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Image Analysis Technique for Evaluating the Quality of Navel Orange Fruits

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Image processing; Orange fruits; RGB Index; ENVI software; biochemical properties.

ABSTRACT

Abstract: The main goal of the current research is to use an image processing system to evaluate the biochemical properties of orange fruits in a non-destructive, rapid and an inexpensive way. Various biochemical properties such as total soluble solid (TSS), T.acidity, total soluble solid / T.acidity, chlorophyll A, chlorophyll B and carotenoids were measured. The ENVI (Environment for Visualization Image) software package was used to analyze the orange fruit images and three RGB bands (red, green and blue) were derived for each image until R, G and B colors were obtained and then color indices such as GRVI, gn, bn, IKAW, ExR and Norm(VARI, VARI1). The results showed that there is a high correlation between color indicators and biochemical characteristics. The ExR gave the highest coefficient of determination with carotenoids ($\boldsymbol{R^2}$ = 0.94^{***}), and also gave the highest coefficient of determination with TSS ($\boldsymbol{R^2}$ =0.90^{***}). While the IKAW index gave the highest coefficient of determination with chlorophyll a and chlorophyll b ($\boldsymbol{R^2}$=0.91^{***} and $\boldsymbol{R^2}$=0.92^{***}), respectively. The IKAW and ExR gave the highest coefficient of determination with TSS/TA ($\boldsymbol{R^2}$= $0.91^{***}$for both).

1. INTRODUCTION

Citrus fruits in Egypt are among the fastest growing agricultural industries in the country. Cultivated areas amounted to about 0.42 million feddans, and citrus production in Egypt reached about 4.25 million tons in 2019/2020 **(ASB, 2020).** The average production of oranges in 2018 was 10.41 tons/feddan, and it increased to 10.64 tons/feddan in 2020 **(FAO, 2021).** Egypt became the first exporter of oranges in the world in 2020. Also, Egypt's citrus exports amounted to about 2 million tons, with a value of $661 million **(El-Khalifa et al 2022).**

Ahmed et al. (2011) indicated that orange juice is a rich source of vitamins, ascorbic acid, and antioxidants that are important for our health. Citrus fruits also provide a large amount of vitamin C, potassium, pectin, folic acid and antioxidants that protect human health. **(Ramful et al. 2010)** indicated that citrus juices and orange extracts contain important antioxidants because they are an important source of phenolic compounds. Apart from the importance of the color of orange juice in product quality, with some techniques, it has been demonstrated that colorimetric measurements can be used to quickly estimate the carotenoid content for quality control purposes **(Meléndez - Martínez et al 2010).**

Wanitchang et al. (2010) indicated that common destructive methods for measuring fruit ripeness such as pH, total soluble solids, as well as TSS/T.acidity which is used to determine individual ripeness index. **(Fouda et al. 2013)** indicated that the Envi (Environment for Visualization Image) software was used to analyze orange images to obtain some color characteristics, among which there are relationships (VARI, R/G band, and RGB band average indices) with chlorophyll a & b and carotenoids. Explain the study of the effect of analyzing the citrus region in terms of skin color in the RGB color model related to the ripeness and sweetness of citrus fruits. TSS was measured with a refractometer **(Ahmad et al 2010).** indicated the use of image processing to characterize the taste of oranges. The features are RGB component, R/G and R/B color component ratio. The results show that image analysis can be used to classify the taste of oranges **(Adelkhani et al 2013).** The vegetation index was associated with the normalized difference (red-blue)/(red+blue) carotenoids, titrated acidity, TSS content and chlorophyll b with R2 values of 0.53, 0.59, 0.57 and 0.57, respectively. The newly developed indicator (NDVI-VARI)/(NDVI-VARI) showed a correlation with chlorophyll a, chlorophyll b and chlorophyll t, where R = 0.71, 0.78 and 0.71, respectively **(Elsayed et al 2016).**

Kaur et al (2018) reported the use of image analysis to identify different ripening stages of a plum cultivar. It showed a strong correlation between the average green color intensity and the acidity of the fruit (R^2 = 0.9966). Also, a strong correlation was found between TSS and the R/G index (R^2 = 0.8464). Show the evolution of many indicators of vegetation. They indicated the development of indicators that use RGB data such as the Visible Atmosphere Resistance Index (VARI) and the NDVI indicator is the most studied and used **(Costa et al 2020).**

The main objective of the present research is to use an image analysis system to non-destructively measure the properties of oranges including liquid ratio, total soluble solid, titrated acidity, TSS/TA ripeness index, chlorophylls a and b, and carotenoids. And also to detect the quality of navel orange fruits at different stages of maturity using color indicators (RGB).

