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Handheld arduino-based near infrared spectrometer for non-destructive quality evaluation of siamese oranges

Handheld arduino-based near infrared spectrometer for non-destructive quality evaluation of siamese oranges

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Abstract. Quality evaluation, in particular chemical properties, of orange fruit commonly conducted by destructive method by extracting its juice. A near infrared spectrometer (NIRS) can be used to quantify orange chemical properties with non-destructive method. This research aimed to design a handheld NIRS using AS7263 sensor and Arduino programming to estimate the Siamesa orange quality in its acidity (pH), total soluble solids (TSS) and vitamin C. The AS7263 sensor has six NIR channels for different wavelengths, i.e. R (610 nm), S (680 nm), T (730 nm), U (760 nm), V (810 nm) and W (860 nm). For that, a performance test was carried out using 300 samples of orange. Result show that evaluation of orange quality in acidity and TSS has mean absolute percentage error (MAPE) < 10%, and the vitamin C shows > 10%. In addition, the estimation of orange chemical properties by backpropagation neural network (BPNN) yielded better results compared to simple regression and multiple regression methods.

1. Introduction

Orange is the most popular fruit in the world, after grapes, with estimated production of 115 million tons per year worldwide [1]. It contains nutrients that are good for health, especially vitamin C. Orange also needed as source of bioactive including antioxidants such as ascorbic acid, flavonoids and phenolic which are needed for human body [2]. In the processing and marketing of fresh fruit sorting and grading, as an effort to evaluate quality, in order to meet standards are important and absolutely necessary activities. Important parameters associated with fruit quality are based on the physical and chemical properties of the fruit, such as size, color, texture, hardness and acidity. It is very important to know the characteristics of oranges because its would be important for designing the tools, machines and systems for harvesting and post-harvest activities. Moreover, the orange characteristic also important to determining the harvesting time.

In general, the process of orange quality evaluation was carried out with destructive method in laboratory. Although this method has accurate result, but its time consuming, require special skills for chemical analysis, and relatively expensive for the instruments. Several studies on the application of visible and infrared (Vis-IR) light sensors for non-destructive evaluation of fruit quality have been carried out. Previously, Torres et al. [3] developing a model for estimating the physical quality of oranges in trees using a portable near-infrared (NIR) spectrometer. Sánchez et al. [4] conducted a study to determine the internal and external quality of mandarin oranges in trees using a portable NIR spectrophotometer. Shao et al. [5] classified oranges based on their growing conditions and geographic

area and predicted the sugar content in citrus fruits using an NIR spectrometer. Lu et al. [6] used an NIR spectrometer to estimate the total dissolved solids of Chinese citrus fruit. Khodabakhshian et al. [7] applied visible/near infrared spectroscopy for non-destructive evaluation of the determination of pomegranate ripeness and quality parameters. Soltanikazemi et al. [8] also applied visible / near infrared spectroscopy with genetic algorithms to predict the internal quality of black mulberry fruit. Alhamdan and Atia [9] used an NIR spectrometer to predict the quality of dates at various levels of maturity. However, these studies use commercially available NIR spectrometers which cost very high (USD 8,000-10,000 per unit).

According to that, there is a challenge to design a simple spectrometer using infrared light spectrum transmitters and its receivers, in purpose to observe the orange quality by non-destructive method, especially with affordable or low-cost. The measurement method should base on electro-optical sensor (near-infrared) on a computer application for non-destructive evaluation, with fast and accurate result. The use of visual system with an electro-optical sensor is more sensitive and precise to capture the changing of electromagnetic wave reflections of fruit due to differences in the physico-chemical characteristics. For that, this research was aimed to design a portable, handled, NIR Spectrometer using sensor AS7263 with Arduino programming language for measuring the chemical characteristics (total soluble solids, vitamin C, and acidity/pH) as quality reflection of Siamese oranges.

