippines, it is the third most important fruit crop of the country based on export volume and value next to banana and pineapple [1]. Most Carabao mango growers in the Philippines are doing intensive cultivation to meet the growing market demand for both domestic and export consumption to countries like Japan, Hongkong and China.

Better agronomic practices such as usage of improved quality planting material, irrigation and fertilization management, and pest and disease control through the application of pesticides are recommended to increase mango production. Thus, possibility of pesticide residue and other agricultural chemicals being applied to control pests and diseases of mangoes are very alarming as they may pose health hazards since mangoes are consumed and eaten as fresh fruits. Observance of proper pre-harvest interval became a problem due to increasing demand particularly during off-season for both local and for export.

In order to guarantee quality and safety export of mangoes, it is necessary that the pesticide residue levels and other agricultural chemicals should be kept below the maximum residue limit (MRL) prescribed by the Japan's Ministry of Health, Labor and Welfare (MHLW).

The problems of strict regulation added to the burden being faced by mango exporters for its pest and disease management program and low production due to weather disturbance like typhoons regarding MRL for certain pesticides.

There are several conventional methods of detecting pesticides like the gas chromatography (GC) and the high performance liquid chromatography (HPLC); however, such methods are expensive, time-consuming and destructive. The quick, environmental and operator friendly, non-destructive and less sample wastage is very promising which is the near infrared (NIR) spectroscopy. The most outstanding feature of NIR spectroscopy lies in its ability to record spectra for both liquid and solid samples with little or no sample preparation. NIR technology is very much needed when faced with immediate decision making. At present, Billeen [2] had been using near-infrared detection of pesticides used in seed dressing, and achieved good results. This technology, based on absorption of radiation in the near infrared

region of the electromagnetic spectrum (780-2500 nm), has successfully been applied since the later 1980s for the quality control of a high range of agrofood products [3].

Two (2) studies on the use of NIRS to determine pesticide levels were published in 2011. One study describes the development of a Partial Least Square Regression (PLSR) model based on DESIR (dry-extract system for near infrared) technique, using pure (aqueous) pesticide solution [4]. The second study considered determination of pesticide in pure methanol or water solutions, using a 1mm transmittance cell [5].

As Acharya [6] had conducted the dry-extract system (DESIR) technique using reflectance near-infrared spectroscopy in context of detection of contact pesticide residues on fruit. This level of analytical performance would support the use of the technique as a rapid screening tool. The main objective of this study was to evaluate the potential of near-infrared spectroscopy as a non-destructive method to detect selected pesticides with active ingredient cypermethrin, chlorpyrifos and profenopos residue on fresh Carabao mangoes fruit. Specifically, this study aimed to identify significant NIR wavelength related to selected pesticides; develop NIR calibration models for predicting levels of pesticide residues on intact fruit and validate the developed calibration models.

II. MATERIALS AND METHODS

A. Sample Preparation of Pure Aqueous Pesticide Solutions

The procedure used for the analysis of diluted pesticide solutions was adapted from Chen, *et al.* [4]; Acharya, *et al.* [6] and was described below. Three commonly used pesticides with active ingredients of chlorpyrifos, cypermethrin and profenopos were diluted into various concentrations (Table I). Pure solutions of pesticides of various concentrations were diluted using deionized water, however Selecron 500 EC (profenopos active ingredient) was diluted through distilled water due to absence of deionized water. The concentrations prepared were 0, 0.01, 0.03, 0.05, 0.1, 0.5, 1, 2, 5 and 10 times the recommended rate of application per pesticide (Table I). After preparation, the solutions were kept in sealed glass jar and kept in a cool, dry place to prevent chemical degradation and contamination. To further minimize degradation of pesticides, scanning of all freshly prepared dilutions (0 to 10 times the recommended application rate) was conducted twice per day. NIR scanning was conducted for three consecutive days. The data collected on the first and third days were used as the calibration set; data collected on the second day was designated as validation set.