2. MATERIALS AND METHODS

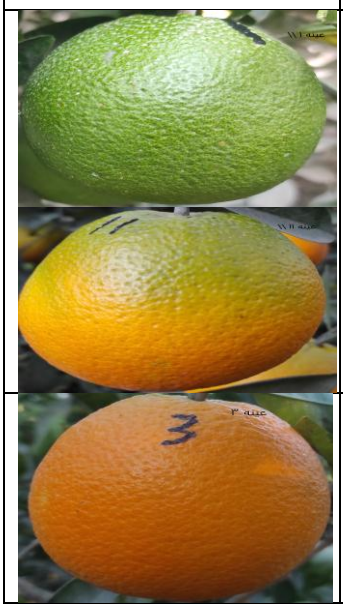
2.1 **Materials**

The experiment was carried out on navel orange fruits in the laboratory of the

Faculty of Agriculture, Tanta University. A sample of navel oranges was collected from a private farm in Gharbia Governorate with different maturity stages. The fruits were picked by hand and randomly. The experiment was conducted throughout the year of 2021 to predict the quality of navel orange fruits using color indicators and link them to the biochemical properties of the fruits (Fig. 1).

Computer vision system: This system consists of a shooting box measuring 25" x 25" x 25" with a black non-reflective fabric attached to a 20MP digital camera. The camera is placed at a height of 25 cm from the bottom of the shooting box. The position of the two light sources has also been adjusted to provide uniform light intensity. Shadow-free fruits were photographed. After the image capture procedure, it was stored for analysis on a personal computer. Capture Cards (WINFAST DV2000, 320H X 240V).

Fig. 1. Navel orange images at different maturity stages

	Dark Green
	Yellowish green
	Orange

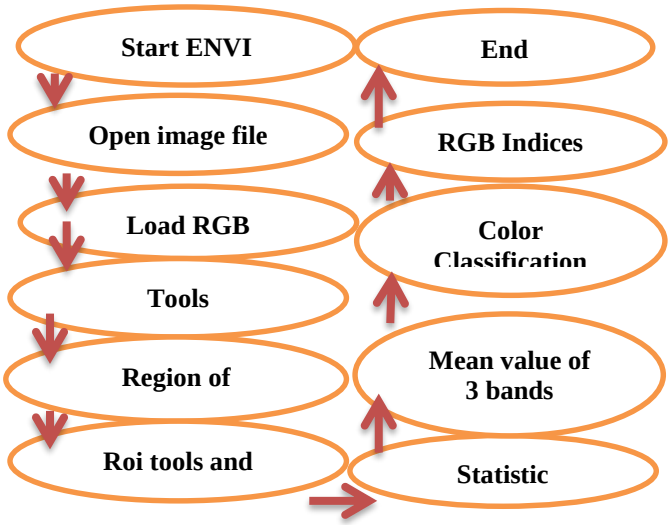


Fig. 2. Image processing flow chart until an average value with three different bands (RGB) and image indices.

ENVI Software: ENVI (Visual Visualization Environment) is the ideal software for visualizing, viewing and analyzing all types of digital images. There are also many ENVI wizards available, which cover almost all functions available in ENVI interactive software. Each processing routine is an IDL action or function and is used like any other IDL routine. A full index of these functions and a complete reference page for each function can be found in the ENVI Reference Guide (available from ENVI Help). The image analysis progresses to an average value with three different RGB bands and the image indicators are shown in Fig. 2).

