Prospects of Modern Technology in Agricultural Engineering and Management of Environmental Problems: 733 - 748

DEVELOPMENT A MACHINE VISION SYSTEM FOR TOMATO SORTING

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ABSTRACT

The main objective of this study is to design, manufacture and evaluate the performance of a color machine vision system for automatically color sorting of tomato depending on light sensors and electronic cycles. By the fruit passing front of light sensor, the LED sent light on the fruit and light sensor receive the reflecting light according to fruit color. By receiving the reflected light, the sensor sending a signal for the air valve circuit subsequently the air valve pushing air for falling tomato fruit on its special receiving unit. Feeding speed in the range of 0.10 m/s to 96.18% give the high value of sorting efficiency of 97.48 to 96.18% with productivity of 80.70 to 94.80 kg/h at sensor high of 35 mm for tomato (Bito 86) with energy requirement of 3.83 to 2.97 kW.h/ton and operation cost of 5.66 L.E/h.

INTRODUCTION

Selection and inspection of the color of tomatoes with human resources is problematic because of fatigue and inconsistencies. Undoubtedly, there is great difference between electronic vision sorting systems and human eye sight. So, eye sight inspection system cannot be considered quantitative analysis and time consuming. But electronic control offers the sensitive quantitative color sorting methods with less operation costs. Machine-vision systems distinguish between good and defective fruit by contrasting the differences in light reflectance off the fruits surfaces (Miller, 1995). In recent ten years, operations in grading systems for fruits and vegetables became highly automated with modern 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. The quality sorting of product is done by worker. But, in cleaning and sorting,

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some assistant systems are used more widely. One of these systems is sorting of product according to the surface color or its reflectance light. It is possible to sort out products without giving harm or changing original structure with this system (Kondo, 2009). Color is a perceptual phenomenon that depends on the observer and the conditions in which the color is observed. It is a characteristic of light, which is measurable in terms of intensity and wavelength. Color of a material becomes visible only when light from a luminous object or source illuminates or strikes the surface. In this study, prototype tomato sorting machine was developed according to the designed tomato brightness or color depending on its color wavelengths or light reflectance. El-Raie et al. (2003) used in their experiments a random sample of fresh tomato (250 fruits). Two types of laser were used, the first one was Argon laser with two wavelengths 488 nm with incident light equals 4640 lux and 514 nm with incident light equals 4680 lux. The second laser was Helium- Neon with wavelength 632.8 nm with incident light equals 700 lux. Eissa et al (2011) they, designed, manufactured and evaluated the performance of grading prototype for orange, onion and potato based on the dimensions, which take place without physical contact. Brennan (2006) stated that, sorting and grading are terms which frequently used interchangeably in the food processing industry. 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. Eissa et al. (2012) they developed a system for sorting fruits and vegetables, will design and construct and evaluate a robotic machine vision system for automatic, non-destructive sorting and grading of orange and tomato fruits. Arias et al. (2000) mentioned that traditionally, the surface color of tomatoes is a major factor for determining the ripeness of tomato fruits. Matlab, (2000) classified tomato fruits using bottom image by calculating the roundness of the tomato outline. Color homogeneity is a significant indicator of the tomato's quality. The red color should spread homogeneously downwards from the blossom end the fruit. A non- homogeneous color spread makes the fruit unsuitable for marketing. Laykin et al. (2002) developed and implemented image processing algorithms to improve quality parameters for tomato-classification: color, color homogeneity, defects, and stem detection. Also, they indicated that only fruits with stem are allowed for marketing.

The main objective of this study is to design, manufacture and evaluate the performance of sorting prototype for tomato according its color. Working principle of the sorting prototype depend on reflecting light.

