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Physical Properties Measurements of Okra Fruits Using Image Processing to Predict of Visual Maturity Index

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ABSTRACT

The investigation on main dimensions using measure methods (Line and rectangle) by image processing of okra pods revealed the following. (1) The length, diameter, mass, volume, and density ranged from (2.63 to 5.50 cm), (1.43 to 2.11 cm), (2.12 to 9.72 g), (4.24 to 19.24 cm^3) and (0.17 to 0.66 g/cm^3), respectively of okra pods. (2) The relationship between the measure and image of the L/D ratio of okra pods has a high correlation (R^2 = 0.9678). So, it can be established the grades standard of okra, according to image process of the L/D ratio of pods. Therefore, the standard grading according to image processing as follows: the "very small" group included pods not more than 1.98 (<1.98) in L/D ratio; the "small" group included pods from 1.98 to 2.28 (1.98 to 2.28); the "medium" class included okra pods from 2.28 to 2.55 (2.28 to 2.55) in length; finally the "large" group included pods larger than 2.55 (> 2.55). (3) The difference percentage between color values, which measuring by line and rectangle pixel methods. The minimum values were of 9.09, 7.22 and 6.67 %, and for maximum values were about 1.69, 2.94, and 6.67 %, and for average values were 6.89, 5.24 and 6.79 % for Red (R) and Green (G) and Blue (B) values, respectively. Therefore, According to measure of color and size of okra fruits, the measurements considering visual means as aMaturity index of okra fruits.

***Keywords*:** Okra, harvesting index, image analysis

INTRODUCTION

Ethiopia was the original home of okra which then propagated in North Africa, in the Mediterranean, in Arabia and India by the 12th century BC.

The plantsproducemany dark green pods with about 5-15 cm in length. The pods ready to harvest after about 45-60 days.

Mohamed *et al.* (2016) seed quality and quantity of okra were obviously influenced by sowing date, harvest date and pod position on the mother plant. Pods at lower or middle positions on the okra plant exhibited the best values in seed yield in terms of seed number/pod, seeds mass/ pod, 100 seed mass and quality of germination percentage, length of root and shoot in seedlings. All possible combinations had a significant effect on pod diameter, seed index, germination percentage and shoot in both seasons.

Daniela *et al.* (2012) investigated okra pods physical properties of four varieties,with moisture content level(7, 14, 21 and 28%)(wet basis) which is important factor in handling,processing and storage equipmentdesign. The mean values of properties obtained were diameter (3.5 cm), length (10.8 cm), mass(13.27g), specific density(0.26g/cm^3), bulk density (0.18g/cm^3), porosity (58.06%), surface area (26.3 cm^2), projected area(7.2 cm^2) and shape index (conic/ribbed). All indicationsfor all varieties increased with increasing moisture content between 7 and 28% wet base.

The total production of okra was 4.8 million ton pods all over the world in which India contributes 70%, Nigeria 15%, Pakistan 2%, Ghana 2%, Egypt 1.7% and Iraq 1.7% (Gulsen *et al*.,2007).

In Egypt, there are many genotypes of okra scattered in different parts of the country having diverse characteristics. In A. R. Egypt the cultivated area of okra during 2009 is about 22203 feddans produced nearly 134665 metric tons with an average of 6.065 ton\Fed (Economic Affairs Sector, Ministry of Agriculture and land Reclamation, 2010).

Shalan *et al.* (2011) mentioned that the field trial was done in the summer season of the two years 2007 and 2008 to evaluate and identify 9 Egyptian okra genotypes. The vegetative growth parameters included the (plant height, number of branches per plant, leaf shape and leaf color), flowering (earliness, node number to the first flower and color of flower), yield of fresh pods (total number and mass per plot), fresh pod characteristics (length, diameter, mucilage, total sugars) and dry seed (index, volume, density, germination %, and total protein).

