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DETECTION OF TOMATO FRUIT MATURITY USING IMAGING ANALYSIS

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ABSTRACT: *The objective of this study was to develop a computer vision and image analysis program to serve as a simple and suitable technique for external fruit inspection and for predicting orange fruits maturity through the image analysis technique. The MATLAB software package was used image processing tools to analysis image of tomato. The study also investigated the effectiveness of some color bands, average intensity of RGB bands and HSI.. The results revealed that the computer vision and image analysis program could be used to differentiate tomato maturity stages. The results also showed that there is a strong response between both RGB band and HSI of tomato fruits and maturity stage also storage period during 21 days.*

Key words: *image analysis, computer vision, Saturation, Hue, RGB mode, Intensity, Maturity.*

INTRODUCTION

Tomatoes (lycopersicon esculentum) , is a major vegetables crop in Egypt which is cultivated in about 216385 thousand faddans to produce 8.5 million tons / year. Egypt is ranked fifth in the world in the production of tomatoes (FAO of agricultural statistics, 2013).

Sorting is a separation based on a single measurable property of raw material units, while grading is the assessment of the overall quality of a food using a number of attributes. Grading of fresh product may also be defined as sorting according to quality, as sorting usually upgrades the product (Brennan, 2006). Sorting of agricultural products is accomplished based on appearance (color and absence defects), texture, shape and sizes. Manual sorting is based on traditional visual quality inspection performed by human operators, which is tedious, time-consuming, slow and non-consistent. It has become increasingly difficult to hire personnel who are adequately trained and willing to undertake the tedious task of inspection. A cost effective, consistent, superior speed and accurate sorting can be achieved with machine vision assisted sorting. In recent ten years, operations in grading systems for fruits and vegetables became highly automated with mechatronics, and robotics technologies. Machine vision systems and near infrared inspection systems have been introduced to many grading facilities with mechanisms for inspecting all sides of fruits and vegetables (Kondo, 2009). Helmy *et al.* (2003) used a digital camera to take images for fresh tomato fruits sample; each fruit had two images, from up and down. The intensity of used light was 530 lux. And classified fresh tomatoes into fifteen maturity grades namely green, spring green, light green, breaker, sand, light orange, peach, turning, color, faded pink, soft pink, pink, tropical pink, light red, neon red and red. They gave average, variance, and standard deviation of reflectance and RGB values of the classified tomatoes. Walailak and Tech (2006) mentioned that, color grading is an important process for the agriculture industry especially in food processing, fruit and vegetable grading. The color of products is often used to determine quality and price. Consumers have developed distinct correlations between color and the overall quality of a specific product. In the agriculture industry, color grading applications are implemented by using color image processing. The advancement of color grading is based on the development of color charge coupled device (CCD) camera.

Based on these considerations, the proposal of this research work was conceived as to adapt the MATLAB code used Image processing tool box to open software to enable the classification system in recognizing color and possibly bruises at a unique glance, driving at to develop low cost and reliable techniques applicable to fruit sorting.

MATERIALS AND METHODS

The present work investigated the potential of image analysis techniques to detect the response of tomato maturity. The experimental work was undertaken at a the Department of Agricultural Engineering - College Agriculture - Menoufia University.

The tomato fruit and varieties

The sample were hand harvest and selected randomized. All samples were individually numbered, four image for each sample occurred .The tomato fruit and varieties under study were (Commercial items),Super Strain (fresh) and Super Marmend (storage) were stored at refrigerator temperature a rang of (10-15º), without exposed to light for 21 days and was taking pictures of tomato samples every three days as shown in Figure (1).

Computer visioning system

The system consists of an imaging box with non reflective black color cloth connected to a digital camera of 14 Mega pixels. The camera was mounted at15 cm from the surface of tomato fruit. Samples were illuminated using two parallel lamps (with two fluorescents tubes in each lamp. Both lamps (60 cm long) were situated 35 cm above the sample and at an angle of 45° to the sample. Following capturing images, they stored on a personal computer for the analysis.

Image Analysis system: tomato samples were captured by the camera, transferred to

Color evaluation: Using the most popular color model RGB color space and HSI. The color was presented with R, G and B, the amount of information is tripled. The RGB system is sensitive to lighting and other surrounding conditions. To evaluate the color of captured images of fruits, the acquired RGB color as shown in Figure (2) information was transformed by MATLAB9 (image processing tools).