MATERIALS AND METHODS

General description of sorting prototype

The designed prototype as presented in Figures (1) and photo (2) consist of the following main parts:

1. Frame: - is manufactured from equal-sided angle steel 40 mm side-lengths and covered with stainless steel sheets with 1.0 mm thickness. The designed sorting machine is shown in photo (1) and its diminutions are shown in fig (2)

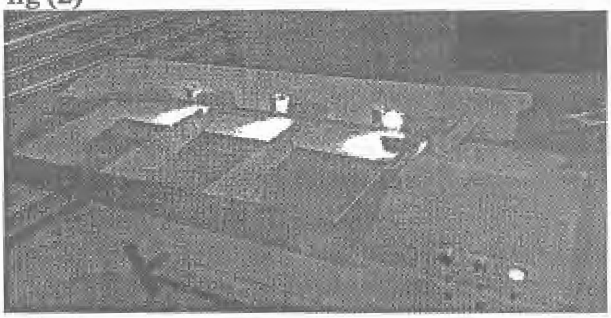


Photo (1) the designed sorting machine

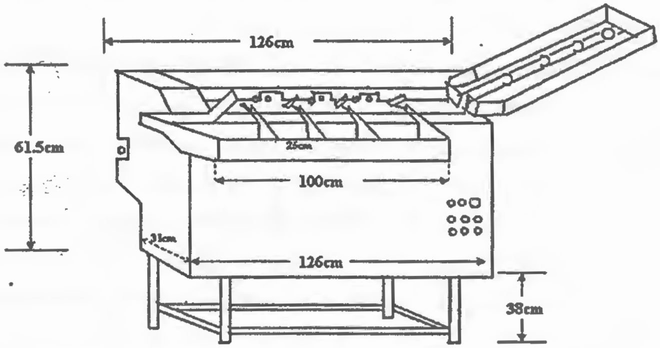


Fig. (2) Schematic of defect sorter system

2. **Feeding unit:** The feeding unit consists of three parts, which are feeding hopper, conveyor belt and electrical motor.

a) **Feeding hopper:** It was manufactured from galvanize smooth iron sheet. The dimensions of its length, width and height were 300 mm, 200 mm and 100 mm respectively. The hopper can adjustable to obtain the proper slope for the fruit to slide smoothly.

b) **Conveyor belt:** The conveyor belt was made of rubber with 2mm thickness, 130 cm length and 10cm width and attached with gear. The gear was connected to the prototype frame by two ball bearings. The external diameter of each ball bearing is 62 mm and the internal diameter is 25 mm. The velocity reduction unit (power transmission system) was used to reduce the motor velocity to the required velocity for the conveyor. The power transmission system consists of two sets of gear, the first set was fixed on motor shaft and it called the drive gear and the second set was fixed on the conveyor shaft and it called the driven gear and motion transmits by the conveyor belt

c) **Electrical motor:** An electrical motor DC **(0.10 kW or 0.172 hp)** with the gear box was used as a power source for the proposed prototype. The motor is selected according to the required usable power output.

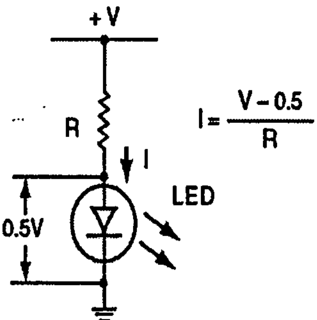
3. **Sensors unit:** The sensors unit consists of two parts one of which is equipped with light emission diodes (LED) and the other with phototransistors.

A - Light-emitting diode circuit (Light Source):

It is a very important light source for light sensors. An LED is a forward-biased semiconductor diode as shown in Fig. (3.2) LEDs are made from special semiconductor materials other than silicon, but still have the same type of junction characteristics. When a rated amount of current is passed through the forward-biased diode it emits light. The amount of current (I), through the diode can be adjusted by choosing the value of R when a given voltage (V), is used. The forward-biased voltage across the diode is approximately 0.5V, positive (+) on the anode and negative (-) on the cathode. Various LEDs, the materials used to make them, and the color of their light output are shown in Fig. (3.3). the wave length in this case is given in Angstroms (Å), where an Angstrom is 10–10 meters. When LEDs are used for light sources for phototransistors, the LED wavelength should be matched to the phototransistor. For example, Fig. (4) shows the relative output from a phototransistor using an LED as a source. An infrared LED with a wavelength of 898 nanometers (8980Å) provides almost three times as much output from the phototransistor as an LED with an orange light output of 650 nanometers (6500Å). The application circuit that was used in this study as shown in (3.5). This circuit has been consisted of eight light-emitting diode (LED), one resistor of 1k? and one potentiometer of10k? .