2.2Measuring and Instruments

Total Soluble solids (TSS) (Brix, %): A digital refractometer was used to measure the TSS content in juice extract from orange fruits and the data was expressed as Brix (%) according to **(Cheour et al. 1991).**

Titrated acidity (TA): The Titrated acidity of orange juice extract as a percentage of anhydrous citric acid was measured by titrating a given volume of juice known to 0.1 N NaOH standard using 1% phenolphthalein as an indicator in accordance with **A.O.A.C. (1990).**

Maturity index (TSS/TA): The TSS/TA ratio was calculated from the soluble solid content values divided by the total acid values.

Spectrophotometer: It was used to measure the absorbance at wavelengths of 480, 645 and 663 nm to measure the content of chlorophyll a (chlorophyll a), chlorophyll b (chlorophyll, b), total chlorophyll and carotenoids (car) content of crude extracts in different plants. On the way **(Arnon, 1949).**

Chlorophyll a mg /g tissue = $12.7(A_{663}) - 2.69(\mathbf{A_{645}}) \times \frac{\boldsymbol{V}}{\mathbf{1{,}000}\times\boldsymbol{W}}$

Chlorophyll b mg /g tissue = $22.9(A_{645}) - 4.68(A_{663}) \times \frac{\boldsymbol{V}}{\mathbf{1{,}000}\times\boldsymbol{W}}$

Total chlorophyll mg /g tissue = $20.2(A_{645}) + 8.02(A_{663}) \times \frac{\boldsymbol{V}}{\mathbf{1{,}000}\times\boldsymbol{W}}$

Total carotenoids (mg/g fw) =$[\mathbf{A_{480}} + (0.114 \times \boldsymbol{A}_{663}) - (0.638 - A_{645})] \times \frac{\boldsymbol{V}}{\mathbf{1{,}000}} \times \boldsymbol{W}$

Where A = absorbance at specific wavelengths. , W = fresh weigh.

V = final volume of chlorophyll extract.

lculations of image indices

Various image indices have been studied and compared in this work using equations in table.1 Various RGB indices

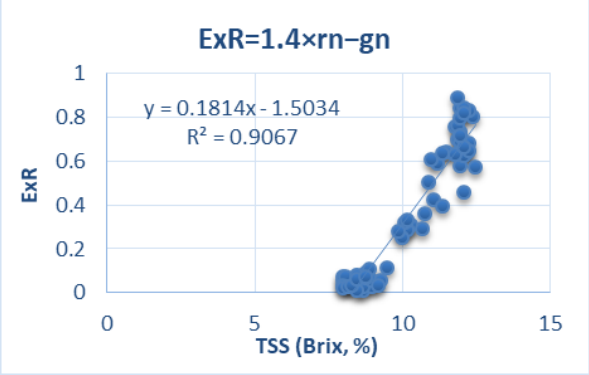
INDEX ABBREVIATION	FORMULAE	REFERENCE
Nomalized green (Gn)	G/(R + G + B)	Kumaseh et al (2013)
Nomalized blue (Bn)	B/(R + G + B)	Kumaseh et al (2013)
Kawashima index (IKAW)	(R−B)/(R+ B)	Elsayed et al .(2016)
Excess red vegetation index (EXR)	1.4×rn−gn	Mao et al (2003)
Norm (VARI, VARI1)	$\frac{(\mathbf{VARI1} - \mathbf{VARI}}{(\mathbf{VARI1} + \mathbf{VARI}}$	Elsayed et al .(2016)
Red blue ratio index (RBRI)	R/B	Aynalem et al. (2006)

3. RESULTS AND DISCUSSION

This research was conducted on an alopecia farm in Gharbia Governorate to predict the quality of navel orange fruits. Experiments were conducted in the laboratories of the Faculty of Agriculture, Tanta University.

3.1 Relation between total soluble solids (TSS) and different image indices

It was found that the total soluble solids (TSS) content correlated with the growth stage of navel orange fruits. At the beginning of growth (green fruit), the (TSS) content is low, and it increases with fruit ripening, so the (TSS) affected the analysis of the image collected from the fruit. The coefficient of determination between the different RGB indices and (TSS) measured for navel orange fruits are shown in (Fig. 3). ExR and IKAW have the highest significant correlations to predict the concentration (TSS) of navel orange fruits, it is evident from the graphs that there is a strong correlation between both indicators and the content of (TSS) of orange fruits ($R^2 = 0.90^{***}$ and $R^2 = 0.88^{***}$), respectively. In general, several of the tested image indices, RBRI, Norm(VARI, VARI1), Bn, and Gn are shown to be ideal indicators for TSS content prediction. The RBRI gave the lowest coefficient of determination with the TSS content ($R^2 = 0.60^{***}$). **Elsayed et al. (2016)** Indicted that the NDVI index (red-blue)/(red+blue) was associated with TSS content, ($R^2 = 0.57^{***}$).