MATLAB steps

-Open image from disk
-Read the original image
-Extract the background from the image
-Separate the three channels
-Show the extracted image as shown in Figure (3)
-Show the analysis of the image
-Show the analysis of three channels
-Display the average of three channels
-Display the average of Hue, Saturation, and Intensity.

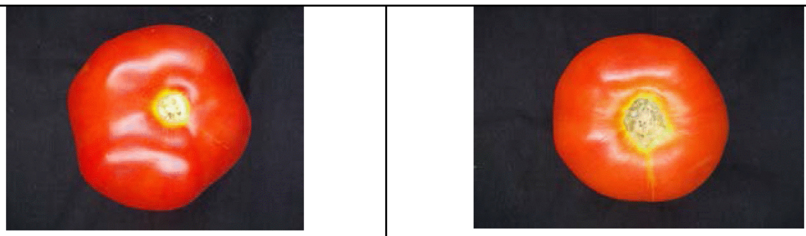
The show of MATLAB code shown in Figure (4).

The following expression show the relationship between HSI values and RGB values:

$$I = (1/3) * (R + G + B)$$

$$S = 1 - \{ 3 [MIN (R , G , B)] \} / (R + G + B)$$

$$H = COS^{-1}\left\{ \frac{(0.5)*[(R-G)+(R-B)]}{[(R-G)^2+(R-G)(G-B)]^{\frac{1}{2}}} \right\}$$



Super Strain (fresh)	Super Marmend (storage)

Fig. (1): The categories of tomato fruits

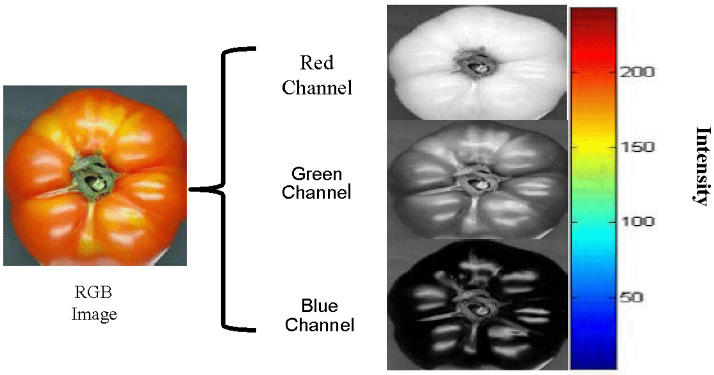


Fig.(2) : Show the color channel splitting of a full RGB color image.

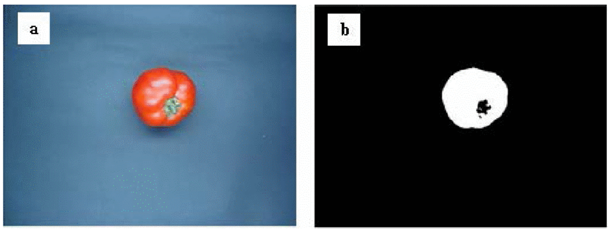


Fig.(3): Tomato fruit regional image segmentation

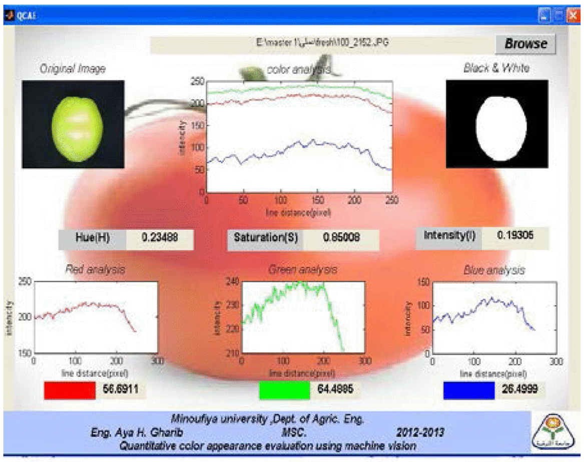


Fig. (4):- MATLAB window show the machine vision system image acquisition unit.

RESULTS AND DISCUSSION

The results of this work are discussed under two heading:

1- Physical characteristics of tomato fruit.
2- Image processing of tomato fruit.

Experimental results obtained for both an unripe and a ripe fruit. The mean value of RGB color and intensity in different maturity stage of fresh tomato fruit.

The relationship between maturity stage of tomato fruit and both of Seasons and RGB :

Maturity of tomato fruit, (M) with red color, green color and blue color content is displayed in Figs. (5) and (6) and Table (1) and (2) in summer and winter season. (R) and (G) increased then decreased with maturity stage, but was increased with maturity stage .Maturity of tomato fruit, (M) with red color, green color and blue color (G) and (R) decreased with increased maturity stage, but (B) was increased with increased maturity stage.