TABLE I. DESCRIPTION OF THREE PESTICIDES USED IN THE STUDY

Commercial Name/Manufacture	Function	Active Ingredient	PHI ^A (Days)	Mode of Action	g/L a.i. ^B	Recommend application rate
Brodan/Planter's Product, Inc	Insecticide	Chlorpyrifos	21	Systemic	210g/L	2.5-3.5tbsp/16L
Bugbuster 5EC /Leads Agri Product, Inc	Insecticide	Cypermethrin	7	Systemic	50g/L	1-3tbsp/16L
Selecron 500 EC/Syngenta Philippines, Inc	Insecticide	Profenopos	7	Systemic	500g/L	1-2tbsp/16L

A. PHI(period of harvest interval);

B. g/L a.i.refers to the concentration of active ingredient;

C. MRL(maximum residue level) from DA-FPA

B. Dry Extract Sample Preparation

A 47 mm diameter glass microfiber filter (GF/A) (Whatman International Ltd., UK, cat. No. 1820 047) placed into a 60 mm diameter glass petri dish for each sample. An aliquot (0.5 mL) solution of pesticides having the various concentrations of 0, 0.01, 0.03, 0.05, 0.1, 0.5, 1, 2, 5 and 10 times the recommended rate of application per pesticide gently delivered using a pipette onto a filter paper just to saturate the filter. The filter then dried in convection oven at 31 °C for 12 hours and stored in a dessicator for a maximum of 12 hours only to avoid water interference. Six replicates per concentration were recorded.

C. Fruit Treatment Preparation

Freshly picked small sized Carabao mango fruit and classified as extra class at the green-mature stage were selected. Weight of individual mangoes were recorded prior to fruit treatment necessary for detection limit calculation. A 10 mL solution of pesticides at different concentrations from 0, 0.01, 0.03, 0.05, 0.1, 0.5, 1, 2, 5

and 10 times the recommended rate of application per pesticide sprayed on the mango fruit inside a separate open zip lock (Zippy) polyethylene (18 cm x 18 cm) bags, and dried for four (4) hours at room temperature 29 °C +/- 2 °C. Mango fruits were rinsed first with thirty (30) mL, then with ten (10mL) of deionized or distilled water depending on the solvent being used for pesticide solution preparation. The two extracts were combined in a beaker. The solution volume was adjusted to 0.5 mL.

D. NIR Scanning

The dry extract samples at various concentrations of pesticides in pure aqueous solutions and samples extracted after fruit treatment were scanned using the NIR reflectance spectroscopy. Samples were scanned to average of 50 times with an integration time of 75ms and boxcar width of 4.

E. Data Analysis

Analysis of data was carried out through ParLes Version 3.1 [7], a chemometric software for multivariate modelling and prediction performing partial least square

regression (PLSR) with leave-one-out cross validation for improving robustness and accuracy of models.

F. Classification

Pre-processed dry-extract spectral data of fresh Carabao fruit subjected to Principal Component Analysis prior to Linear Discriminant Analysis. Principal Component Analysis of SAS (ver 9.4) was first employed for data reduction. Through PCA, the variables are reduced into a smaller number of variables called components which are uncorrelated. Only components with eigenvalues greater than one were retained. After performing PCA, the data were run using the Linear Discriminant Analysis to classify samples into a group using the characteristics of samples. The derived PC's were used to create a discriminant function or equation that best separate the groups. This function was estimated using the calibration data test. After estimation, this function was used to determine the group classification of those in the validation set. This was done to verify the function obtained has discriminating ability. Classification of mango fruits according to the average recommended application rate as the threshold level. Any predicted value above the threshold was designated as belonging to ABOVE while the converse were designated as belonging to BELOW. The % correct classification for each model was calculated.

III. RESULTS AND DISCUSSIONS

A. Near Infrared Spectra Analysis

The original spectrum of the three pure pesticides for reflectance measurements were shown in Fig. 1. Unsuitable spectral noises from 898-1110 nm ranges were eliminated to improve the spectral data attribute for pure pesticides.