2. Materials and methods

2.1. Fruit samples collection
Orange fruits were obtained from agro-tourism park, Botani Garden (Bogar), in Karangcengis, Purbalingga. In total, 300 oranges fruit were picked randomly.

2.2. Design of handheld Arduino-based on near infrared spectrometer
In this study, we used AS7263 sensor from ams (ams.com) to capture the NIR reflectance of the oranges. AS7263 sensor has 6 NIR channels for measuring the reflectance of different wavelengths, i.e. R (610 nm), S (680 nm), T (730 nm), U (760 nm), V (810 nm) and W (860 nm). The functional block diagram of the sensor is shown in Figure 1.
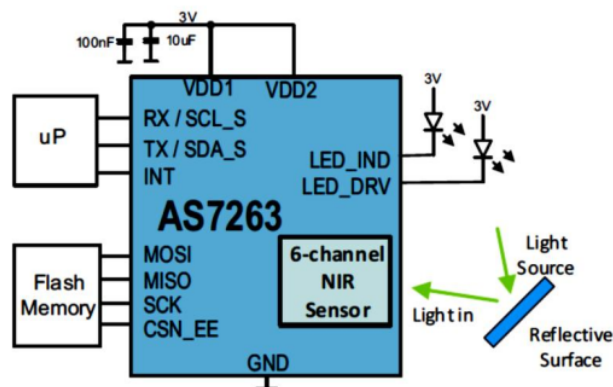

Figure 1. Block diagram of AS7263 sensor.

In Figure 2, we showed the schematic design of the developed device. A light emitting diode (LED) was utilized as light source, then the emitted light fell on the surface of an orange as an object. A quantity of light was reflected and this reflection signal will be captured by the sensor. The signal was subsequently quantify using an Arduino-based program and displayed as outputs of the sensor in the screen.

The measurement procedure of the orange fruit NIR reflectance can be seen in Figure 3. An orange was firstly placed in front of the sensor. From the Arduino-based program, the sensor was activated. During measurement, the LED emitted bright light and the sensor captured object reflectance periodically. The reflectance signals were then displayed as device outputs in the computer.

1. LED light source
2. NIR-sensor
3. PC/laptop
4. Orange fruit
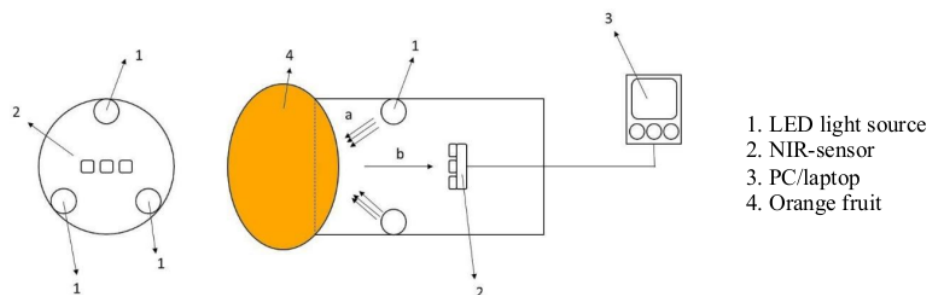
**Figure 2.** Schematic design of handheld NIR spectrometer.

Figure 3. The reflectance measurement using handheld NIR spectrometer.
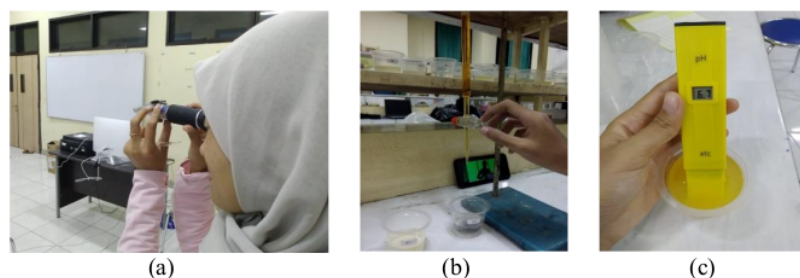
2.3. Measurement of chemical properties of oranges

Three chemicals properties of orange were measured by destructive method, i.e. acidity/pH, total soluble solids (TSS) and vitamin C. These results were used as actual chemical properties. Orange fruit samples were firstly squeezed to extract the juice then purified using filter papers and poured into a small plastic cup.