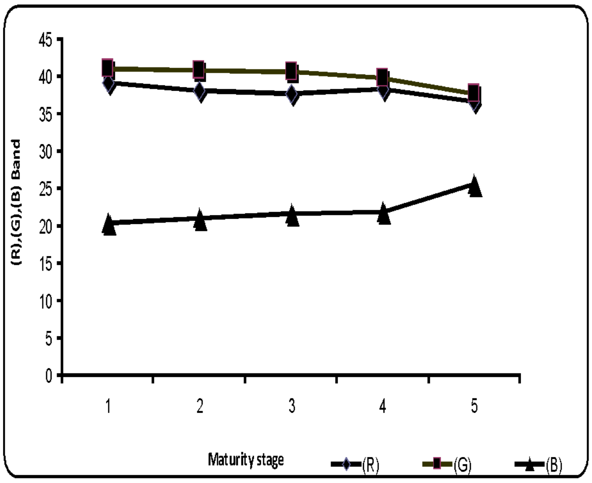


Fig (5): Relationship between Maturity and both of red color, green color and blue color of tomato fruit in summer.

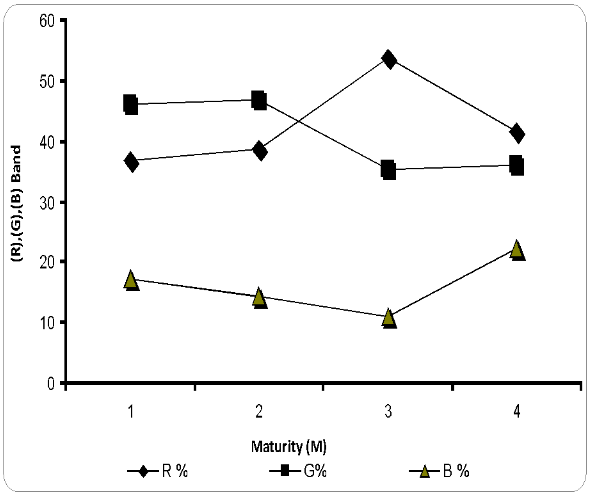


Fig (6): Relationship between Maturity and both of red color, green color and blue color of tomato fruit in winter.

Table (1): value of RGB color in different maturity stage in summer.

Maturity stage	Mean of red color	Mean of green color	Mean of blue color	Mean of intensity
(1) Green	39.1	41.01	20.4	0.2064
(2)Breaker	38.19	40.75	21.05	0.2133
(3) Pink	37.72	40.69	21.58	0.1821
(4)Light red	38.25	39.87	21.86	0.1944
(5) Red	36.65	37.65	25.69	0.1306

Table (2): Value of RGB color in different maturity stage in winter

Maturity stage	Mean of red color	Mean of green color	Mean of blue color	Mean of intensity
(1) Green	36.734	46.162	17.102	0.2367
(2)Breaker	38.74	46.927	14.332	0.2084
(3) Pink	53.686	35.339	10.973	0.2067
(4) Red	41.66	36.06	22.278	0.1653

The relationship between maturity stage of tomato fruit and intensity in summer.

Maturity stage of tomato fruit, with intensity content is displayed in Fig. (7). Intensity increased with increased Storage time (T) then decreased .

The relationship between maturity stage of tomato fruit and intensity in winter.

Maturity stage of tomato fruit, with intensity content is displayed in Fig (8). Intensity decreased with increased maturity stage.

Storage tomato fruit

Ripe tomatoes fruit were stored at refrigerator temperature arang of (10-15°), without exposed to light for 21 days and was taking pictures of tomato samples every three days.

The relationship between storage day of tomato fruit and RGB.

Storage time (T) of tomato fruit, with red color (R), green color (G) and blue (B) color content is displayed in Fig. (9) and Table (3).(G) color decreased with increased Storage time(T), but (R) and (B) color was increased with Storage time (T).

The relationship between storage day of tomato fruit and intensity.

Storage time (T) of tomato fruit, with intensity content is displayed in Fig. (10). Intensity increased with increased Storage time (T) then decreased.

Relationships between Blue color (B) and both of Green color (G) and Red color(R) of tomato fruit (fresh).

