An Open Library Development for Pesticide Residue Analytics in Vegetables

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บทคัดย่อ—งานวิจัยฉบับนี้มีวัตถุประสงค์เพื่อพัฒนาไลบรารี่เพื่อการเรียกใช้ฟังก์ชั่นสำหรับวิเคราะห์และแสดงจินตทัศน์ของสารพิษที่ปนเปื้อนในผัก จากการทบทวนวรรณกรรม พบว่า สารเคมีจำพวก Chlorinated-hydrocarbons (CHCs) ซึ่งเป็นส่วนประกอบด้านเคมีที่ใช้สำหรับจำกัดศัตรูพืช โดยทั่วไปของการทดสอบปริมาณสารตกค้างนั้น ผู้ทดสอบจะนำสวนผักมาทำการแยกการสะท้อนคลื่นสเปกตรัมด้วยใช้อินฟราเรดสเปกโตรสโกปี (Infrared Spectroscopy) ซึ่งจะให้สเปกโตรสโกปีที่เป็นเส้นกราฟที่บอกหมายเลขคลื่นของสารเคมีและต้องแปลงหมายเลขคลื่นให้เป็นความยาวคลื่นเพื่อใช้แยกสีตามแบบจำลองสีอาร์จีบี (Red-Green-Blue: RGB) เนื่องจากความยาวคลื่นที่ได้มีความยาวคลื่นเกินกว่าสายมนุษย์มองเห็น จึงจำเป็นต้องแปลงค่าของคลื่นสเปกตรัมทั้งหมดอยู่ในรูปช่วงคลื่นที่มองเห็นได้ ซึ่งมีค่าระหว่าง 380 –780 nm โดยที่ค่าของคลื่นที่มองเห็นได้เหล่านี้จะอยู่ในรูปแบบจำลองสีอาร์จีบี หลังจากนั้นสีอาร์จีบีก็จะถูกแปลงเป็นแบบจำลองสีเอชเอสไอ (Hue-Saturation-Intensity: HSI) สำหรับใช้วิเคราะห์ส่วนประกอบของสีโดยใช้ฮีสโตแกรม (Histogram) เพื่อให้รู้ถึงว่าสารเคมีที่แยกออกมาเป็นสีสเปกตรัมโดยใช้หลักการของการแสดงจินตทัศน์ของสีสเปกตรัมย่อย ๆ ซึ่งการแสดงจินตทัศน์นี้เองจะช่วยให้นักพัฒนาโปรแกรมสามารถเรียกใช้ส่วนโมดูลของไลบรารี่นี้เพื่อช่วยให้เกษตรกรท้องถิ่นสามารถมองเห็นภาพและผลกระทบที่เกิดขึ้นได้อย่างชัดเจนมากยิ่งขึ้น โดยการประเมินคุณภาพของไลบราลีที่พัฒนาขึ้นนั้น จะถูกทวนสอบโดยผู้เชี่ยวชาญ 2 ท่าน ซึ่งมีผลค่าฉลี่ยรวมเท่ากับ 4.0 ในระดับดี ในส่วนของชุดข้อมูลที่ใช้ทำการทดสอบโปรแกรมตรวจสอบสารพิษที่พัฒนาขึ้นมาโดยเก็บตัวอย่าง ผักบุ้ง คะน้า กะหล่ำปลี และถั่วฝักยาว ที่มีความสดของผักไม่เกิน 5 ชั่วโมงมาจากตลาดเพื่อทำการทดสอบสารพิษตกค้าง ผลการทดสอบที่ได้นั้น พบว่า มีสารพิษตกค้างในตัวอย่างผักที่เก็บมาทดสอบอยู่จริง

คำสำคัญ: การวิเคราะห์สารพิษตกค้างในพืช, แบบจำลองสี, การพัฒนาไลบรารี่ของภาษาคอมพิวเตอร์

Abstract—This paper develops a non-volatile library to visually analyze the residual pesticide in vegetables. From the literature, we found that some chemical compounds that consist of Chlorinated-hydrocarbons (CHCs). The CHCs always use to destroy those pests and insects. By the way, the residual pesticide verification is done by spectrum classification using infrared spectroscopy which shows the line-graph of chemical compounds. However, some spectral wavelengths are not visible that must be reformed into visible wavelength as 380-780 nm, in term of Red-Green-Blue (RGB) model. And the RGB is also converted to Hue-Saturation-Intensity (HSI) to count and visualize the histogram of chemical-color frequencies, especially for developers to use this library to obviously visualize the negative effects to local agriculturists. The residual pesticide library was validated by 2 senior-experts that were averagely 4.0 in the level of goodness. For researching materials, we used the fresh vegetables from some markets like Morning-glories, Chinese-kales, Cabbages and Cow-peas that the buying times from some markets were not more than 5 hours. From the results, some pesticide was obviously residual in these vegetables. ***(Abstract)***