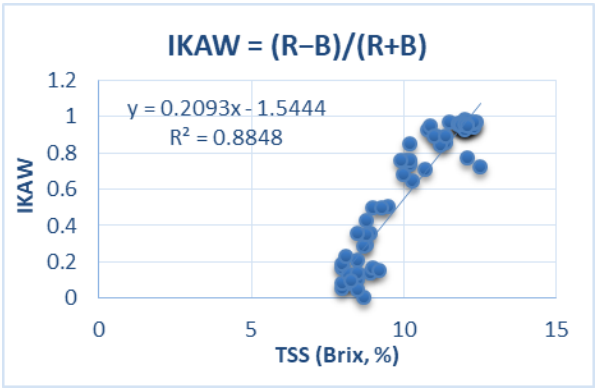


Fig.3. Relation between total soluble solids (TSS) and different image indices**.**

3.2 Relation between Titrated acidity (T.acidity) and different image indices.

It was found that the Titrated acidity (T.acidity) content correlated with the growth stage of navel orange fruits. At the beginning of growth (green fruit), the (T.acidity) content is high, and it decreases with fruit ripening, so the (T.acidity) affected the analysis of the image collected from the fruit. The coefficient of determination between the different RGB indices and (T.acidity) measured for navel orange fruits are shown in (Fig. 4). IKAW and Bn have the highest correlation significant correlations to predict the concentration (T.acidity) of navel orange fruits, it is evident from the graphs that there are strong correlations between both indicators and the content of (T.acidity) of orange fruits (R^2 = 0.91*** and R^2 = 0.89***), respectively. In general, several of the tested image indices, RBRI, Norm (VARI, VARI1), EXR, and Gn were shown to be ideal indicators for (T.acidity) content prediction. The RBRI gave the lowest coefficient of determination with the (T.acidity) content (R^2 = 0.46****). Kaur et al (2018)** Indicted a strong correlation between the average intensity of green color and fruit T.acidity (R^2= 0.99***). **Elsayed et al (2016)** Indicted that the NDVI index (red–blue)/(red + blue) was also correlated with the T.acidity, (R^2 = 0.59***).

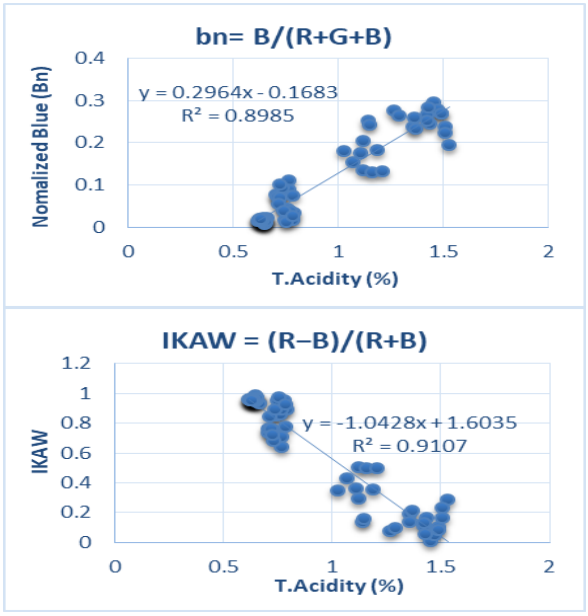


Fig.4. Relation between Titrated acidity (T.acidity) and different image indices.