The obtained results were presented in Table (4) showed that, the correlation between Blue color and both of Green color and Red color of tomato fruit., were significant, where, they were 0.648 and -0.565 at $P<0.01$, respectively. The carve Represents all the values of the red ,green and blue color of the different of maturity stage. Pairs of values Blue color and Green color specific contour line dark red on the horizontal plane shows the highest values for Red color as shown in Fig. (11) (>500) .

Relationships between Intensity (I) and Saturation (S) and Hue (H) of tomato fruit (fresh).

The obtained results were presented in Table (4) showed that, the correlation between Intensity and both of Saturation and Hue of tomato fruit, were significant, where, they were -0.410 and -0.189 at P<0.01, respectively. Pairs of values Intensity and Saturation specific contour line dark red on the horizontal plane shows the highest values for Hue as shown in Fig. (12) (> .25) .

Relationships between Green Color (G) and both of Blue Color (B) and Red Color (R) of storage tomato fruit).

The obtained results were presented in Table (5) showed that, the correlation between Green Color and both of Blue Color and Red Color (R) of tomato fruit, were significant, where, they were 0.427 and 0.783 at P<0.01,respectively . Pairs of values Green Color and Blue Color specific contour line dark red on the horizontal plane shows the highest values for Red Color as shown in Fig. (13) (>140) .

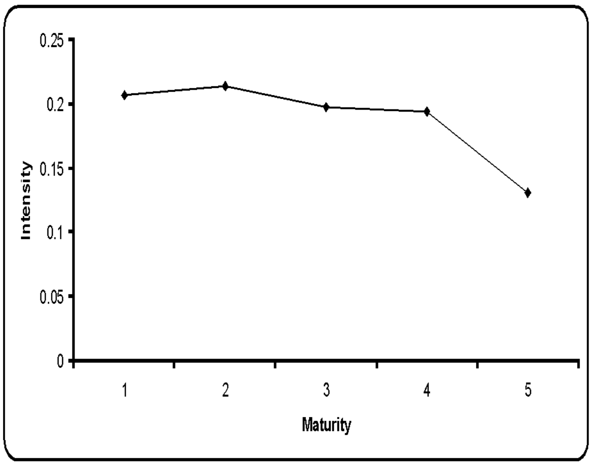


Fig (7): The relationship between maturity stage of tomato fruit and intensity in summer.

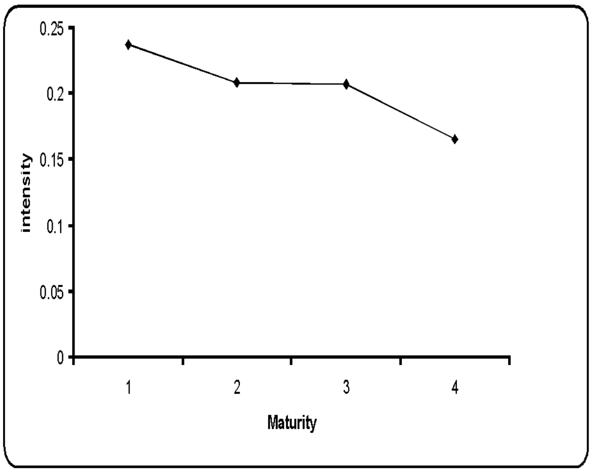


Fig (8): The relationship between maturity stage of tomato fruit and intensity winter.

Table (3): Value of RGB color in different and intensity in time storage of tomato fruit.

Storage time	Mean of red color	Mean of green color	Mean of blue color	Mean of intensity

0	35.08	37.53	27.37	0.1255
3	37.7	42.58	19.7	0.1488
6	41.36	42.82	15.81	0.1419
9	42.89	40.26	16.83	0.1745
12	43.71	39.13	17.15	0.1622
15	43.36	39.13	17.15	0.1623
18	40.59	36.17	23.23	0.1568
21	40.59	36.17	23.23	0.1568

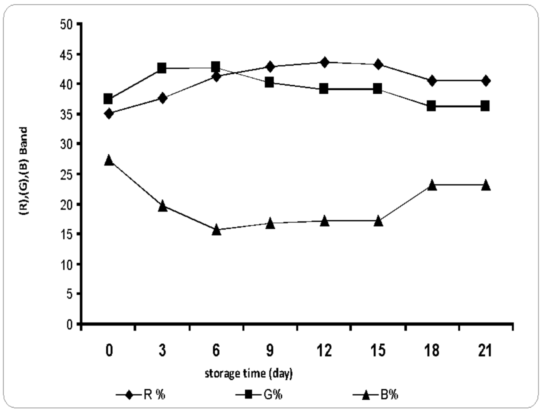


Fig (9): Relationship between Storage time (T)of tomato fruit and both of red color (R), green color (G) and blue color (B) of tomato.