Keywords- Pesticide Residue Analytics; Image Color Models; Library Development (key words)

I. INTRODUCTION

Thailand is one of the best cultivated lands in the world [1] that exports successfully many agricultural commodities [2] such as rice, corns, cassavas and orchids. Thailand is segmented into 5 regions [3]: North, Central, North-east, East and South that are totally different geo-graphical terrains and climates. Some plants are appropriately cultivated in cool weather on the elevated lands like North and North-east. Many plants need lots of water that must grow in alluvial plains like Central. Other ones are well-grown in the rain areas in East and South. Apart from tourism [4], the agribusiness is one of the major economic factors in Thailand [5].

Since the vegetables and fruits are commonly high consumption and demand [6] within domestic country. Moreover, these agricultural commodities are really expensive in dry season. Many agriculturists use pesticides and fertilizers to increase the agricultural products and prevent the insects.

Even if many anti-chemical/organic agricultural campaigns are available but some organic products are not real secured from the chemical substances. These residues totally affect to food/sweetmeat [7-8] ingredients. Most agriculturists lack of knowledge to use those chemical compounds [9]. Too much or ill-timed chemical usage easily makes some residual pesticides within the agricultural products. If a consumer has some chemical compounds (especially, the pesticides) every day, he/she will gradually amass these poisons. When a human gets too many pesticides, some cells will finally transform themselves into the worst-case forms [10] like cancers/tumors within a human's body.

This paper developed an open library to analyze and visualize the residual pesticide in vegetables. Firstly, some fresh vegetables: Morning-glories, Chinese-kales, Cabbages and Cow-peas were randomly selected that were not more than 5 hours from some blinded name markets as Market A, Market B and Market C, respectively. Then, a vegetable was input to infrared spectroscopy to classify the spectral wavelengths. After that, these spectrums were reformed into the visible wavelengths as 380-780 nm [11-12], in term of Red-Green-Blue (RGB) model [13]. Finally, the RGB model [14] was converted into to Hue-Saturation-Intensity (HSI) [15-16]. Importantly, the open residual pesticide library could easily visualize the histogram of chemical-color frequencies [17] for developers to use this library to obviously visualize the negative effects to local agriculturists. All things considered, the agriculturists see the right direction to measure/improve their long-term agricultural commodities according to the international standards.

The organization of this paper can be classified into "Visible Wavelength Reform" in part II and "RGB Formulation" in part III. Part IV and V describe "HSI Formulation and Histograms" and "Discussion and Results". And the conclusion is in part VI.

II. Visible Wavelength Reform

Some fresh vegetables were collected from some well-known markets like Morning-glories, Chinese-kales, Cabbages and Cow-peas, as shown in Figure 1.

These vegetables were checked the pesticide residue by spectrum classification using an infrared spectroscopy that could show the absorbance of chemical compounds in form of line-graph like Mono-chlorobenzene (MCB), Ortho-dichlorobenzene (o-DCB), M-Dichlorobenzene (m-DCB), Tri-chloroethylene (TCE), Perchloroethylene (PCE) and Chloroform (CF), respectively. These chemical compounds are also called Chlorinated-hydrocarbons (CHCs) and always found in many pesticides, as shown in Figure 2.

(a.) Morning-glories

(b.) Chinese-kales

(c.) Cabbages

(d.) Cow-peas

Figure 1. Some fresh vegetables.

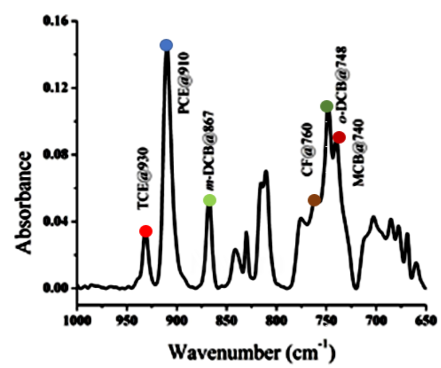

Figure 2. The line-graph of CHC(s) absorbance [18].

Notwithstanding, the signals from an infrared spectroscopy could not be seen by human's eyes. The visible length reform should be done according to these wavelength conditions.