3.3 Relation between Maturity index (TSS /TA) and different image indices

It was found that the Maturity index (TSS /TA) content correlated with the growth stage of navel orange fruits. At the beginning of growth (green fruit), the (TSS /TA) content is low, and it increases with fruit ripening, so the (TSS /TA) affected the analysis of the image collected from the fruit. The coefficient of determination between the different RGB indices and (TSS /TA) measured for navel orange fruits are shown in (Fig. 5). ExR and IKAW have the highest significant correlations to predict the concentration (TSS /TA) of navel orange fruits, it is evident from the graphs that there are strong correlations between both indicators and the content of (TSS /TA) of orange fruits (R2 = 0.91***). In general, several of the tested image indices, RBRI, Norm(VARI, VARI1), Bn, and Gn were shown to be ideal indicators for (TSS /TA) content prediction. The RBRI had the lowest coefficient of determination with the (TSS /TA) content (R^2 = 0.61). **Pires et al. (2022)** Indicted that the non-destructive assessment of the maturity of Citrus based on a prediction of internal quality characteristics (IQA).

Which gave a good predictive performance for maturity index (MI) (R^2 = 0.80)

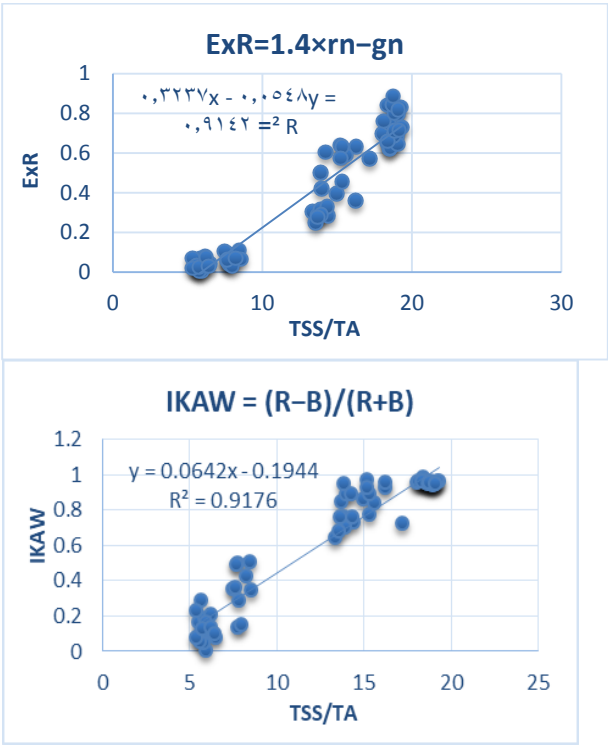


Fig.5. Relation between Maturity index (TSS /TA) and different image indices

3.4 Relation between Chlorophyll a (Chl, a) and different image indices

It was found that the Chlorophyll a (Chl, a) content correlated with the growth stage of navel orange fruits. At the beginning of growth (green fruit), the (Chl, a) content is high, and it decreases with fruit ripening, so the (Chl, a) affected the analysis of the image collected from the fruit. The coefficient of determination between the different RGB indices and (Chl, a) measured for navel orange fruits are shown in (Fig. 6). IKAW and Bn have the highest significant correlations to predict the concentration (Chl, a) of navel orange fruits, it is evident from the graphs that there are strong correlations between both indicators and the content of (Chl, a) of orange fruits (R^2 = 0.91*** and R^2 = 0.88***), respectively. In general, several of the tested image indices, RBRI, Norm (VARI, VARI1), EXR, and Gn were shown to be ideal indicators for (Chl, a) content prediction. The RBRI had the lowest coefficient of determination with the (Chl, a) content (R^2 = 0.47**). **Rasool et al (2022)** Indicted that the (GRVI) and (VARI) showed the highest coefficients of determination for the chlorophyll a of (R^2=0.86*** and R^2=0.85***), respectively. **Elsayed et al (2016)** Indicted that the newly developed index (NDVI-VARI)/(NDVI-VARI) showed highly significant and close correlations with chlorophyll a, (R^2 = 0.71***).

