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Design, Construction and Evaluation of Cherry Tomato Sorter Machine

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ABSTRACT

There are very few mechanized and intelligent methods for separating produced, especially agricultural products, and among them, products such as cherry tomatoes, which have a high production rate in Iran, require grading and sorting to help human resources increase productivity and prevent the fruit from opening during harvesting, grading, storage, and shipping to places of consumption. The device was designed using SolidWorks 2019 software, and the data was analyzed with SPSS software and modeled with Abaqus software. This machine is capable of separating the mentioned fruit into three sizes: large, medium, and small diameters. Three treatments were considered based on size, variety, and moisture percentage. After being released on the belt, the fruits entered the perforated roller, which performed the sorting operation in three sizes. The purpose of this research was to design, construct, and evaluate this device, and to introduce a dedicated device for cherry tomatoes as a practical product in Iran. The results showed that by using the device, it was registered and presented for 100 cherry tomatoes and finally provided an acceptable answer with 89% correct separation. Modeling for the machine showed that the size model presented with a coefficient of explanation of 85% was significant. The regression model showed that by increasing the distance between the holes by one unit, the percentage of healthy fruit will increase by 67%. This value can be minimized by eliminating the causes of the error, and as a result, this device can be used for sorting cherry tomatoes with a high degree of reliability and high speed (89% resolution).

1. Introduction

Lycopene, a biologically active phytochemical with health benefits, is a key quality indicator for cherry tomatoes. While Ultraviolet/Visible/Near-infrared (UV/Vis/NIR) spectroscopy holds promise for large-scale online lycopene detection, capturing its characteristic signals is challenging due to the low lycopene concentration in cherry tomatoes. This study improved the prediction accuracy of lycopene by supplementing spectral data with image information through spectral feature enhancement and spectra-image fusion. The feasibility of using UV/Vis/NIR spectra and image features to predict lycopene content was validated. By enhancing spectral bands corresponding to colors correlated with lycopene, the performance of the spectral model was improved. Additionally, direct spectra-image fusion further enhanced the prediction accuracy, achieving, RMSEP, and RPD as 0.95, 8.96mg/kg, and 4.25, respectively (Zheng et al., 2025).

In the modern era, population growth has led to an increase in mango-related issues. One of these is the causes related to agriculture. Farmers around the world have vague and varied views on the integration of technology into agricultural activities. Some of them are eager and focused on cultivating this technology. Others are ways of introducing modern technologies, while most of them are cautious about using technologies to increase efficiency and increase performance (Rakhra & Singh, 2021). Today, the use of machinery in various aspects of agriculture has become more common. Adapted because it helps to improve agricultural machinery have been introduced in all sectors of development (Munar et al., 2021). The priorities of using mechanized planting methods in crop production are determined according to the technical. Economic and social conditions of each society, so increasing the production potential per unit of technology use and machine innovation in agriculture can be effective (Sepehr & Haji Agha Alizadeh, 2022).

Today, the demand for agricultural equipment that requires less time and effort is increasing (Jaberi et al., 2020). Adaptation to the basic planting technology is of particular importance for the cultivation of any agricultural crop because the yield and quality of the crop depend on the financial costs of the seed, the level of plant nutrition, as well as the design

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features of the machinery used. The seeds used in Russia are both Fine-grained and coarse-grained. The amount of seed is regulated in the final density and therefore delays in the growth of individual plans are not allowed. In this regard, serious requirements are applied in the design of the seed planter (Soloviev et al., 2021).

Sorting is a term that refers to the grading and classification of agricultural products. Sorting of agricultural products refers to the grading of various fruits and other agricultural products based on size, color, appearance, and other factors, and the separation of impurities, spoiled fruits, and products (Balistani et al., 2012). In most cases, sorting is considered an introduction to packaging agricultural products. In addition, in the fruit and vegetable markets of modern societies, almost all fruits and vegetables are offered in sorted and labeled form, which makes it easier for customers to recognize the quality of the product and leads to more regular distribution and supply (Balistani et al., 2012). Today, the science and technology of sorting and equipment related to grading and classifying various agricultural products in developed countries have advanced to the point that sorting equipment can be found in most large agricultural units or their vicinity, which will facilitate the initial packaging and transportation of the product and will bring more added value to the farmers of these countries (Balistani et al., 2012). Unfortunately, in Iran, for many people, sorting and packaging of various fruits, packaging of dried fruits, etc. is still considered a fantasy, luxury and luxury, which increases the price of the product supply, and especially the traditional strata of society continue to consume products supplied in bulk and ungraded. Grading and packaging of agricultural products play a role in maintaining, protecting, and standardizing the product, and also, supplying products in the same sizes will help find new foreign markets and increase exports and foreign exchange inflow into the country (Balistani et al., 2012).