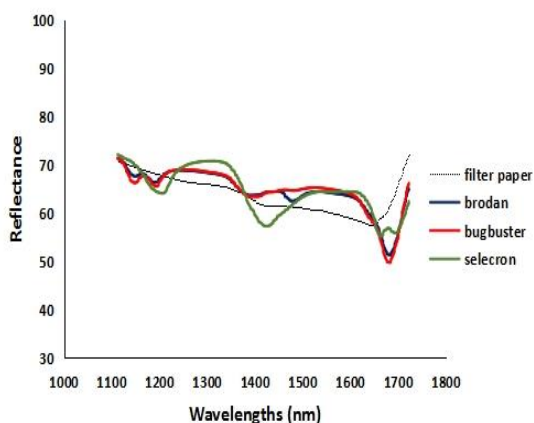
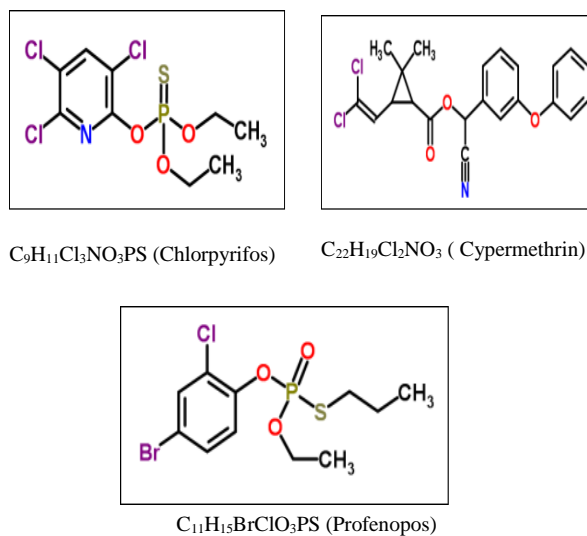


Figure 1. Reflectance MSC corrected spectra of DESIR preparations of 0.5 mL of pure solutions of the three pesticides namely Bugbuster (a.i. cypermethrin), Brodan (a.i. chlorpyrifos) and Seleccion (a.i. profenopos) at 50, 210 and 500 g/L of active ingredient respectively.

Relative to the featureless spectra of the blank glass filter paper, all three pesticide treated glass filter papers showed unique spectra along the wavelength range of 1111 nm- 1724 nm (Fig. 1). Several common peaks had been observed for both Brodan (a.i. chlorpyrifos) and

Bugbuster (a.i. cypermethrin) pesticides which was related to O-H stretching (1410-1500 nm) and C-H stretching (second overtone 1100-1225 nm, combination 1300-1420 nm and first overtone 1650-1800 nm) as identified [8], however Brodan had more and sharper peaks than Bugbuster. Likewise Seleccion (a.i. profenopos) almost had the same peaks with the rest but broader ones.

The spectral features can be ascribed to overtone and combination bands of various C-H and O-H bonds within these molecules. Chlorpyrifos had 1 C-H, 1P=S, 2 CH₂ and 2 CH₃ bonds, cypermethrin has 1C=O, 1C≡N, 13 C-H and 1 CH₃ bonds, and profenopos had 1P=S, 2 C-H, 3 CH₂ and 2 CH₃ bonds (Fig. 2).



Source: (<https://pubchem.ncbi.nlm.nih.gov/compound/2730>)

Figure 2. Chemical structure of chlorpyrifos, cypermethrin and profenopos

The extinction coefficient of these chemicals were the parameters in defining how strongly a substance absorbs light at a given wavelength regardless of its concentration and would decrease in relation to absorption per unit concentration in the order presented (cypermethrin > chlorpyrifos = profenopos). Absorption around 1400-1500 nm was consistent with a strong O-H feature 1st overtone [6] with major absorbance peak at 1450 nm [5]

B. Significant Wavelengths Pertaining to Chlorpyrifos, Cypermethrin and Profenopos

Average spectrum of the solvent was subtracted from the average spectrum of the various dilutions of Brodan (chlorpyrifos a.i.), Bugbuster (cypermethrin a.i.) and Seleccion (profenopos a.i.). For the dry extract samples (Fig. 3), the wavelength regions that were most affected by the addition of each pesticide was observed on 1142-1143nm attributed for C-H aromatic, 1195nm and 1360nm for C-H methyl (CH₃), 1225 nm for C-H secondary or tertiary carbon and 1400-1500 nm to O-H stretching.