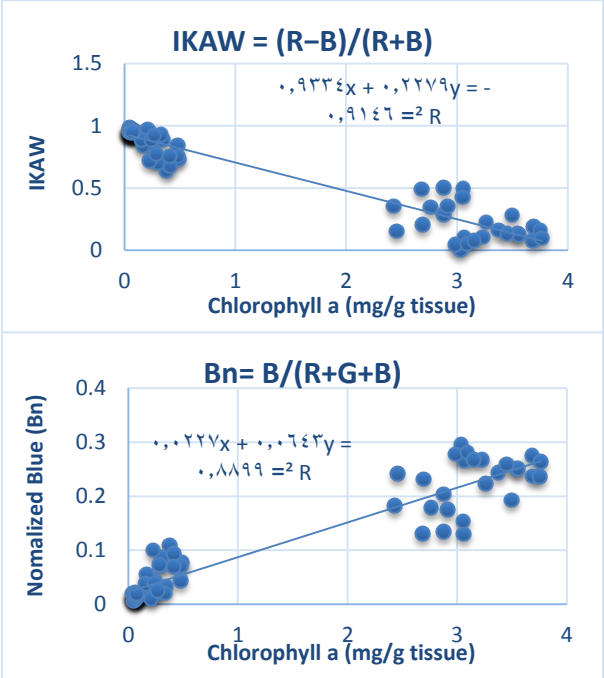


Fig.6. Relation between Chlorophyll a (Chl, a) and different image indices

3.5 Relation between Chlorophyll b (Chl, b) and different image indices

It was found that the Chlorophyll a (Chl, b) content correlated with the growth stage of navel orange fruits. At the beginning of growth (green fruit), the (Chl, b) content is high, and it decreases with fruit ripening, so the (Chl, b) affected the analysis of the image collected from the fruit. The coefficient of determination between the different RGB indices and (Chl, b) measured for navel orange fruits are shown in (Fig. 7). IKAW and Bn have the highest significant correlations to predict the

concentration (Chl, b) of navel orange fruits, it is evident from the graphs that there are strong correlations between both indicators and the content of (Chl, b) of orange fruits (R2 = 0.92*** and R2 = 0.90***), respectively. In general, several of the tested image indices, RBRI, Norm (VARI, VARI1), EXR, and Gn were shown to be ideal indicators for (Chl, b) content prediction. The RBRI had the lowest coefficient of determination with the (Chl, b) content (R^2 = 0.48**). **Rasool et al (2022)** indicated that the image index (GRVI) and (VARI) showed the highest coefficients of determination for the fruit chlorophyll a, of (R^2=0.86 and R^2=0.85), respectively.

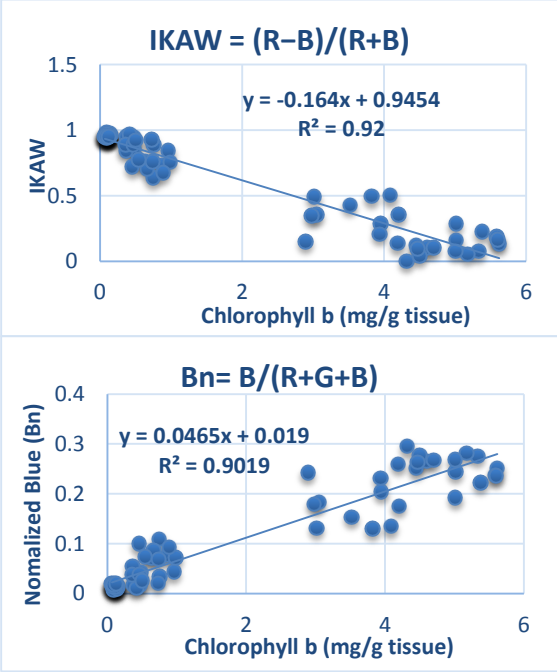


Fig.7. Relation between Chlorophyll b (Chl, b) and different image indices

3.6 Relation between Carotenoids (Cart) and different image indices

It was found that the Carotenoids (Cart) content correlated with the growth stage of navel orange fruits. At the beginning of growth (green fruit), the (Cart) content is low, and it increases with fruit ripening, so the (Cart) affected the analysis of the image collected from the fruit. The coefficient of determination between the different RGB indices and (Cart) measured for navel orange fruits are shown in (Fig. 8). ExR and IKAW have the highest significant correlations to predict the concentration (Cart) of navel orange fruits, it is evident from the graphs that there are strong correlations between both indicators and the content of (Cart) of orange fruits (R^2 = 0.94*** and R^2=0.88***). In general, several of the tested image indices, RBRI, Norm(VARI, VARI1), Bn, and Gn were shown to be ideal indicators for (Cart) content prediction. The RBRI had the lowest coefficient of determination with the (Cart) content (R^2 = 0.62***). **Elsayed et al (2016)** Indicated that the NDVI index (red-blue)/(red+blue) was correlated with the Carotenoids, (R^2= 0.53***).