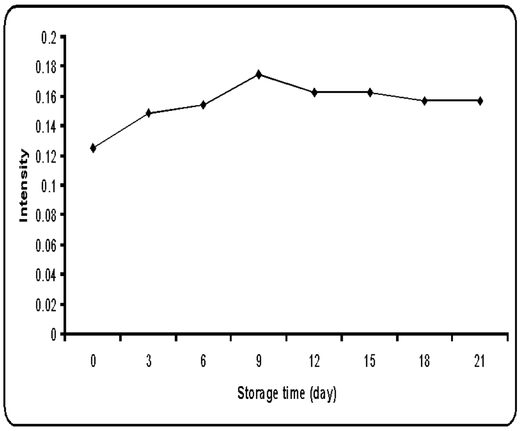


Fig (10): The relationship between storage day of tomato fruit and intensity.

Table (4): Correlation between RGB and HIS model of fresh tomato fruit.

Items	H	S	I	Red Color	Green color
H					
S	0.185				
	*				
I	-0.189	-0.410			
	*	**			

R	-0.306	-0.555	0.512		
	**	**	**		
G	-0.188	-0.649	0.530	0.925	
	*	**	**	**	
B	-0.390	-0.787	0.463	0.565	0.648
	**	**	**	**	**
(**), Significant at level P≤ 0.01, (*), significant at level P≤ 0.05, N.S.), no significant.					
Where: S Saturation, the color is Saturated. I Intensity. H Hue, is the angle between the red axis and cp vector.					

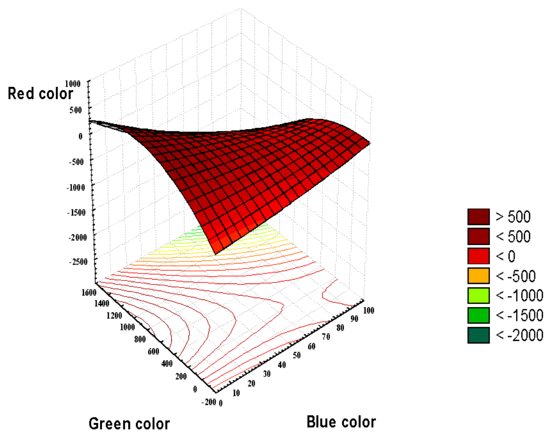


Fig (11): Relationship between Blue color and both of of Green color and Red color of tomato fruit.

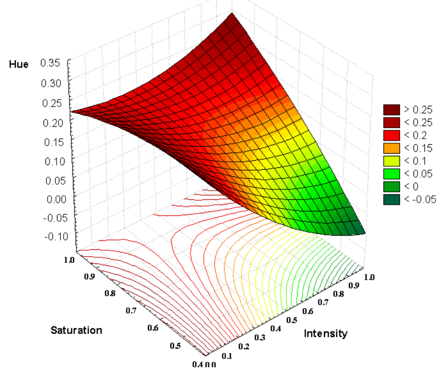


Fig (12): Relationship between Intensity and Saturation and Hue of tomato fruit.

Table (5): Correlation between RGB and HIS model of storage tomato fruit.

	H	S	I	Red Color	Green color
H					
S	0.103				
	*				
I	-0.187	-0.221			
	**	**			
R	-0.387	-0.270	0.525		

	**	**	**		
G	-0.240	-0.280	0.471	0.783	
	**	**	**	**	
B	-0.153	-0.458	0.363	0.393	0.427
	**	**	**	**	**
(**), Significant at level P≤ 0.01, (*), significant at level P≤ 0.05, (N.S.), no significant.					
Where: S Saturation, the color is Saturated. I Intensity. H Hue, is the angle between the red axis and cp vector.					

Relationships between Intensity (I) and both of Saturation (S) and Hue (H) of storage tomato fruit.

The obtained results were presented in Table (5) showed that, the correlation between Intensity and both of Saturation and Hue of tomato fruit, were significant, where, they were -0.221and -0.187 at P<0.01, respectively. Pairs of values Intensity and Saturation specific contour line dark red on the horizontal plane shows the highest values for Hue as shown in Fig. (14) (> 0.5) .