The use of intelligent machines in agriculture to raise the quality of the produce, lower production costs, and reduce manual labor is promising. Adoption of robotic technology is inevitable in modern agricultural systems and can increase the efficiency of post-harvest tasks such as sizing and sorting fruits (Rasekhi & Reofat, 2015).

The increasing demand of consumers for high-quality fresh fruits and vegetables has led to an effective movement towards improving the quality of fruits and vegetables, both in the food industry and in the fresh fruit market. Product quality mainly includes the sensory characteristics of the fruit (appearance, texture, taste, and smell), nutritional value, chemical composition, mechanical properties, and the absence of defects in the fruit (Abbott, 1999). The creative mind of man on the one hand and curiosity and welfare on the other hand have caused mankind to undertake many initiatives and inventions. Among these, automation and roboticization of hard, harmful, boring, and repetitive tasks are among the achievements of man in recent years, but the industry is progressing and developing day by day by utilizing different sciences and combining them. The agricultural sector has also found a need for close and comprehensive relations with the industry for progress and productivity. To prevent the wastage of agricultural products, by taking advantage of mechanization, devices have been invented for each product that, while increasing productivity, ensure that healthy, uniform, and sufficient products reach the buyer, and the producers of these products can also produce more products in a short time with the help of these tools (Khalili, 2002).

Due to the lack of attention to the sorting category in Iran, many of the high-quality and unique products of the vast country of Iran, such as saffron, citrus fruits, dates, pistachios, strawberries, various dried fruits (dried fruits, fruit leaves, raisins, etc.), do not have the ability and permission to penetrate and compete in foreign markets due to the lack of compliance with the principles and standards of sorting, packaging and bulk supply, and a significant part of them also becomes waste (Brantley et al., 1975). The steps of the fruit sorting plan production process are carried out as a combination of an automatic system and human power. Initially, the baskets of fruits picked from the orchards are transferred by the operator to the washing basin with a circulation pump and the submerged fruits move forward using a paddle conveyor (Sepehr, 2024); at this stage, they are washed and disinfected. Of course, it is worth noting that this stage depends on the type of fruit entering the machine and may not be performed for some fruits. Then the fruits are automatically placed on the fruit placement cups by a chain conveyor and each cup, depending on the weight of the fruit, empties the fruit into its compartment along the machine. Next to the machine, the production operators collect the fruits graded by weight into the desired cartons or packages and place them on the upper conveyor of the machine for collection at the end of the production line and transfer to the next stage (Cartz, 1995). In some advanced production lines, this section of the feasibility study may also include a computerized fruit scanner that uses special radiation to examine the inside of the fruit so that if there is damage to a part of the fruit, that fruit can be separated from the rest of the product so that it can be used for other applications such as jam or marmalade making (Al-Mallahi et al., 2008). At the end of the line, the fruit cartons are arranged in blocks by the operator and transferred to the palletizing machine using a forklift or pallet jack to be strapped and stacked. In principle, given the high costs of packaging, it is cost-effective to have the cartooning section or at least the carton-forming section inside the factory at the end of the line (Elbatawi, 2008).

The product under consideration in this plan is fruit sorting. In general, the purpose of fruit sorting is to classify and grade fruit types based on size and quality. So that the final product can be presented uniformly and in the same size in different packages in the market and the end customer can be sure of the uniformity of his purchase with the desired brand over time. The final packaging of fruits and vegetables is done after the sorting operation for easy handling and also to protect the sorted final product (Cheng & Haugh, 1994). The features of proper fruit packaging include the absence of harmful and chemical substances in the packaging structure, ease of

Fig. 1. Cherry tomatoes

freezing and storage in cold storage, proper transportability, meeting the final needs of the market in different weights and packages that cover all tastes, appropriate physical strength of the packaging, especially in the case of export sorting of fruits and vegetables, palletizing and correct placement of cartons inside the pallet. Also, the packaging should be such that the inside of the package and the sorted product are completely clear (Spanos & Wrolstad., 1990). Fruit size has a significant effect on other parameters The use of sorted and packaged agricultural products will lead to the development of modern chain stores and the gradual elimination of traditional stores selling agricultural products (Diezma-Iglesias et al., 2004). The results of this action will be a reduction in the growth of small and traditional commercial spaces in residential areas, as well as uniformity in the price of the product offered and a more modern supply and control system (Kim et al., 2004). The sale of various agricultural products, including fruits, vegetables, meat, poultry, nuts, etc., graded and packaged in uniform and standard pieces and sizes, will lead to the growth of e-commerce in the future, and many buyers can purchase sorted and standard packaged products through telephone orders or online shopping, and this will eliminate some of the unnecessary trips within the city that are currently made to search for various agricultural products (Hoseinpour & Abbott, 2011).