If the chemical compounds were m-DCB, TCE or CF, the equation (1) was used to compute the visible wavelength reform.

$$W_{ref} = W_{abs} \pmod{\max(W_{vis})} \quad (1)$$

If it was MCB, o-DCB or PCE, the visible wavelength reform was done by (2).

$$W_{ref} = \left(W_{abs} \left(\bmod\ \max(W_{vis})\right)\right) + \left|\max(W_{vis}) - \min(W_{vis})\right| \quad (2)$$

where W_{abs} is a raw absorbance wavelength from infrared spectroscopy, W_{vis} is any visible wavelength, between 380-780 nm, $\min(W_{vis})$ is the minimum of visible wavelength as 380 nm, $\max(W_{vis})$ is the maximum of visible wavelength as 780 nm, and W_{ref} is the visible wavelength reform.

III. RGB FORMULATION

The previous part explains to reform the spectral reflectance into visible wavelength. In this part, all visible wavelengths are formulated in form of Red-Green-Blue (RGB) color model.

The red dimension (R) was formulated according to the visible wavelength, by (3).

$$R = \begin{cases} 0.6 - 0.41\left(\dfrac{(410 - W_{ref})}{30}\right) & \text{If } 380 \le W_{ref} < 410 \\ 0.19 - 0.19\left(\dfrac{440 - W_{ref}}{30}\right) & \text{If } 410 \le W_{ref} < 440 \\ 0 & \text{If } 440 \le W_{ref} < 510 \\ 1 - \left(\dfrac{580 - W_{ref}}{70}\right) & \text{If } 510 \le W_{ref} < 580 \\ 1 & \text{If } 580 \le W_{ref} < 700 \\ 0.3 - 0.65\left(\dfrac{780 - W_{ref}}{80}\right) & \text{If } 700 \le W_{ref} \le 780 \end{cases} \quad (3)$$

The green (G) dimensional view was computed as the condition in (4).

$$G = \begin{cases} 0 & \text{If } 380 \le W_{ref} < 440 \\ 1 - \left(\dfrac{490 - W_{ref}}{50}\right) & \text{If } 440 \le W_{ref} < 490 \\ 1 & \text{If } 490 \le W_{ref} < 580 \\ \left(\dfrac{640 - W_{ref}}{60}\right) & \text{If } 580 \le W_{ref} < 640 \\ 0 & \text{If } 640 \le W_{ref} \le 780 \end{cases} \quad (4)$$

And the equation (5) was used to formulate the blue (B) dimension.

$$B = \begin{cases} 0.39 - 0.6\left(\dfrac{410 - W_{ref}}{30}\right) & \text{If } 380 \le W_{ref} < 410 \\ 1 & \text{If } 410 \le W_{ref} < 490 \\ \left(\dfrac{510 - W_{ref}}{20}\right) & \text{If } 490 \le W_{ref} < 510 \\ 0 & \text{If } 510 \le W_{ref} \le 780 \end{cases} \quad (5)$$

The possible values in Red, Green or Blue dimensions were between 0-1 but they could be 0-255 (256 possible values) by multiplied by the number 255 that can synthesize the 256^3 = 16,777,216 different colors.

All Chlorinated-hydrocarbons (CHCs): Mono-chlorobenzene (MCB), Ortho-dichlorobenzene (o-DCB), M-Dichlorobenzene (m-DCB), Tri-chloroethylene (TCE), Perchloroethylene (PCE) and Chloroform (CF) can be mixed by RGB model into different colors as shown in Figure 3.

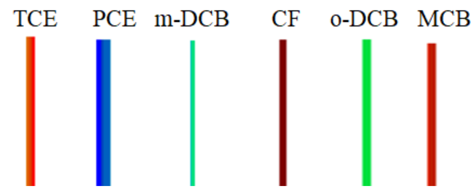

Figure 3. RGB Classification of CHCs.

IV. HSI FORMULATION AND HISTOGRAMS

The RGB format of all pixels from the previous part was converted into Hue-Saturation-Intensity (HSI) model and visualized the histogram of all Chlorinated-hydrocarbons (CHCs).

A. *RGB-to-HSI Conversion*

The HSI model consists of Hue (H as (6)), Saturation (S as (7)) and Intensity (I as (8)) that were really clear to classify the CHCs and visualize the different Chemical compounds in vegetables.

$$H = \cos^{-1}\left(\frac{(R-G)+(R-B)}{\sqrt{(R-G)^2 + ((R-B)(G-B))}}\right) \quad (6)$$

$$S = (1 - \min(R,G,B)) \times \left(\frac{3}{(R+G+B)}\right) \quad (7)$$

$$I = \left(\frac{R+G+B}{3}\right) \quad (8)$$

where R, G and B are red green and blue dimensions that have their values between 0-255. The $\min(R,G,B)$ is a selection of the lowest values from the R, G or B dimension.