CONCLUSION

An image analysis technique was found to serve as a suitable and accurate method for external tomato fruit inspection. Relationships were determined between average of RGB bands and HSI. Multiple regression analysis and correlation coefficient tested the association between RGB and HSI identify the optimum index sensitive to maturity. possible discrimination by analyzing the colors between the different stages of maturity Tomato Accordingly machine vision can be used successfully in sorting tomatoes on the basis of color. It is recommended using a sophisticated system by connecting the processor directly online by using camera and is connected to a computer program to give signals to the gates of each degree of sorting by color on a continuous basis. The quantitative color appearance evaluation an adequate system for access to a system that works directly on the sorting and grading machines.

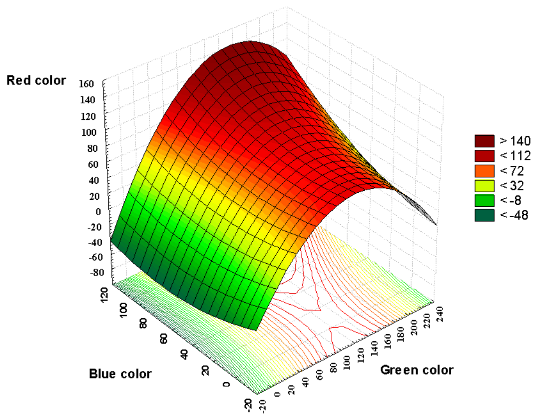


Fig (13): Relationship between Green Color and both of Blue Color and Red Color of tomato fruit.

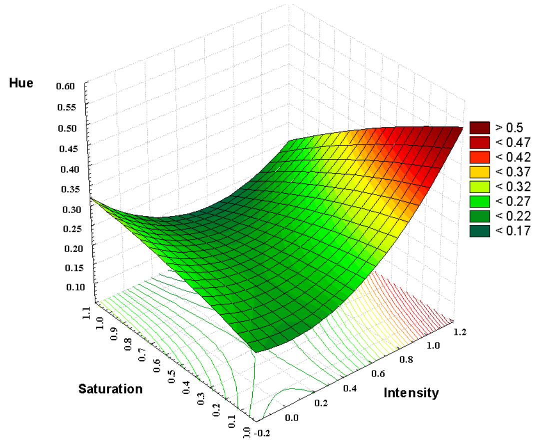


Fig (14): Relationship between intensity and both of Saturation and Hue of tomato fruit.

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تحديد أطوار النضج لثمار الطماطم باستخدام تحليل الصور

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الملخص العربي

تعتمد هذه الدراسة على التقييم الكمى باستخدام الرؤية الآلية حيث يقوم بتحديد نسب اللون الاحمر والاخضر والازرق ويتم تطبيق ذلك عن طريق كاميرا ذات صورة رقمية يتم تحديد نسبة اللون من خلال كود خاص باستخدام برنامج MATLAB9 حيث يقوم بتحليل الصورة وتحديد نسب اللون الاحمر والاخضر والازرق ومن خلاله يتم تحديد درجة نضج ثمار الطماطم على نسبب الالوان حيث استخدم فى هذه الدراسه صنفين من الطماطم (سوبر استرين) فى خمس اطوار نضج و(سوبر مارمند) تخزين لمدة ٢١ يوم فى درجة حرارة تراوحت بين(١٠-١٥).

اهم ما توصل اليه البحث:-

تدريج ثمار الطماطم حسب درجة النضج بنسب الالوان حيث كانت:-

زيادة نسبة اللون الاحمر من(36.734) فى طور النضج الاول الى(53.686) فى طور النضج الثالث ثم انخفضت الى(41.66) فى طور النضج الرابع. انخفاض نسبة اللون الاخضر من(41.01) فى طور النضج الاول الى(37.65) فى طور النضج الخامس. زيادة نسبة اللونالازرق من(20.4) فى طور النضج الاول الى(25.69) فى طور النضج الخامس.

تدريج الثمار التى تم تخزينها كانت نسب الالوان على النحو التالى:-

زيادة نسبة اللون الاحمر من(35.08) عند اول يوم من التخزين الى(43.36) بعد١٥ يوم من التخزين ثم انخفضت الى(40.59) بعد ٢١ يوم من التخزين. زيادة نسبة اللون الاخضر من(37.53) بعد اول يوم من التخزين الى (40.26) بعد ٩ ايام من التخزين ثم انخفض الى (36.17) بعد ٢١ يوم من التخزين. انخفاض نسبة اللون الازرق من (27.37) عند اول يوم من التخزين الى (16.83) بعد ٩ ايام من التخزين ثم تزايدت الى (23.23) بعد ٢١ يوم من التخزين.