B- Transistors light sensor and circuit applications

The transistor designed to be activated by light, has the same basic operation as the NPN and PNP transistor described except it has no base connection ((N) negative (P) positive). The circuit application that was used in this study is illustrated in Fig.(3). This circuit has been consisted of two IC LM339, two IC 7442, two IC 4069, one IC uln2003, four relays, four capacitor, four diode, eight Phototransistor and eight variable resistor. The value of variable resistor depends on the input light intensity, ambient temperature, response velocity.



Material	λ (Å)	Color
Indium Phosphide	9850	Infrared
Gallium Arsenide	8980	Infrared
Gallium Arsenide Phosphide	6500	Orange
Gallium Phosphide	5650	Green
Gallium Nitride	4000	Purple

Fig.(3): Fundamental LED circuits and typical LEDs.

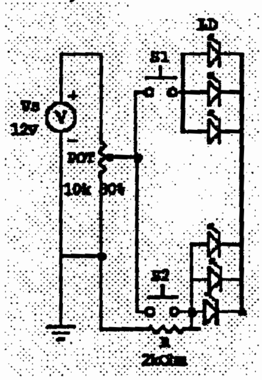
B- Transistors light sensor and circuit applications

The transistor designed to be activated by light, has the same basic operation as the NPN and PNP transistor described except it has no base connection ((N) negative (P) positive). Its wide base junction is left exposed to light. Phototransistors are most sensitive to light. Light rays that impact the base-emitter junction effectively produce base current that activates the phototransistor. Through transistor action a larger collector current is produced. The phototransistor as sketched a photographed in Fig (4) shows a phototransistor sensing the presence of light to make a logic-level driver for a relay. The presence of light closes the normally-open contact to the center terminal to activate a connected circuit. The circuit application that was used in this study is illustrated in Fig. (5). This circuit has been consisted of two IC LM339, two IC 7442, two IC 4069, one IC uln2003, four relays, four capacitor, four diode, eight Phototransistor and eight variable resistor. The value of variable resistor depends on the input light intensity, ambient temperature, response velocity

2-4- Electrical control units

The control unit has been comprised a number of electronic circuits. It consists of two main systems of electronic circuits:

1- Controlling in feeding rates: - controlling the feeding rates by means of the control in the feeding velocity (the control unit sends a signal to feeding motor for adjusting feeding speed according to the required as a volt value).



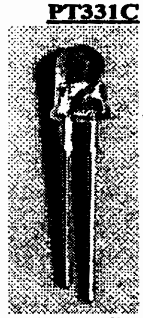
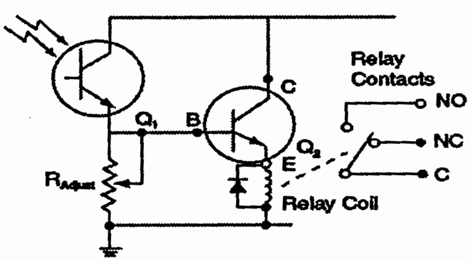
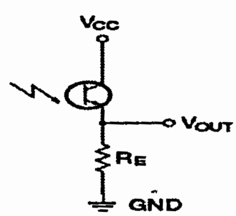
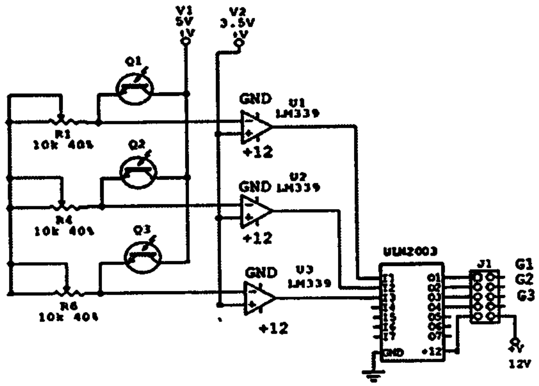


Fig. (4): transistors light sensor Fig.(5): Light-emitting diode (LED) circuit.





A) Common-collector amplifier **b) Relay driver**



c. Application circuit of phototransistor

Fig. (6): Phototransistor circuit.