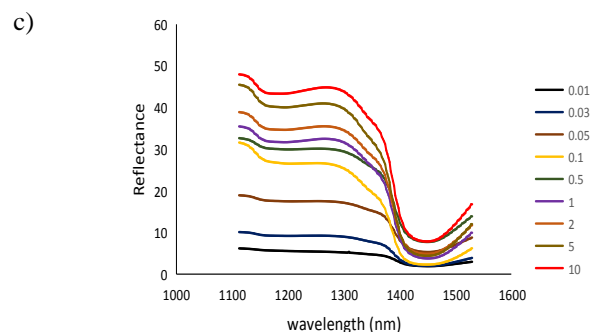
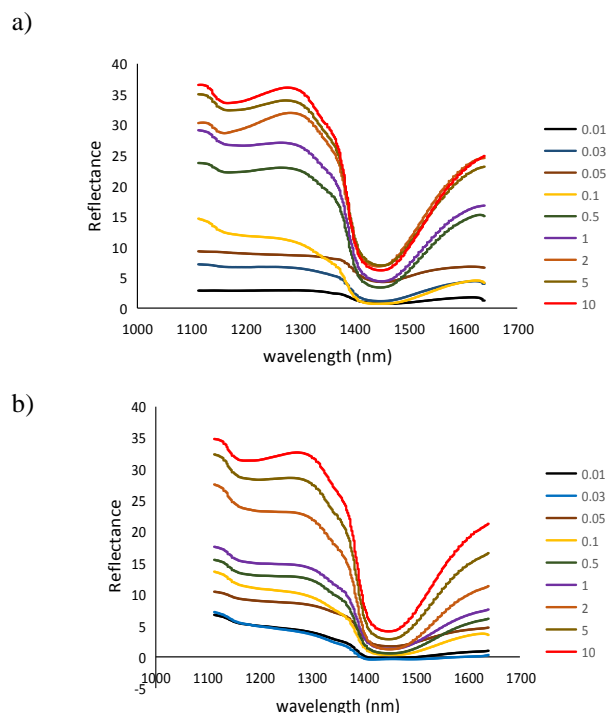


Figure 3. DESIR mean spectra of the various concentrations subtracted by the average spectrum of the solvent a) chlorpyrifos; b) cypermethrin and c) profenopos

C. Prediction of the DESIR in Aqueous Solutions of the Different Concentrations of Chlorpyrifos, Cypermethrin and Profenopos

The dry extract system on glass fibre filter paper for the three pesticides having different concentrations were detected using near infrared spectroscopy (Table II). Values of R^2 for all models for the three pesticides can be used with caution in most applications, including research. Its RPD value are applicable for very rough screening.

TABLE II. PARTIAL LEAST SQUARE (PLS) REGRESSION MODELS BASED ON REFLECTANCE SPECTRA OF DESIR SAMPLES OF DIFFERENT CONCENTRATIONS OF ALL THREE PESTICIDES AT 1112-1640 NM (CHLORPYRIFOS AND CYPERMETHRIN) AND 1112-1530 NM (PROFENOPOS)

PESTICIDE	PRE-PROCESSING TECHNIQUES	NO. OF FACTORS	CALIBRATION (LEAVE-ONE-OUT)			PREDICTION		
			R^2	RMSE	RPD	R^2	RMSE	RPD
Chlorpyrifos	Raw MC	15	0.859	0.545	2.64	0.868	0.535	2.72
	MSC MC	15	0.859	0.543	2.65	0.858	0.599	2.43
	SNV MC	15	0.853	0.554	2.59	0.876	0.553	2.63
Cypermethrin	Raw MC	6	0.836	0.118	2.49	0.801	0.142	2.09
	MSC MC	4	0.845	0.114	2.57	0.821	0.14	2.12
	SNV MC	4	0.848	0.113	2.59	0.823	0.143	2.08
Profenopos	Raw MC	12	0.884	0.664	2.94	0.848	0.985	2.01
	MSC MC	11	0.89	0.647	3.02	0.858	1.156	1.71
	SNV MC	11	0.886	0.66	2.96	0.856	1.085	1.82

D. Prediction of the DESIR of the Different Concentrations of Chlorpyrifos, Cypermethrin and Profenopos from Fresh Carabao Mango Fruit

Individual fresh carabao mango fruit was sprayed with a ten (10) mL known volume of a known concentration per pesticide inside an open ziplock polyethylene bag. Therefore, all its corresponding active ingredient were contained inside the bag. After spraying, it was then dried and recovered using the solvent being used for dilution for the pesticides. Water was being used as wash solution

instead of acetone because acetone wash carried a range of other chemicals like dissolved cuticular wax that varied in quantity and composition as it was discolored due to the extraction of some of its pigments [9]. Acharya [6] conducted a study and showed comparable results to the pure aqueous solutions using water rather than acetone as the wash solvent. All derived calibration models in Table III showed suitability for screening and other approximate calibrations.