Sowing date considers as important critical factor which starts from January onwards as an off-season, on quantity and quality of seeds, and germination takes place up to 16°C. Monthswith average temperatures 21 to 30°C are optimum for okra growth, also for both flowering and pods production (Moniruzzaman *et al*., 2007; El-Waraky 2014).

Yadav and Dhankar (2007) stated that higher seed yield and germination percentage were recorded forthe pods which harvested from the lower position of the plant.

Hedau *et al.* (2010) reported that, maximum exhibitionin germination and vigourfrom the seeds produced from fruits positioned at middle of plant, closely followed by thoseproduced from the fruits at lower portion of the plant. Meanwhile, seeds produced from the upper fruits yieldedpoor quantity and qualityseeds.

Singh (2002) and El-Shaikh (2005) implied that, with high phosphorus fertilization rates pod length, number of pods per plant, number of seeds per pod and 1000-seed massafforded the highest average values.

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In India, okra considered as great source of foreign exchange gaining crop, since it was about 60% of the total exported fresh vegetables (Sankar *et al*., 2008).

In general, 4 months needed for most okra cultivars from seeding to harvesting, although other varieties produce full matured pods after 50 days only in the tropical regions. Moreover, these varieties are more endure to low temperature. (BishtandBhat, 2006).

At the beginning of the 90's, first okra experimental hybrids emerged in the USA, as a new technique (Díaz-Franco *et al*., 2007).

Okra hybrids is characterized as shorter production cycle and higher yield verities. Annie Oakley hybrid produces smoother pods with bright green in color. Although the commercial varieties and hybrids have great advantages, the traditional varieties also have preference from farmers in developing countries, technologists and scientists (WinartoandArdhianto, 2007).

Image processing is gaining more importance over traditional methods for quality inspection of food materials because of many advantages. (Minz *et al*., 2020)

The pricing of okra pods depend mainly on grade of them. The grading step is based on the size parameter into four classes (small, medium, large and extra-large). Also, the grading can be based on freshness, color, shape, decay, bruised, infections and trim (Raikar, 2020).

Length, diameter and mass as physical characteristic measured of each okra fruit. Also, color parameter extracted in terms of (L*, a*, b*, C*, H*). It was found significant vary differences in length, diameter, mass, but it wasn't vary on color (Utami, 2020).

Objectives

The present study carried out in order to rank okra (Abelmoschusesculentus) pods which is the Egyptian variety according to their dimension sand color quality attributes by measuring tools and extraction from image processing to assess the suitable use of each category.

MATERIALS AND METHODS

Sample preparation

Okra (*Abelmoschusesculentus*) plants were fielded-grown in theExperimental Research Station, which belongs to the Horticulture Research Institute, Agricultural Research Center, Ministry of Agriculture, Dakhlia Governorate, Egypt, to evaluate and measure, dimensions and color of okra (*Abelmoschusesculentus L.*, Moench) morphologically. The present study was carried out during the summer season of 2020. Okra fruits were harvested at 15th to 25th February. Ripped and matured okra pods were cultivated.

The harvesting of okra pods was done in the morning and sent immediately to the laboratory. Any physically damaged and/or disease symptoms infected fruits were excluded from the samples. 100 pods were categorized according to their lengths (cm).Fig.(1) shows okra pods with different length, diameter and color. Cleaning of okra generally included the elimination of leaves, stem sections, cut pods. This should be done in the packing area while the pods are spread on a flat surface.Okra should not be washed, since this would lead to a greater incidence of postharvest decay.

(a) Linear dimensions of okra pod **(b) Okra pods samples**

Fig. 1. Okra pod samples and its linear dimensions

Measurements

Initial moisture content

The Okra pods moisture content determined by drying samples in an air circulating oven set at 105^{o}Cfor 24 h to be 11.03% wet basis (w.b) as mentioned in literature. Viswanathan *et al.* (2012).

Pod length and diameter

Each sample consisted of twenty fresh okra pods selected randomly from the selected variety. Two linear dimensions -length and diameter- were measured by a Vernier Caliper, 0.01 cm accuracy, pod length measured from the cap scar to the tip end. The estimated diameter was measured at the mid of the pod. (USDA, 1997).