2 - Controlling in air valve: The function of air valve control circuit was to control in falling the tomato fruit which carries a fruit determined category color in its collecting containers. Fig. (7). shows the air valve control circuit has been consisted of three relay 12V. The output signals from the one of opto-electronic circuit (from any Phototransistors) the control circuit sends a signal to Air valve which emit tomato fruit in its container according its color.

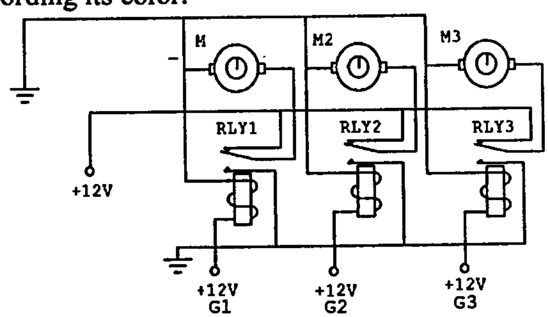


Fig. (7)Air control circuit

2-5 Power unit: - It consists of the following components:

1- Transformers

The function of transformer is to transform the 220V "mains" to a lower value, say 24V. A common type of transformer has primary and secondary sides, the primary side which connects to the 220V and (or several) the secondary side for the low voltages.

2 - Diode rectification: Many devices, in particular electronics, must use direct current (DC). A diode is a solid-state device that conducts in one direction only. The image and circuit of Diode Bridge illustrated in Fig (8). D1 and D2 conduct during the positive half-cycle while D3 and D4 conduct during the negative half-cycle. Power delivered here is twice that of half-wave rectification because due to using both half-cycles.

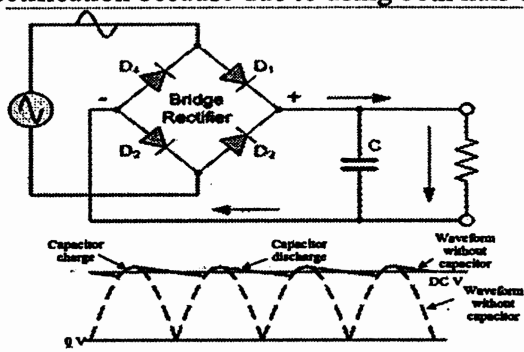


Fig (8) typical bridge rectifiers

3- Voltage regulators and power supply distribution circuit

Higher-current regulators in order to handle larger currents and, thus, more power dissipation for the regulator, external devices can be connected as shown in Fig. (9) .Many integrate circuit (IC) regulators (7805, 7812, 7912, 7905) have the connections for the external device provided in the design. Fig. (9). shows an electronic system that needs regulated voltages of +12V, -12V +5V,-5V, +3.3V, +3V, and +1.8V.

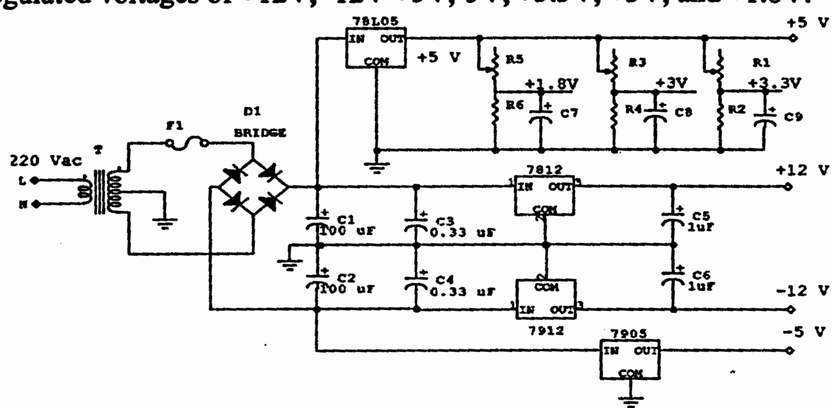


Fig. (9): Electronic circuit that produced regulated voltages of +12V, -12V , -12V +5V, -5,+3.3V, +3V, and +1.8V

Testing the development Machine Vision system for Tomato Sorting (Bito 86) with suitable feed speed and Sensor Height

Measurements

- Sorting Productivity (kg / h).
- Sorting Efficiency (%).
- Power (kW) and consumption energy (kW. H / kg).
- The Cost required for the process of sorting (L.E / h).