B. *Histogram Visualization*

The HSI was finally visualized in form of histogram to show the chemical classification of all CHCs that can be computed by (9) and (10).

$$h_{ci} = \frac{n(h_{ci} \mid pixels)}{n(pixels)} \quad (9)$$

$$His = \{h_{c1}, h_{c2}, h_{c3}, h_{c4}, \ldots, h_{cn}\} \quad (10)$$

TABLE I. OVERALL VISIBLE WAVELENGTH REFORM AND COLOR MODELS

Chlorinated-hydrocarbons (CHCs)	***Wavelength (W_{abs}) (nm)***	***Visible Wavelength Reform (W_{ref}) (nm)***	***RGB Model***			***HSI Model***		
			Red (R)	***Green (G)***	***Blue (B)***	***Hue (H)***	***Saturation (S)***	***Intensity (I)***
Tri-chloroethylene (TCE)	10,753	613	255	173	0	42	1	0.559
Perchloroethylene (PCE)	10,989	469	0	148	255	205	1	0.527
M-Dichlorobenzene (m-DCB)	11,416	496	0	255	179	163	1	0.567
Chloroform (CF)	13,158	678	255	0	0	0	1	0.333
Ortho-dichlorobenzene (o-DCB)	13,369	509	0	255	13	123	1	0.350
Mono-chlorobenzene (MCB)	13,514	654	255	0	0	0	1	0.333

where h_{ci} is a histogram that the h_{c1} is at minimum as violet and the h_{cn} is at maximum as red. The $n(pixels)$ is a number of all pixels within an image. The $n(h_{ci} \mid pixels)$ is a number of h_{ci} within an image. And the His is the set of all histograms.

V. DISCUSSION AND RESULTS

The results of all Chlorinated-hydrocarbons (CHCs) like Mono-chlorobenzene (MCB), Ortho-dichlorobenzene (o-DCB), M-Dichlorobenzene (m-DCB), Tri-chloroethylene (TCE), Perchloroethylene (PCE) and Chloroform (CF) could be shown in Table I in terms of “Visible Wavelength Reform”, “RGB Formulation” and “HSI Formulation”, respectively.

And all vegetables like Morning-glories, Chinese-kales, Cabbages and Cow-peas were tested with the proposed library in different periods like a day, 5-days and 7-days to verify some pesticide residue and the results in Table II.

TABLE II. VEGETABLES IN DIFFERENT PERIODS

Period (Day(s))	***Morning-glories***	***Chinese-kales***	***Cabbages***	***Cow-peas***
1	Some pesticide residue	Some pesticide residue	Some pesticide residue	Some pesticide residue
5	Some pesticide residue	Some pesticide residue	Some pesticide residue	Some pesticide residue
7	No pesticide residue	No pesticide residue	Some pesticide residue	No pesticide residue

Notice that the cabbages still had some pesticide residue, even case of 7-days. Because the physical characteristic of cabbages are wrapped that make some residual pesticides are available.

Moreover, some random markets like Market A, Market B and Market C have different pesticide residue for those agricultural commodities as shown in Table III. And we found that the cabbages have some pesticide in all markets. The most secured vegetable markets were Market A and Market C.

TABLE III. VEGETABLES FROM DIFFERENT MARKETS

Market	***Morning-glories***	***Chinese-kales***	***Cabbages***	***Cow-peas***
Market A	No pesticide residue	No pesticide residue	Some pesticide residue	No pesticide residue
Market B	Some pesticide residue	Some pesticide residue	Some pesticide residue	Some pesticide residue
Market C	No pesticide residue	Some pesticide residue	Some pesticide residue	No pesticide residue

VI. CONCLUSION

This paper used some vegetables like Morning-glories, Chinese-kales, Cabbages and Cow-peas to develop an open library for analyzing and visualizing pesticide residue in vegetables. All vegetables were collected from Market A, Market B and Market C that were tested in the Infrared Spectroscopy within 5 hours. The wavelength absorbance from Infrared Spectroscopy could not be seen by human’s eyes that it was reformed into visible wavelength in part II. In part III, the visible wavelength was formulated into Red-Green-Blue (RGB) model. And the RGB was converted into Hue-Saturation-Intensity (HSI) model and visualized in form of histograms in part IV. All quantitative results were shown in part V. This proposed non-volatile library can be used by programmers/developers to automatically detect the pesticide via some sensors.