To measure the TSS content, a small volume of orange juice was pipetted and dropped onto the daylight plate of a refractometer. The TSS value (^{o}Brix) was then observed through an eyepiece of the refractometer (Figure 4a). The concentration of vitamin C, which is more properly called ascorbic acid, was determined by titration method using iodine (Figure 4b). During the titration, the ascorbic acid was oxidized to dehydroascorbic acid, while the iodine was reduced to iodide ions as formulated in the following chemical reaction:

$$ascorbic\ acid\ +\ I_2\ \rightarrow\ 2\,I^-\ +\ dehydroascorbic\ acid$$
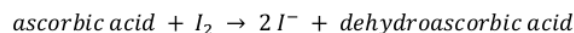
Once all the ascorbic acid was oxidized, the excess iodine is free to react with the starch or amylum indicator, forming the blue-black starch-iodine complex. This is the endpoint of the titration. Lastly, the rest of orange juice was utilized to determine its acidity (pH). The pH was measured using pH meter, by dipping the probe into orange juice, result then observed in the device screen (Figure 4c).

Figure 4. The measurement of chemical properties of orange, (a) TSS, (b) Vitamin C, (c) acidity/pH.

2.4. Data analysis

In this study we applied three methods to estimate the chemical properties of orange based on the NIR reflectance obtained by means of the developed device, i.e. simple regression, multiple regression and backpropagation neural network (BPNN). In the simple regression method, the correlations of each NIR channel output (R, S, T, U, V, and W) and chemical characteristics of oranges were analyzed. Meanwhile, the correlations of combination of NIR channel outputs and chemical characteristics of oranges were analysed using multiple regression.

Architecture of the developed BPNN consisted of 6 nodes input layer, which represented the outputs of all NIR channel, and 3 nodes of output layer, corresponded to chemical properties of orange (Figure 5). The developed BPNN had one hidden layer with node number determined by this following formula [10]:

$$n_h = \left(\frac{n_i + n_o}{2}\right) + \sqrt{N}$$

where n_i, n_o, n_h are the numbers of input-layer, output-layer, and hidden-layer nodes, respectively, and N is the number of sample in the dataset.

As we had 300 orange fruit samples, the number of hidden-layer node was 22 nodes. Furthermore, we split the dataset into training and testing data with portion of 70 and 30%, respectively. Therefore, the training and testing data consisted of 210 and 90 samples, respectively.
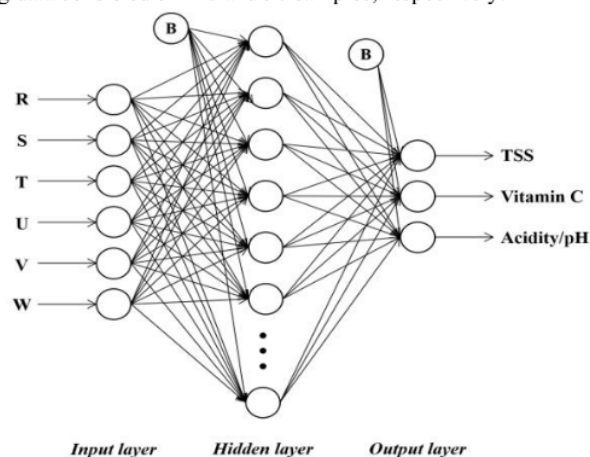
Figure 5. The architecture of the developed BPNN for estimating orange chemical properties.