Some Measurements connected with crop

❖ **Rotational speed of the rotating shaft:**

This velocity was measured by means of a multi-range hand tachometer

❖ **Electric power:** A digital clamp meter and voltmeter were used for measuring current intensity and voltage respectively. Figure (3.14) represents on image of the used digital clamp meter device. (Suliman and Abd El maksoud, 2001). The electric power (P, Watt) was calculated based on current intensity (I, Ampere) and the voltage (V, volt) measurements, by using Digital clamp meter for measuring current and voltage using the following formula:

$$P = \cos \varnothing . I. V \quad (3.3)$$

Where:

Cos Ø Power factor (being equal to 0.85); and

V= Voltage (220 volt).

3- Net consumptive power:

Net Power requirement was calculated by the following formula:

Net power = Electric power (load) - Electric power (no load)...(3.7)

Net consumptive energy was calculated by the following formula:

$$E = P / Fr \quad (3.4)$$

Where:

E = Net power consumptive, W. h /kg; P = Net power, W; and

Fr = productivity, kg/h.

❖ **Prototype productivity**

Productivity for the developed prototype was calculated by using the following formula:-

$$\text{Prototype productivity,(kg/h)} = Q / t \qquad (3.5)$$

Where: Q = total tomato fruits mass,

kg and T = operational time, h

❖ **Sorting efficiency:**

The total sorting efficiency of the prototype was estimated according to **(Klenin et al., 1985)** and **(Ismail, 1995 in Arabic reference)** and using the following formula:

$$?G = (m1+m2+ m3+) \times 100 / m \,\% \text{ ....(3.6)}$$

Where: ?G = total prototype sorting efficiency(%),

m = total mass of fruit, kg and

m1, m2, and m3= weight of fruit in different collected sorting fruit from collected box A, B, and C, (kg).

RESULTS AND DISCUSSION

- **Problems aroused during developing the machine Vision system:**

1- In primary tests, it was noticed that, the air stream was pushing tomato fruits over its container, this problem was solved by calibrated air stream. It was noticed that, 0.10 m/s for air stream speed was suitable to putting tomato fruits in different containers according its color. And also it is necessary calibrated air stream according any crop. This idea gives good results by putting all fruits in its container.

2- Inserting two fruits together in the same time from open of feeding hopper on conveyor belt, this is lead to decrease sorting efficiency and productivity. This problem was solved by adjusting the open of feeding hopper to allow passes one fruit only.

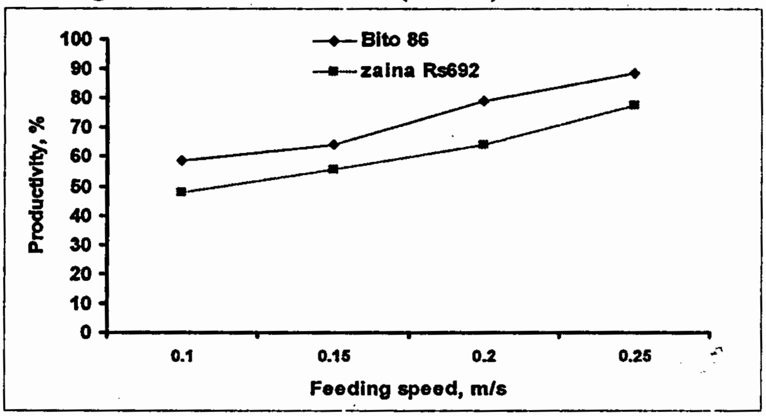
3- Also the first tests show that, more fruit jamming at the end of feeding hopper, sometimes closed the open of feeding hopper and prevent sorting fruits. This problem was solved by narrow the two sides of feeding hopper to feed the fruits one and other respectively.

4- It is noticed that, the distance between fruits and other not regulator. This problem was solved by fixing two sheet fiber on the opening of feeding hopper .This idea put the fruits on distance equal 15 cm and lead to raise sorting productivity and efficiency.