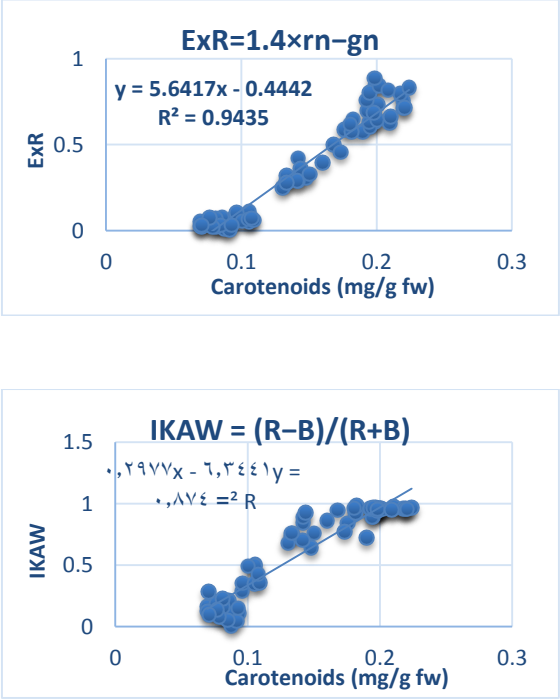


Fig.8. Relation between Carotenoids (Cart) and different image indices.

4. CONCLUSION

The image processing technique was found to be a suitable and accurate method for evaluating the quality of orange fruits. Relationships between GRVI, gn, bn, IKAW, ExR and Norm (VARI, VARI1) indices with TSS, titrated acidity, and maturity index (TSS/TA), chlorophyll a,

chlorophyll b, and carotenoids were presented. Correlation
coefficient and multiple regression coefficients tested the correlation between biochemical characteristics and RGB indicators to determine the best indicators for fruit quality evaluation. The results showed that the indicators bn, IKAW, ExR and Norm (VARI, VARI1) provided a better indicator of the concentrations of TSS, titrated acidity, maturity index (TSS/TA), chlorophyll a, chlorophyll b and carotenoids.

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استخدام تقنية تحليل الصور لتقييم جودة ثمار برتقال السرة

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مجلة العلوم الزراعية والبيئية المستدامة

الكلمات المفتاحية: معالجة الصور ، الفاكهة البرتقالية ، مؤشر RGB ، برنامج ENVI ، الخصائص البيوكيميائية

الملخص العربي

الهدف من البحث هو استخدام نظام معالجة الصور لتقييم الخواص البيوكيميائية لثمار البرتقال بطريقة غير مدمرة وسريعة وغير مكلفة. تم قياس خواص كيميائية حيوية مختلفة مثل TSS ، الحموضة ، TSS / TA ، الكلوروفيل أ ، الكلوروفيل ب والكاروتينات. تم استخدام حزمة برامج ENVI لتحليل صور الفاكهة البرتقالية وتم اشتقاق ثلاثة نطاقات RGB (أحمر وأخضر وأزرق) لكل صورة حتى تم الحصول على ألوان R و G و B ثم مؤشرات الألوان مثل GRVI و gn و bn و IKAW، ExR و VARI) Norm، VARI1). أظهرت النتائج أن هناك علاقة ارتباط قوية بين مؤشرات اللون والخصائص البيوكيميائية. أعطى ExR أعلى معامل تحديد مع الكاروتينات ($R^2 = 0.94$) ، كما أعطى أعلى معامل تحديد مع TSS ($R^2 = 0.90$). بينما أعطى مؤشر IKAW أعلى معامل تحديد مع الكلوروفيل أ والكلوروفيل ب ($R^2 = 0.91$ و $R^2 = 0.92$) على التوالي. أعطى IKAW و ExR أعلى معامل تحديد معTSS / TA ($R^2 = 0.91$) لكل منهما.