Pod mass

Okra fruits mass (g) obtained by weigh pods individually using a digital balance with accuracy ±0.001 g. Then, average value calculatedof at least 50 fruits.

Pod bulk density

The bulk density of okra pods was obtained by filling a cuboid container (200 x 100 x 100 mm) of known mass and weighed to determine the net mass of the pods. The containers tapped 10 times to obtain uniformity of pods, the bulk density was established as:

$$Pb = (Ws / Wo) * 100 \ldots\ldots\ldots\ldots (1)$$

Where Pb is bulk density (g/cm^3), Ws is mass of sample (g) and Wo is volume occupied (cm^3)

Pod surface color

Minolta CR 300 colorimeter was used to determine the surface color of pods. The instrument calibrated with a standard white plate. Readings were taken by directly put the colorimeter head on the surface of the fruit. Color was measured of 10 different okra pods with different fruit size. The coordinates recorded were Red, Green and Blue of the CIE scale to analyze the derived functions.

Statistical analysis

Descriptive statistics calculated and regression analysis done for the fruit size and color values to describe them as physical properties.

RESULTS AND DISCUSSION

Physical properties

Some of the physical properties of okra fruits were studied. The length, diameter, mass, volume, and density

ranged from (2.63 to 5.50 cm), (1.43 to 2.11 cm), (2.12 to 9.72 g), (4.24 to 19.24 cm^3) and (0.17 to 0.66 g/cm^3), respectively. Table (1) shows some statistical indicators of some okra pods physical properties under studying.

Table 1. Show some physical properties of okra pods.

	Measure length, cm	Measure large diam., cm	Mass, g	Volume, cm^3	Bulk density, g/cm^3	L/D
Min.	2.63	1.43	2.12	4.24	0.17	1.83
Max.	5.50	2.11	9.72	19.24	0.66	2.69
Average	39.39	16.78	4.85	5.37	1.05	2.32
SD	9.97	2.51	2.28	3.10	0.46	0.33
CV (%)	25.30%	14.94%	46.95%	57.70%	44.16%	14.28%

The obtained data clearly showed the existence of pod variations among the different physical properties of okra (Table 1). Thus, it was shown that the longest pod resulted in 5.50 cm, While, the shortest one was obtained in 2.63 cm, with no differences of the length. On the other hand, the largest pod diameter existed of 2.11 cm. While, the lowest values exerted of 1.43 cm.

Studies on the physical characteristics revealed that maturity index in mass pods of okra, was the heaviest one 9.72 g. While, that 2.12 g was the lightest. The determination of the pod volume showed that 19.24 cm^3possessed the largest pod volume while, 4.24 cm^3 was showed the smallest one. Concerning the okra pod density, it was clear that 0.66 g/cm^3were the highest ones and surpassed all the tested in this character. Meanwhile the 0.17 g/cm^3exhibited the lowest ones.

Regarding the existed differences in the pod quality of the various genotypes, it is easy to say that the numbers of pods per plant depending on the best pollination and the amount of supply carbohydrates of the pods (Bakry, 2005).

Measure length okra pod

Data illustrated in Table (1) reveals that the increment in pod length may be due to the effect of prevailing environmental conditions on flowering, different dates of sowing, pollination and subsequent pod development. Differences in pod length due to different dates of sowing were also reported by several workers, such as Hossain*et al*. (2003) and Muhammad *et al.* 2015).

There was a significant increase in pod length at 40 days after seeding as compared with the other harvest dates. Pod length was significantly influenced by fruits position. The highest value (6.10 cm) was observed with pods obtained from pods collected at 40 days after seeding and middle pods, while the lowest value (2.42 cm) was obtained from upper pods.