To assess the estimation results, we used mean absolute percentage error (MAPE) as the basis of accuracy level. The interpretation of MAPE values can be described as follows:
1. MAPE < 10%   : highly accurate estimation
2. 10% < MAPE < 20% : good estimation
3. 20% < MAPE < 50% : reasonable estimation
4. MAPE > 50%   : inaccurate estimation

3. Results and Discussion

3.1. Total soluble solids

The estimation of TSS using simple regression, multiple regression and BPNN methods can be seen in Table 1. The result of the developed BPNN was superior, indicated by lower MAPE value, to that of simple and multiple regressions. However, the estimation of TSS using all applied techniques was in the range of highly accurate estimation.

Table 1. The MAPE of TSS estimation

Parameter	Mean absolute percentage error (MAPE)							
	Simple regression						Multiple regression	BPNN
	R	S	T	U	V	W		
TSS	8.25%	8.27%	8.13%	8.27%	8.08%	8.19%	7.84%	6.95%

3.2. Vitamin C

The result of orange vitamin C or ascorbic acid estimation was shown in Table 2. Likewise, TSS estimation, the developed BPNN resulted better accuracy compared to simple and multiple regressions. According to the MAPE interpretations, the result of vitamin C estimation can be categorized as good estimation.

Table 2. The MAPE of vitamin C estimation

Parameter	Mean absolute percentage error (MAPE)							
	Simple regression						Multiple regression	BPNN
	R	S	T	U	V	W		
Vitamin C	13.38%	13.55%	15.40%	13.46%	14.27%	13.68%	12.83%	11.50%

3.3. Acidity/pH

The estimation result of orange acidity can be seen in Table 3. Its showed that the MAPE of all applied methods were less than 10%, which means the estimation of orange acidity was categorized as accurate. Despite its high accuracy, the developed BPNN could improve the estimation result compared to simple and multiple regressions.

Table 3. The MAPE of acidity/pH estimation

Parameter	Mean absolute percentage error (MAPE)							
	Simple regression						Multiple regression	BPNN
	R	S	T	U	V	W		
Acidity (pH)	1.52%	1.58%	1.99%	1.66%	1.60%	1.49%	1.45%	1.38%

4. Conclusion

The developed portable NIR Spectrometer using sensor AS7263 and Arduino language can be used to estimate chemical characteristics of Siamese oranges. Backpropagation neural network can improve the estimation results compared to simple regression and multiple regression analysis.

References

[1]   Olabinjo O O, Ogunlowo A S, Ajayi O O and Olalusi A P 2017 *International Journal of Environment, Agriculture and Biotechnology (IJEAB)* **2** 2201

[2]   Kamran G, Youcef G and Ebrahimzadeh M A 2009 *Pakistan Journal of Pharmaceutical Sciences* **22** 277

[3]   Torres I, Perez-Marin D, Haba M D and Sanchez M 2017 *Biosystems Engineering* **153** 140

[4]   Sanchez M, Haba M D and Perez-Marin D 2013 *Computers and Electronics in Agriculture* **92** 66

[5]   Shao Y, He Y, Bao Y and Mao J 2009 *International Journal of Food Properties* **12** 644

[6]   Lu H, Ying Y, Liu Y, Fu X, Yu H and Tian H 2005 *SPIE Conference Proceedings: Optical Sensors and Sensing Systems for Natural Resources and Food Safety and Quality* vol 5996 (Boston, MA, United States: SPIE) 599614

[7]   Khodabakhshian R, Emadi B, Khojastehpour M, Golzarian M R and Sazgarnia A 2017 *International Journal of Food Properties* **20** 41

[8]   Soltanikazemi M, Mehdizadeh S A and Heydari M 2017 *International Journal of Food Properties* **20** 2437

[9]   Alhamdan A M and Atia A 2017 *International Journal of Food Properties*, **20** S2950

[10]   Sulistyo S B, Woo W L and Dlay S S 2017 *IEEE Transactions on Industrial Informatics* **13** 103–114

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