TABLE III. PARTIAL LEAST SQUARE (PLS) REGRESSION MODELS BASED ON REFLECTANCE SPECTRA OF DESIR SAMPLES OF DIFFERENT CONCENTRATIONS OF THE THREE PESTICIDES FROM FRESH CARABAO MANGO FRUIT

PESTICIDE	PRE-PROCESSING TECHNIQUES	NO. OF FACTORS	CALIBRATION (LEAVE-ONE-OUT)			PREDICTION		
			R ²	RMSE	RPD	R ²	RMSE	RPD
Chlorpyrifos	Raw MC	15	0.796	0.644	2.23	0.704	0.836	1.74
	MSC MC	15	0.802	0.639	2.25	0.705	0.875	1.66
	SNV MC	15	0.767	0.708	2.03	0.695	0.872	1.67
Cypermethrin	Raw MC	15	0.772	0.141	2.09	0.798	0.205	1.45
	Raw SG 1st Der-MC	14	0.705	0.16	1.84	0.888	0.184	1.61
	Raw WF-MC	15	0.806	0.13	2.26	0.764	0.215	1.38
Profenopos	Raw MC	15	0.73	1.014	1.93	0.72	1.063	1.86
	Raw MF-MC	14	0.734	1	1.96	0.7	1.065	1.86
	Raw SG-MC	15	0.736	1.004	1.95	0.745	1.004	1.97

E. Prediction of DESIR from Fresh Carabao Mango Fruit with that of DESIR in Pure Aqueous Solution

It was necessary to predict the recovered pesticides from the fresh mango fruit using water as the wash solvent if the results were comparable to that in its pure aqueous solutions. Three replicates (one replicate each for every fresh stock done for three consecutive days) of different concentrations of pure aqueous solution per pesticide were used as calibrations set. However, only two replicates were used as independent set (validation set) after it was sprayed to mango fruit then recovered by

water wash. Spectral outliers that were identified and discarded were considered of little interest. These outliers where most calibration methods are highly sensitive [10] and [11] as displayed by the assessment statistics.

In Table IV, $R^2 > 0.5$ which predicted the model well for two pesticides namely chlorpyrifos and cypermethrin, however, recovery of the different concentrations of profenopos on the sprayed fresh Carabao mango fruit was incomparable to its corresponding pure aqueous solutions.

TABLE IV. CALIBRATION AND PREDICTION RESULTS FOR PLSR MODELS BASED ON REFLECTANCE SPECTRA OF DESIR SAMPLES OF DIFFERENT CONCENTRATIONS OF THE THREE PESTICIDES AND OF THEIR WASH FROM SPRAYED CARABAO MANGO FRUIT, RESPECTIVELY

PESTICIDE	PRE-PROCESSING TECHNIQUES	NO. OF FACTORS	CALIBRATION (LEAVE-ONE-OUT)			PREDICTION		
			R ²	RMSE	RPD	R ²	RMSE	RPD
Chlorpyrifos	Raw	5	0.675	0.811	1.78	0.725	0.953	1.53
	MSC	4	0.721	0.749	1.93	0.756	0.815	1.79
	SNV	4	0.721	0.749	1.93	0.756	0.849	1.71
Cypermethrin	Raw	4	0.742	0.147	2	0.813	0.225	1.32
	MSC	3	0.777	0.137	2.15	0.778	0.228	1.3
	SNV	3	0.777	0.137	2.15	0.778	0.227	1.31
Profenopos	Raw MC	16	0.723	1.037	1.89	0.619	1.381	1.43
	Raw MF-MC	15	0.665	1.171	1.68	0.52	1.431	1.38
	Raw SG-MC	15	0.705	1.076	1.82	0.596	1.339	1.48

F. Classification Result

Principal Component Analysis, a well known method for clustering and data compression [12] was first applied to pre-processed DESIR spectral data of the fruit for wavelength ranges of 1112-1640 nm for chlorpyrifos and cypermethrin, 1112-1530 nm for profenopos before subjecting to Linear Discriminant Analysis. Principal components (PC's) were retained according to the minimum eigenvalue criterion with eigenvalues greater than one. Eigenvector values showed a similar grouping of water for wavelength range 1400-1460 nm.