From our point view, it could establish Egyptian okra grades standards for different uses. The "very small" pods includes those less than 2.57 cm in length; the "small" pods includes thosefrom 2.57 cm to 3.59 cm; the "medium" pods includes those3.59 - 5.18 cm, while, "large" pods includes thosegreater than 5.18 cm. USDA has established the US categories for freezing or canning processing. In this guide classified on the basis of lengths in inches the pods into "very small" less than 1.75 inches (<4.4 cm), the "small" (or baby) includes pods 1.75 - 3.5 inches (4.4 to 8.9 cm); the "medium" includes pods 3.5 - 5 inches (8.9 cm to 12.7 cm), and the "large" includes pods greater than5 inches (>12.7 cm (Marsh *et al*., 1990).

Measure pod diameter

From our point view, it could establish measuring scale for different uses. The "very small" pods includes those less than 1.25 cm in diameter; the "small" pods includes those from1.25 to 1.62 cm; the "medium" pods includes thosefrom1.62 to 2.30 cm; and the "large" pods includes those more than 2.30 cm. The data in table (1) reveal that the maximum pod diameter (2.52 cm), while, minimum pod diameter (1.22 cm) this result maybe pointed to different sowing dates and pod position.

This result is agreed with that of Moniruzzaman*et al*., (2007), who implied that the maximum fruit diameter was recorded for sowing on 15 April. The same table also shows that the harvest date has significant effect on okra pods diameter. The pod maximum diameter observed for those harvested at 40 days after sowing, and collected from the middle position of the plants. While, The pods maximum diameter observed for those harvested at 50 days after sowing, and collected from the lower position of the plants.

The practical guide (IICA, 2006) reported that the pods with minimum diameter to be acceptable in USA markets not less than half an inch (about 1.27 cm).

Ratio of L/D for okra pods

From our point view, it could establish Egyptian okra grades standards for different uses. The "very small" pods includes those less than 1.83in L/D ratio; the "small" pods includes thosefrom1.83to 2.31; the "medium" pods includes those from 2.21 to 2.69; and the "large" pods includes those more than 2.69. The data in Table (1) reveal that the maximum L/D of the okra pod (> 2.69), while, minimum L/D of the okra pod (< 1.83), according to concerning fruit diameter, okrapods had similar diameters, showing that sample pods lower L/D ratio, while, pods have bigger diameter, the okra samples had the highest L/D ratio.

The previous results of pods length, diameter and L/D leaded to establish a relationship with possible use. Pickling or canning suitable for smaller sound fruits, fresh consumption for medium size and processingas slices for large.

Relationship between measure and image diameter of okra pods

From image processing data of the okra pod diameter, it was found that the relationship between the measure and image of has a high correlation (R^2 = 0.9117). So, the standards for Egyptian okra grades according to the diameter of okra podscould be established from image processing as follows: The "very small" pods includes those less than 1.22 cm in diameter; the "small" pods includes those from 1.22 to 1.77 cm; the "medium" pods includes those from 1.77 to 2.52 cm; and the "large" pods includes those more than 2.52 cm.

The following equation showed that the relation between the measure and image of the diameter of okra pods

$$y = 2.0726x - 1.7764 \quad \ldots\ldots\ldots\ldots (2)$$

y: is the image diameter of okra pods, and x: is the measured diameter of okra pod

Relationship between measure and image length of okra pods

From image processing data of the pod length of okra fruit, it was found that the relationship between the measure and image of okra pods length has a high correlation (R^2 = 0.9783). So, the standards for Egyptian okra grades according to the length of okra pods could be established from image processing as follows: the "very small" pods includes those less than 2.42

cm in length; the "small" pods includes those from 2.42 to 4.08 cm; the "medium" pods includes those from 4.08 to 6.10 cm; and the "large" pods includes those more than 6.10 cm.