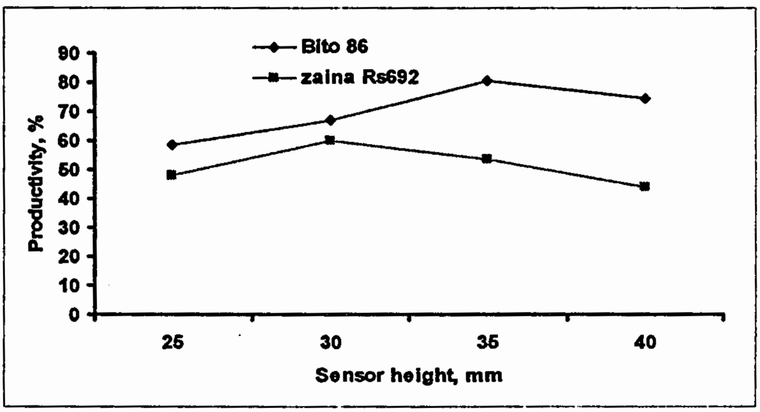
• **Also the result showed that:**

1 - Productivity and efficiency:

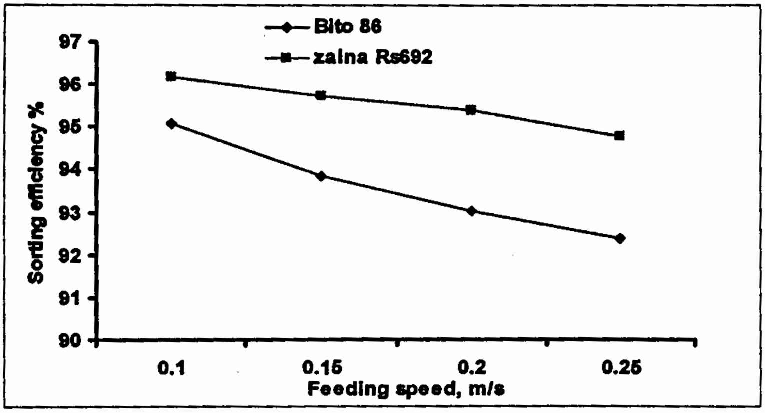
The feeding speed in the range (0.10 to 0.15 m /s) gives the height value of efficiency (97.48 to 96.18%) with productivity of (80.70 to 94.80 kg/h) at sensor height of 35 mm for tomato (Bito86).



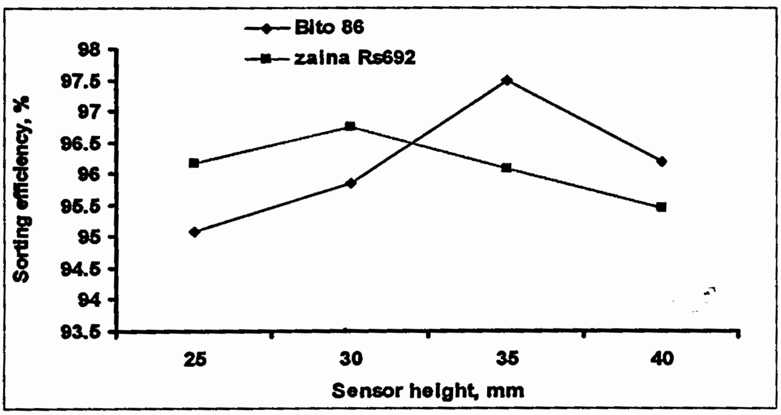
Effect of feeding speed on prototype Productivity, kg/h



Effect of sensor height on prototype Productivity, kg/h



Effect of feeding speed on prototype sorting efficiency



Effect of sensor height on prototype sorting efficiency

2 - Energy unit requirement:

Relating to the effect of feeding speed on energy requirement, the obtained data show that, by increasing feeding speed from 0.10 to 0.25 m/s, the energy requirement decreased from 3.83 to 2.97 Kw.h /ton for tomato crop.(Bito 86)

3 - Operational cost unit:

The operation cost of sorting machine depended mainly on the sorting productivity, required power and workers. Referring to the effect of the previous factors operation cost equal 5.66 L.E / h.

2 - It could be concluding that:

1- Feeding speed in the range (0.10 to 0.15 m /s) gives the height value of efficiency (97.48 to 96.18%) with productivity of (80.70 to 94.80 kg/h) at sensor height of 35 mm for tomato (Bito86). With the energy requirement from 3.83 to 2.97 Kw. h/ton and operation cost equal 5.66 L.E/h.