(Lalam et al., 2025) introduces a computer vision-based system designed for the automated grading and sorting of agricultural products based on their size and maturity. The proposed machine vision system aims to replace traditional manual methods commonly used for sorting and grading fruits. Manual inspection often struggles to ensure consistency in grading and uniformity in sorting. To address these challenges and enhance the quality of fruit grading, image processing, and machine learning algorithms can be employed. Key attributes such as the fruit's shape, color, and size can be analyzed to enable a non-destructive approach to classification and grading. Automation of these processes becomes feasible when standardized criteria for grading are established. Such systems offer faster operations, save time, and reduce manual labor, making them highly valuable to meet the increasing demand for premium-quality agricultural produce.

The purpose of this research is to design, construct, and evaluate this device, and to introduce a dedicated device for cherry tomatoes as a practical product in Iran.

2. Materials and Methods

This project was carried out in the Biosystems Mechanical Engineering Laboratory of Bu-Ali Sina University, Hamadan. In this study, a cherry tomato variety was designed as a laboratory sample using SolidWorks 2019 software; and finally, SPSS 2019 software was used for data analysis. The modeling was performed with Abaqus 2018 software to extract the diameter of the roller holes. Small, medium, and large sizes of this type of tomato were used randomly from the fruit and vegetable market of Hamadan province. The varieties used were three varieties of Selin, Canyon, and Red Stretched in three treatments in the form of RCBD[1] design Fig. 1 Other parameters of handling, health, and cleanliness were also taken into account (because dirt affects the size of the hole design).

In this design, 100 cherry tomato samples were initially selected, such that 35 cherry tomatoes were within the size range of 15mm, 35 cherry tomatoes were within the size range of 15 to 20mm, and 30 were within the size range of 20 to 25mm. By separating these tomatoes by manual measurement (with calipers), the tomatoes were graded visually and in real terms. Then, the fruits were labeled. In this way, fruit number one was the smallest, number two were medium, and number three were the largest, and were placed in their respective block treatments.

Torque: The nominal torque was calculated using the Eq. 1:

$$T=\frac{9.55\times P\times 1000}{n} \tag{1}$$

1. Randomized Complete block design (RCBD)

In this relation, P is the output power in kilowatts and n is the speed in revolutions per minute. It should be noted that if the voltage deviates from the nominal value within the permissible range, the locked-rotor torque, pull-up torque, and breaking torque will change approximately as the square of the voltage.

Voltage: Increasing or decreasing the voltage beyond a certain limit can affect the performance of the motor. A 10% increase in voltage from the nominal value will increase the starting torque by 20%, which can damage the motor due to increased current at the nominal load and heat.

Frequency: Changes in frequency can affect motor characteristics such as torque and speed.

Altitude: Another factor that affects the performance is altitude. Electric motors are usually rated for altitudes up to 1000 meters above sea level. At altitudes above this value, the air is thinner and heat does not transfer easily.

2.1. Power, Torque, and Speed Relationships

The relationship between the power and torque of an electric motor is given by Eq. 2:

$$P = T \times \omega \tag{2}$$

Where:
P: Mechanical power (w)
T: Torque (N.M)
ω: Angular velocity (radi.s)

Using these parameters and calculations, we selected our engine. A tarpaulin belt was used to hold the tomatoes. An electric motor mounted on a four-legged chassis was used to rotate the roller and conveyor belt. The power was transferred to the conveyor belt and roller through a metal chain wheel. To prevent the tomatoes from falling off the sides of the conveyor belt, a 1mm thick metal sheet with a height of 10cm was used as a wall. To prevent the fruit from slipping on the rotating roller, the friction of the roller was increased by roughening the inner surface of the roller. Table 1 shows the materials used in the production of this machine.