The following equation showed that the relation between a measure and image of length of okra pods.

$$y = 1.2075x - 0.7598 \ldots\ldots\ldots\ldots (3)$$

y: is the image length of okra pods, and x:is the measured length of okra pod

Relationship between measure and image of L/D ratio of okra pods

From image processing data for length and diameter ratio of pod okra fruit, it was found that the relationship between the measure and image of the L/D ratio of okra pods has a high correlation ($R^2 = 0.9678$). So, the standards for Egyptian okra grades according to the L/D ratio of okra pods as follows: the "very small" pods includes those less than 1.98 in L/D ratio; the "small" pods includes thosefrom1.98 to 2.28; the "medium" pods includes thosefrom2.28 to 2.55; and the "large" pods includes those more than 2.55.

The following equation showed that the relation between a measure and image of the L/D ratio of okra pods

$$y = 0.136x + 1.886 \ldots\ldots\ldots\ldots (4)$$

y: is the image L/D, and x:is the measure L/D

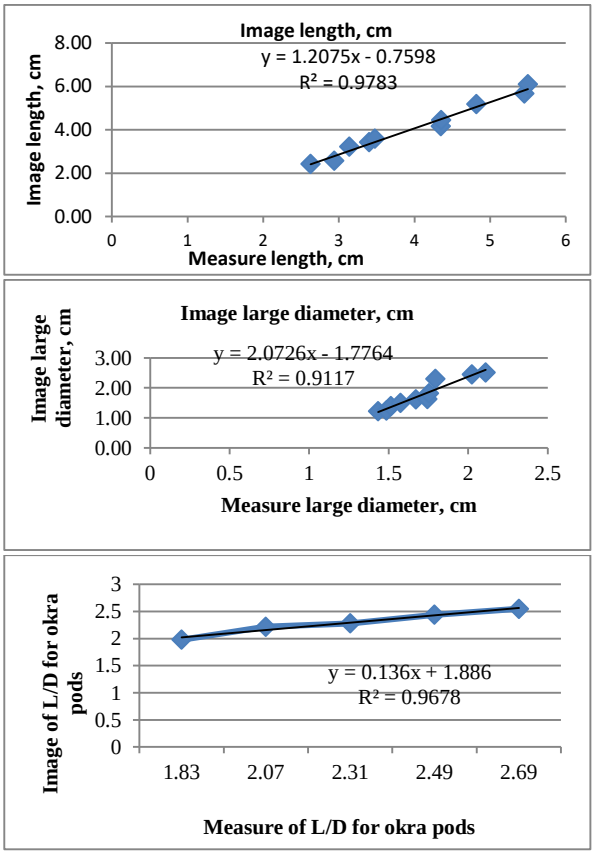

Fig. 2. Relationship between measure and image of L/D ratio of okra pods

Color measure methods of okra pod

Data illustrated in figure (3) reveals that the measurements of color okra pods samples by two scales, one them is line pixel and the second one is a rectangle. It was shown hat the difference between color values measuring by line and rectangle methods of okra pods

It was noticed that the measure color of the okra pod by the line pixel method were ranged as (Minimum and Maximum), from 15.4 to 29.5 values, 19.4 to 34.0 values, and 7.5 to 12.0 values for Red (R) and Green (G) and Blue (B) values, respectively. Meanwhile, the measure color of the okra pod by the Rectangle pixel method were ranged from 14.0 to 29.0 values, 18.0 to 33.0 value, and 7.0 to 11.2 value for Red (R) and Green (G) and Blue (B) values, respectively.

Also, the color average values of the okra pod by the line pixel method were 24.8, 28.6 and 9.87 values for Red (R) and Green (G) and Blue (B) values, respectively. Meanwhile, the measure color average value of the okra pod by the Rectangle pixel method were 22.7, 27.1 and 9.2 values for Red (R) and Green (G) and Blue (B) values, respectively.

From previous results, it was shown that the difference percentage between color values, which measuring by line and rectangle pixel methods. It was noticed that the difference percentage of minimum values were about 9.09, 7.22 and 6.67 %, and for maximum values were about 1.69, 2.94, and 6.67 %, and for average values were 6.89, 5.24 and 6.79 % for Red (R) and Green (G) and Blue (B) values, respectively.

Regarding surface colour determinations (Fig. 3), Color scale of different color okra pods was showed no significant differences in the coordinate RGB.