2- Feasibility of using this prototype for sorting different kinds of fruits and vegetables after simple adjusting.

3 - This prototype increasing productivity and efficiency by using local materials for decrease manufacturing cost.

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زكريا إبراهيم إسماعيل (١٩٩٥) محصول البطاطس – الزراعة – الحصاد –التداول- التخزين . منشاة المعارف بالإسكندرية.

<u>الملخص العربى</u>

تطوير آلة الرؤية الآلية لفرز الطماطم

محمد أحمد الشيخة، جمال السيد، هبه لطفى

الفرز الجيد يؤدى إلي رفع جودة المنتج ويجعله مطابق للمواصفات المحددة لكل درجة في حالة التصدير. وقد لوحظ أن الفرز اليدوي له عيوب كثيرة أهمها التكلفة العالية للعمالة المدربة وعدم توافرها، وانخفاض كفاءتها و معدل إنتاجها بالإضافة إلي تعرض المنتجات للتلوث. وتعتمد الطرق المستخدمة فى الفرز علي الاختلاف في صفة أو أكثر من الصفات الطبيعية للثمار مثل اللون أو الأبعاد أو الوزن أو درجة النضج.....الخ. و نظرا لعدم توفر ماكينات الفرز الصغيرة التي تناسب محطات الإعداد الصغيرة ، وعدم ملائمة ماكينات الفرز الكبيرة للارتفاع الهائل في أسعارها وكذلك عدم انتشار آلات الفرز الالكترونية المحلية الصنع, لذا أجريت هذه الدراسة التي تهدف إلي تصميم

وتطوير وتصنيع وتقييم أداء نموذج لفرز ثمار الطماطم حسب اللون وتصلح لأستخدامها مع بعض ثمار الخضر والفاكهة .وتم تصميم النموذج علي أساس الفرزباللون لثمار الطماطم باستخدام الدوائر الالكترونية والحساسات الضوئية والتحكم الالكترونى فى عملية فرز الثمار.

<u>أهداف الدراسة: -</u>

١- تصنيع نموذج مبدني لفرزثمار الطماطم علي أساس اللون .

٢- دراسة تأثير بعض العوامل الهندسية المؤثرة علي الأنتاجية وكفاءة الفرز واستهلاك القدرة الكهربية للنموذج المبدني الذي تم تصنيعه على صنف من الطماطم (بيتو٨٦) .

٣- تحليل وحساب الطاقة و التكاليف للنموذج المصنع.

<u>مكونات وعناصر نموذج وحدة الفرز</u>

١- الهيكل: وهو المكون الرئيسي للنموذج وتم تصنيعه من الصاج المجلفن بسمك ١ مم و زوايا من الحديد ٤٠×٤٠مم وبسمك ٢مم عن طريق التجميع باللحام الكهربي والمسامير والبرشام.

٢- الحساسات الضوئية: -الألة مزودة بثلاث وحدات من الحساسات الضوئية لفرز الثمار حسب اللون. وكل وحدة من الحساسات تتكون من : -اثنين من الباعثات الضوئية(المرسلة للضوء) وواحد من الحساسات الضوئية(المستقبلة للضوء المنعكس من الثمار)والتى يتم بواسطتها إرسال إشارة كهربية تتوقف على لون الثمار إلي دائرة التحكم الالكترونية

٣- دائرة التحكم الإلكترونية: وهى التى تستقبل الاشارة من الحساسات الضوئية(المستقبلة للضوء المنعكس من الثمار) والتى بدورها تعطى اشارة لتيار الهواء بالانطلاق فيدفع الثمار حسب لونها فى الوعاء المخصص لها .

٤- - وحدة التغذية: ووظيفتها توصيل الثمار إلي وحدة الفرز مفرده وتتكون من (ماتور كهربائى صغير والقادوس المستطيل والسيرالناقل).

<u>عوامل الدراسة</u>: وشملت عوامل الدراسة العوامل التالية

١- اختبار ألة الرؤية الألية التى تم تطويرها فى فرز الطماطم للو صول لأفضل معدل تغذية للثماروكذلك أفضل ارتفاع لوحدة الرؤية الألية.