Chlorpyrifos' DESIR spectral data from the fruit, pre-processed using Multiple Scatter Correction and Mean Centered retained only four Principal Components. Eigenvalue for Principal Components 1, 2, 3 and 4 were 210.628, 48.37, 4.22 and 1.52, respectively. It was 92.5% and 60% correctly classified for the calibration set and validation set, respectively. Less successful classification observed for its validation set. On the other hand, DESIR spectral data of cypermethrin pre-processed by Wavelet Filter and Mean Centered resulted to 75% and 60% correct classification for its calibration and validation set. Moreover, 4 principal components were identified with

eigenvalues of 135.38, 72.86, 48.43 and 6.89. Results for profenopos' DESIR spectral data showed 85% for both calibration and validation sets correctly classified. It was pre-processed using Savitzky-Golay and then Mean Centered. Two principal components were retained with eigenvalues of 198.017 and 11.86. (Table V)

TABLE V. CLASSIFICATION SUMMARY

PESTICIDE	PRE-TREATMENT	%CORRECT CLASSIFICATION IN THE CALIBRATION SET	%CORRECT CLASSIFICATION IN THE VALIDATION SET
Chlorpyrifos	MSC-MC	92.5	60
Cypermethrin	WF-MC	75	60
Profenopos	SG-MC	85	85

G. Detection Limit

A detection limit similar to the study conducted by Saranwong [9] and Acharya [6] showed results in Table VI for the three different concentrations of profenopos sprayed on the fruit. A detection limit for the lowest concentration for profenopos was 0.0005% active ingredient in a 0.5 mL sample was equivalent to 0.0025 mg of active ingredient. If this amount of product was washed from the 201.59 grams fresh Carabao mango fruit, it would yield an analytical equivalence of detection of 0.0124 ppm (w/fw). The MRL for profenopos in Table I was 0.05 ppm.

TABLE VI. DETECTION LIMIT OF DRY EXTRACT IN GLASS FILTER PAPER OF RECOVERED WASH FROM SPRAYED PROFENOPOS PESTICIDE ON FRESH CARABAO MANGO FRUIT

WEIGHT OF FRUIT SAMPLE (grams)	CONCENTRATIONS	CONCENTRATION OF ACTIVE INGREDIENT (mg/kg)	RESULT (mg/kg of fresh fruit)
201.59	0.01 times the recommended application rate	5	0.0124
201.25	0.5 times the recommended application rate	315	0.783
202.85	10 times the recommended application rate	6250	15.41

H. Confirmation Procedure Result

Due to budget constraint only three samples sprayed with active ingredient profenopos (at least one kilogram of fruit peel for every sample) were subjected for analysis. The peel of the fruit was removed, frozen and submitted to Bureau of Plant Industry-National Pesticide Analytical Laboratory for residue analysis including organochlorines, pyrethroids and organophosphates, however only the residue with active ingredient profenopos was detected.

Results with different known (low, medium and high) concentrations were shown in Table VII. Sample with the lowest concentration's MRL was 0.033 mg/kg and 0.774 mg/kg for the highest concentration. The results were

obtained using the gas liquid chromatography. The BPI-NPAL analysis for pesticides residues possessed the limit of quantification up to 0.01 mg/kg.

TABLE VII. RESULTS OF SUBMITTED SAMPLES SPRAYED WITH PROFENOPOS FROM BPI-NATIONAL PESTICIDE ANALYTICAL LABORATORY*

NO. OF SAMPLE	CONCENTRATIONS	CONCENTRATION OF ACTIVE INGREDIENT (mg/kg)	RESULT (mg/kg of fresh fruit)
1	0.01 times the recommended application rate	5	0.033
1	0.5 times the recommended application rate	315	0.115
1	10 times the recommended application rate	6250	0.774

*based from issued Certificate of Analysis of BPI-NPAL

IV. CONCLUSION

The calibration results are consistent with previous study of Acharya [6] and Gowen [5] on the sensitivity of NIRS in detecting pesticides and pesticides residues. Detection of pesticide residues using the dry extract sample preparation which supported the use of water as the solvent in washing the Carabao mango fruit for detecting pesticides with active ingredients chlorpyrifos, cypermethrin and profenopos. This level of analytical performance may replace the gas chromatography as the analytical method of choice based on detection limit but further tests and extensive analysis must be done to validate the results. Furthermore, NIR technology is very much applicable for rapid, low cost and immediate decision making with only suspected samples subjected to GC analysis.