ACKNOWLEDGMENT

The research fund was support by Computer Science Department, Faculty of Science, Chandrakasem Rajabhat University. that make this library to be possible and successful.

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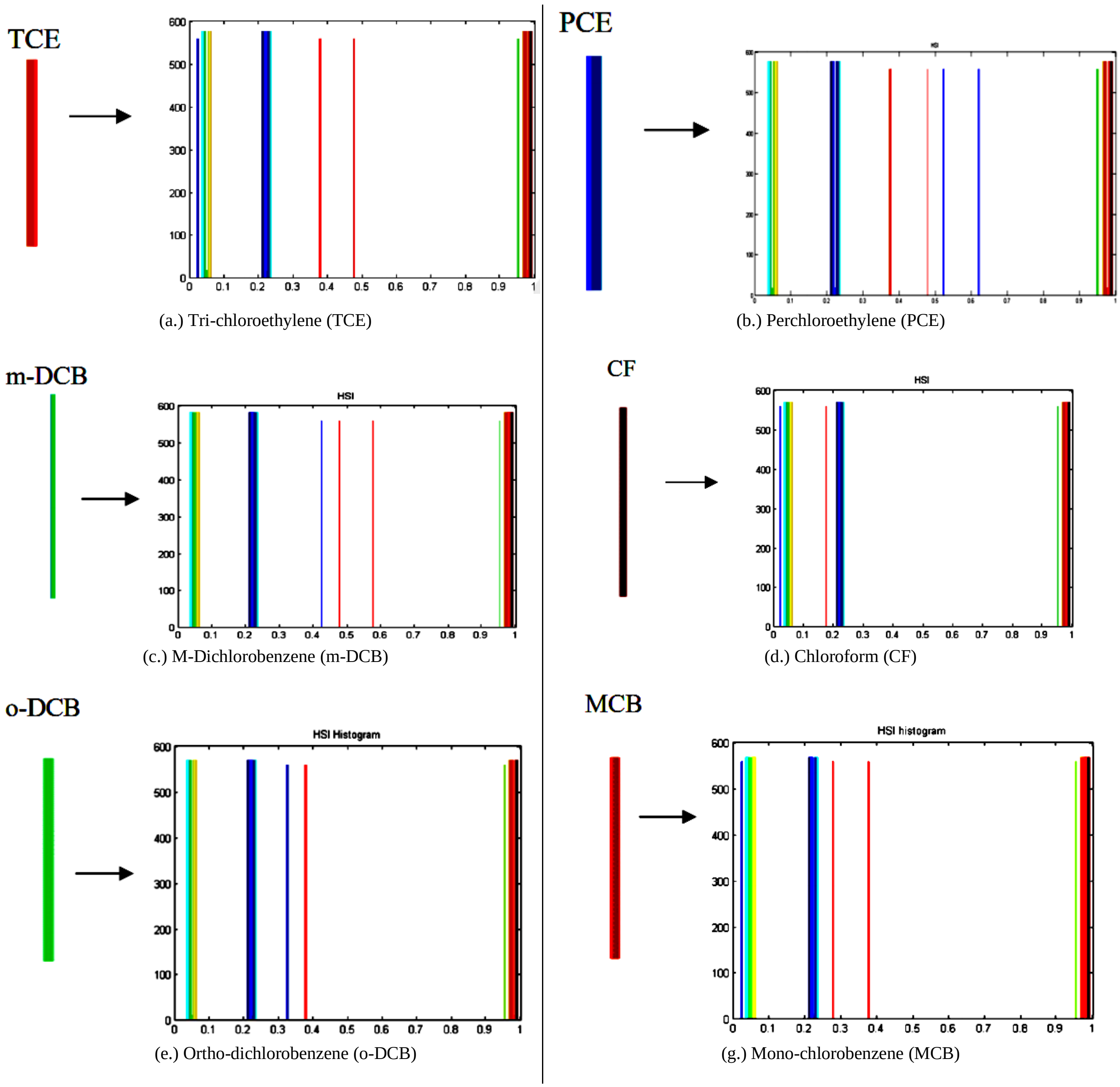

(a.) Tri-chloroethylene (TCE)

(b.) Perchloroethylene (PCE)

(c.) M-Dichlorobenzene (m-DCB)

(d.) Chloroform (CF)

(e.) Ortho-dichlorobenzene (o-DCB)

(g.) Mono-chlorobenzene (MCB)

Figure 4. Chlorinated-hydrocarbons (CHCs) histograms.