<u>تقييم نموذج الفرز:</u> وقد تم تقييم النموزج من خلال العوامل التالية

١ - إنتاجية النموذج (كجم/ساعة). ٢- كفاءة نموذج التدريج (%).

٣- القدرة اللازمة (ك وات) والطاقة اللازمة لتشغيل النموذج (ك وات ساعة/طن) .

٤- تكاليف التصنيع وكذلك التكاليف اللازمة لعملية الفرز باستخدام النموذج (جنيه/ساعة).

<u>النتـائج</u>

<u>أولا - أهم المشاكل التى واجهت التطوير</u>

١ – فى الأختبارات الأولية للألة لوحظ أن تيار الهواء يدفع الثماربعيدا عن المكان المحدد لها. هذه المشكلة تم حلها بمعايرة تيار الهواء للوصول للمعدل المطلوب لدفع الثمار فى موضعها المحدد ودون ضرر وكان المعدل المناسب هواستخدام تيار هواء بسرعة ٠,١٠م/ث.

٢ – خروج أكثر من ثمرة من فتحة التغذية فى نفس الوقت مما يعيق عملية التغذية للثمار ويؤدى الى نقص كفاءة الآلة .وقد حلت هذة المشكلة بتعديل فتحة التغذية ليكون قطرها أكبر بقليل من قطر الثمرة لتسمح بمرور ثمرة واحدة فقط

٣ – لوحظ أيضا أكثر من ثمرة تقفز الى فتحة التغذية فتعيق عملية التغذية وقد تغلق فتحة التغذية. وقد حلت هذه المشكلة بتضييق جانبى صندوق التغذية ليسمح بمرور الثمار واحدة تلى الأخرى وهذا أدى الى منع التكدس للثمار ومنع اعاقة التغذية.

٤ – لوحظ أيضا أن المسافة بين الثمرة والتى تليها على سير التغذية غير منتظمة. هذة المشكلة تم حلها بتثبيت أثنين من شرائح البلاستك على فتحة التغذية تم استبدالهما عدة مرات للوصول لأثنين من الشرائح سمحت خاصية المقاومه لهما للحركة بأن تكون المسافة بين الثمرة والتى تليها فى المتوسط على مسافة ١٥ سم .

ثانيا - أهم النتائج

١ – بينت النتائج أن معدل التغذية للثمار بسرعة ٠.١٠ الى ٠.١٥ م/ث اعطى أعلى كفاءة ٩٧,٤٨ الى ٩٦,١٨ % مع معدل انتاج تراوح بين ٨٠,٧٠ الى ٩٤,٨٠ كيلو جرام/ساعة مع ارتفاع لوحدة الرؤية الالية لمسافة ٣٥ سم وذلك للطماطم صنف Bito 86

ثالثا: الطاقة اللازمة لتشغيل النموذج: قد تبين من التجارب :

بزيادة سرعة تغذية الثمار من ٠,١٠ الى ٠,٢٥ م/ث نقصت الطاقة المطلوبة من ٣,٨٣ الى٢,٩٧ كيلوات. ساعة / طن للطماطم صنف Bito 86.

رابعا : حساب تكاليف التصنيع والتشغيل

التكاليف اللازمة لتشغيل الالة كانت ٥,٦٦ جنيه/الساعة. وتتوقف على الانتاجية بالطن .

التوصيات

١ - سرعة سير التغذية فى حدود من ٠,١٠-٠,١٥ م/ث أعطت أعلى قيمة للكفاءة (٩٧,٤٨٪ - ٩٦,١٨) مع معدل انتاج يتراوح بين ٨٠,٧٠ الى ٩٤,٨٠ كيلو جرام/ساعة مع ارتفاع لوحدة الرؤية الالية لمسافة ٣٥ سم وذلك للطماطم صنف Bito 86

٢- هذا النموذج يمكن تنفيذه بحجم أكبر بخامات محليه منخفضة التكاليف و بكفاءة وانتاجية عاليه.

٣- امكانية استخدام هذا النموذج لفرز العديد من ثمار الخضر والفاكهة ويمكن ضبطة ليناسب فرز الثمار المختلفة.