ACKNOWLEDGEMENT

The main author recognized the financial assistance provided by the DOST-ERDT scholarship program spearheaded by Dr. Arnold R. Elepaño, Dean of Engineering and Agro-Industrial Technology and the DOST-ERDT Project Leader of University of Philippines, Los Baños, Laguna. She also acknowledges the privilege being given by her sending institution Central Mindanao University for letting her pursue her graduate studies under the CMU's Faculty Development Program.

REFERENCES

- [1] DA. (2013). Department of Agriculture High Value Crops Development Program (RA 7900). [Online]. Available: <http://hvcdp.da.gov.ph/mango.htm>
- [2] P. Billeen, "Testing seeds protected with an insecticide by NIR," in *Proc. 9th International Conference*, 2000, pp. 625-628.
- [3] P. C. Williams and K. H. Norris, *Near Infrared Technology in the Agricultural and Food Industries*, St Paul, MN, USA: American Association of Cereal Chemists, Inc., 1987.
- [4] J. Chen, Y. Peng, Y. Li, W. Wang, and J. Wu, "A method for determining organophosphate pesticide concentration based on

near infra-red spectroscopy,” *Transactions of the ASABE*, vol. 54, pp. 1025-1030, 2011.

- [5] A. Gowen, *et al.*, “Investigation of the potential of near infrared spectroscopy for the detection and quantification of pesticides in aqueous solution,” *American Journal of Analytical Chemistry*, vol. 2, pp. 573-576, 2011.
- [6] U. K. Acharya, P. P. Subedi, and K. B. Walsh, “Evaluation of a Dry Extract System Involving NIR Spectroscopy (DESIR) for rapid assessment of pesticide contamination of fruit surfaces,” *American Journal of Analytical Chemistry*, vol. 3, pp. 524-533, 2012.
- [7] R. A. Viscarra-Rossel, “ParLeS: Software for chemometric analysis of spectroscopic data,” *Chemometrics and Intelligent Laboratory Systems*, vol. 90, pp. 72-83, 2008.
- [8] P. Williams, “Near infrared technology- Getting the best out of light,” A Short Course in the Practical Implementation of Near-infrared Spectroscopy for the User, 2005
- [9] S. Saranwong and S. Kawano, “Rapid determination of fungicide contaminated on tomato surfaces using DESIR-NIR: A system for ppm-order concentration,” *Journal of Near Infrared Spectroscopy*, vol. 13, no. 3, pp. 169-175, 2005.
- [10] M. Hubert and S. D. Veeken, “Outlier detection for skewed data,” *Journal of Chemometrics*, 2008.
- [11] I. V. Kovalenko, G. R. Rippe, and C. R. Hurburgh, “Determination of amino acid composition of soybeans (gram lysine max) by near-infrared spectroscopy,” *J. Agric. Food Chem.*, vol. 54, pp. 3485-3491, 2006.
- [12] L. A. Esteve, “Single seed discriminative applications using near infrared technologies,” PhD Dissertation, Iowa State University, 2011.



Jula Mae E. Beseos was born in Bukidnon, Philippines in 1983. She was a grantee of Central Mindanao University Faculty Development Program and also a grantee of the Department of Science and Technology-Engineering Research and Development Technology scholarship. She was a master student of the University of the Philippines Los Baños from 2014-2016.



Kevin F. Yaptenco is a professor of the Institute of Agricultural Engineering at the University of the Philippines Los Baños. He earned his PhD degree in 2000 from Tokyo University of Agriculture, Japan and his master's degree in Agricultural Engineering from University of Illinois at Urbana, USA in 1993. His research interests are the following (1) handling, packaging, transport, and storage of fresh fruits and vegetables (2) drying and processing of agricultural/biological materials and (3) near-infrared spectroscopy for non-destructive testing of food/agricultural materials



Elda B. Esguerra is a professor of the College of Agriculture at the University of the Philippines Los Baños. She received her PhD degree in Post-harvest Horticulture from Kagawa University, Japan in 1993 and her MS degree in Horticulture-Postharvest Physiology from University of the Philippines in 1982. Her research interests are on post-harvest technologies for fruits and vegetables.



Engelbert K. Peralta is a professor of the Institute of Agricultural Engineering at the University of the Philippines Los Baños. He got his PhD degree in Agricultural Engineering from Texas A & M University, USA in 1990 and his Master's degree of Engineering in 1981 from Asian Institute of Technology, Thailand. His research interests are on biosystems engineering and nanotechnology applications in engineering.