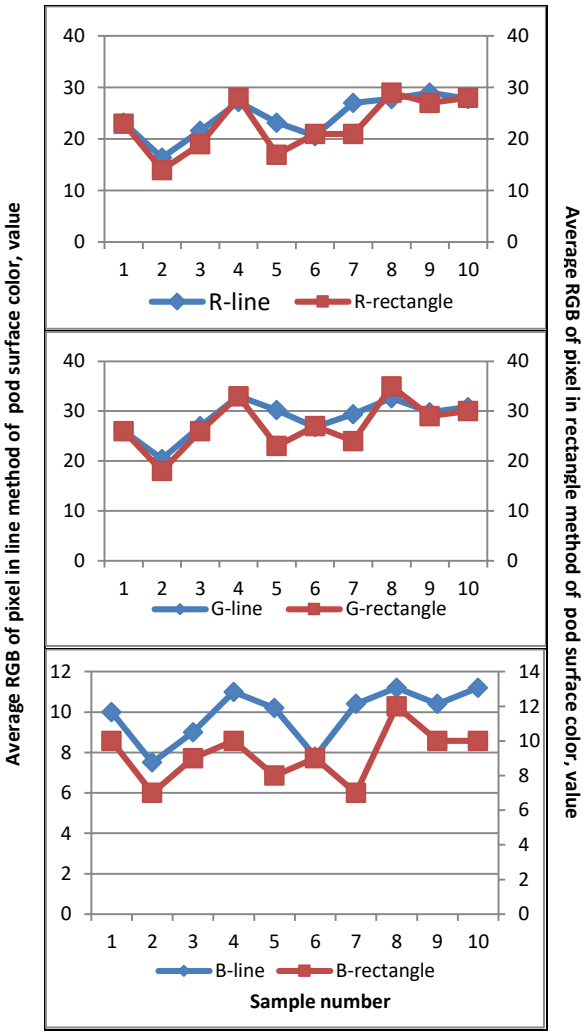

Fig. 3. Measure surface color (RGB) of okra pods by Line and Rectangle methods

According to the tender pods easily damage during handling, especially along the ribs. This leads to cause brown and black discoloration. So, the pods should be tender and not fibrous, and have a colour typical of the cultivar (generally bright green). Therefore, immature green tender fruits should be picked 3rd to 5th day from the time of first pod formation or 3 to 7 days after flowering. When the okra fruits are bright

green, the pods are fleshy and seeds are small should be harvested. So, very important for knowing the harvest maturity, to well understood a difference between ripe and mature. The ripe pods are mature and ready for sale and consumed. While, mature pods may or may not be ripe but will ripen if given the right conditions.

Skin color factor is commonly applied to fruits, since skin colour changes as fruit ripens or matures. Some fruits exhibit no visual color change during maturation, depending on the type of fruit or vegetable. Assessment of harvest maturity by skin colour depends on the judgment of the harvester, but colour charts are available for cultivars, such as apples, tomatoes, peaches, peppers, etc.

CONCLUSION

The investigation on various main dimensions using to measure methods (Line and rectangle) by image processing of okra pods revealed the following. (1) The length, diameter, mass, volume, and density ranged from (2.63 to 5.50 cm), (1.43 to 2.11 cm), (2.12 to 9.72 g), (4.24 to 19.24 cm^3) and (0.17 to 0.66 g/cm^3), respectively of okra pods. (2) From image processing data of the pod diameter of okra fruit, it was found that the relationship between the measure and image of the diameter of okra pods has a high correlation ($R^2 = 0.9117$). So, the standards for Egyptian okra grades according to the diameter of okra pods could be established from image processing as follows: The "very small" pods includes those less than 1.22 cm in diameter; the "small" pods includes those from 1.22 cm to 1.77 cm; the "medium" pods includes those from 1.77 cm to 2.52 cm; and the "large" pods includes those more than 2.52 cm. (3) From image processing data of the pod length of okra fruit, it was found that the relationship between the measure and image of the length of okra pods has a high correlation ($R^2 = 0.9783$). So, the standards for Egyptian okra grades according to the length of okra pods could be established from image processing as follows: The "very small" pods includes those less than 2.42 cm in length; the "small" pods includes those from 2.42 cm to 4.08 cm; the "medium" pods includes those from 4.08 cm to 6.10 cm; and the "large" pods includes those more than 6.10 cm. (4) From image processing data for length and diameter ratio of pod okra fruit, it was found that the relationship between the measure and image of the L/D ratio of okra pods has a high correlation ($R^2 = 0.9678$). So, the standards for Egyptian okra grades according to the L/D ratio of okra pods as follows: the "very small" pods includes those less than 1.98 in L/D ratio; the "small" pods includes those from 1.98 to 2.28; the "medium" pods includes those from 2.28 to 2.55; and the "large" pods includes those more than 2.55. (5) The difference percentage between color values, which measuring by line and rectangle pixel methods. The minimum values were about 9.09, 7.22 and 6.67 %, and for maximum values were about 1.69, 2.94, and 6.67 %, and for average values were 6.89, 5.24 and 6.79 % for Red (R) and Green (G) and Blue (B) values, respectively. (6) According to measure of color and size of okra fruits, the measurements considering visual means as amaturity index of okra fruits.

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قياسات الخواص الفيزيائية لثمار البامية باستخدام معالجة الصور للتنبؤ بمؤشر النضج البصري

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الملخص

يهدف البحث إلى تصنيف قرون البامية من خلال معالجة الصورة وأظهرت النتائج: (1) تراوح الطول والقطر والوزن والحجم والكثافة لقرون البامية من (2.63 إلى 5.50 سم) و (1.43 إلى 2.11 سم) و (2.12 إلى 9.72 جم) و (4.24 إلى 19.24 سم 3) و (0.17 إلى 0.66 جم / سم 3) على التوالي. (2) اوضحت العلاقة بين القياس التجريبي والقياس من الصورة أن قطر قرون لها ارتباط كبير (R^2 = 0.9117). ولذلك ، يمكن وضع معايير الجودة.وكان التصنيف القياسي هو: المجموعة "الصغيرة جدًا" يقل قطرها عن 1.22 سم؛ المجموعة "الصغيرة" 1.22 - 1.77 سم؛ الفئة "المتوسطة" 1.77 - 2.52 سم ؛ المجموعة "الكبيرة" يزيد قطرها عن 2.52 سم. (3) الطول له علاقة ارتباط عالية (R^2 = 0.9783). لذلك ، يمكن وضع معايير جودة البامية ، وفقًا لمعالجة الصورة للطول. المجموعة "الصغيرة جدًا" يقل طولها عن 2.42 سم ؛ المجموعة "الصغيرة" 2.42 - 4.08 سم ؛ "المتوسطة" 4.08 - 6.10 سم ؛ والمجموعة "الكبيرة" يزيد طولها عن 6.10. (4) نسبة الطول/العرض لها ارتباط كبير (R^2 = 0.9678). لذلك ، يمكنها تحديد معايير درجات الجودة. المجموعة "الصغيرة جدًا" الأقل من 1.98 ؛ المجموعة "الصغيرة" 1.98 - 2.28 ؛ الفئة "المتوسطة" نسبتها 2.28 - 2.55 ؛ المجموعة "الكبيرة" أكثر من 2.55. (5) نسبة الاختلاف بين قيم اللون كانت أقل قيم 9.09 و 7.22 و 6.67٪ ، وأعلى قيم كالتالي 1.69 و 2.94 و 6.67٪ ، والقيم المتوسطة 6.89 و 5.24 و 6.79٪ للأحمر والأخضروالأزرق ، وبالتالي تلك القياسات تعتبر وسائل بصرية كمؤشر نضج لثمار البامية.

الكلمات الدالة : البامية ، مؤشر الحصاد ، تحليل الصور