Table 1. Material of manufactured parts

Part	Material
Roller bearing	One millimeter cold metal sheet
belt	Tarpaulin
bases	2×3 cans (hot foil)
Collection box	Compressed plastic
Gear	St37

3. Method

3.1. Effective farm capacity

Since it is practically impossible to measure the effective parameters in calculating the field capacity in test plots with a length of 100m, so in the plot of land of the experimental farm with a length of 200m, and the same working conditions as the test plots round trip times and bypasses and lameness at work were measured and finally the effective field capacity was calculated using Eqs. 3 and 4.

$$C_e = \frac{w \times s \times \eta_f}{10} \tag{3}$$

Where in:
C_e : Effective farm capacity (ha/h)
W: working width (*m*)
S: forward speed (*Km/h*)
ς_f : Field yield according to Eq. 4.

$$\eta_r = \frac{T_t}{T_e + T_a + T_n} \tag{4}$$

Where in:
T_t : Net of effective time spent to operate is in minutes
T_o: Total time (T_e+T_a+T_h)

3.2. Use Method

The way the machine works is that after collecting the fruit inside the box, it is released onto the belt, and the electric motor is turned on. Then the conveyor belt, which is sealed by pulleys at both ends, receives power from the electric motor and rotates the belt. As the belt rotates, the tomatoes start moving and are discharged into the rotating roller. The rotating roller also receives its rotational power from the electric motor and rotates. The rotating roller is positioned at an angle of 25 degrees from top to bottom so that the tomatoes move inside the plate.

3.3. Design

SolidWorks software has been used to design this machine. The turntable is divided into three sections, each with a different diameter (The size of the cylindrical meshes has been based on measurements taken on the tomatoes). A plastic box is placed under each section to collect the product. Then the product is sorted and packaged in order from smallest to largest.

The components of the cherry tomato sorting system are as follows:

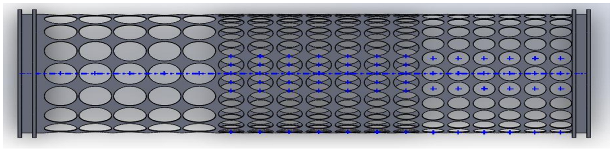

Fig. 2. Perforated rotating roller

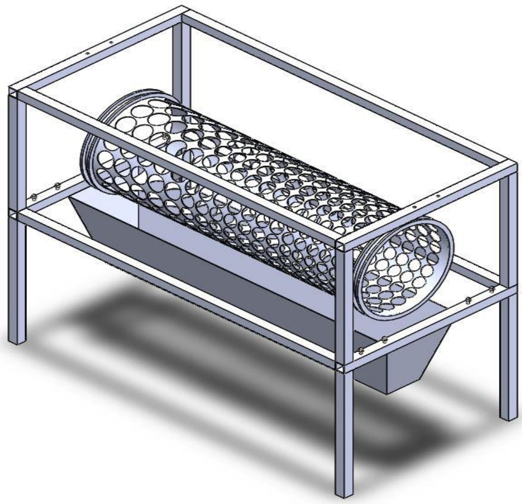

Fig. 3. Perforated rotating roller

3.3.1. Part one: Computer design designed and implemented with SolidWorks software.

3.3.2. Part two: Cutting and welding of sheets and chassis.

3.3.3. Part three: Skeleton and chassis on which the conveyor belt, pulleys, and retaining plates are mounted.

3.3.4. Part four: Electric motor, collection boxes, dividing valves, and sprockets.

The overall design of the designed parts of the device is shown in Fig s.2 to 5.

3.4. Modeling

For modeling, the physical properties are required as shown in Table 2 (Humidity, Density, Modulus of elasticity, Poisson coefficient, Adhesion, Surrender stress ratio, Dilation angle, and Size).

4. Results and Discution

To evaluate and determine the accuracy of product separation detection, the values obtained for 100 cherry tomatoes were performed under the following conditions, and the accuracy of the device was determined. In this design, 100 samples were initially selected from the available samples, and three blocks were used. So in block 1, 35 tomatoes were in the size range of 15mm (first treatment), 35 were between 15 and 20mm (second treatment) and 30 were in the range of 20 to 25mm (third treatment); the numbers and results obtained are shown in Table 3 and interpreted in Fig. 6.

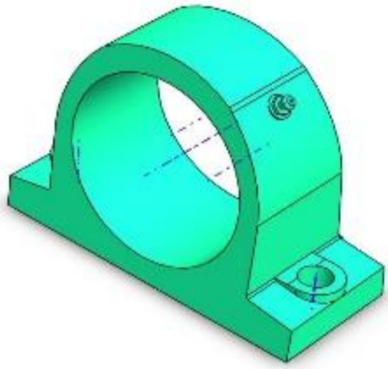

Fig. 4. Bearing

As shown in Fig. 6, an error of less than 8% is observed in comparing sorting by machine and manual sorting. In the repeated and monthly analysis obtained by consecutive measurements for these 100 samples in 30 consecutive days of operation with the device, and using data analysis, the test significance percentage was 89%.

These numbers indicate that the error percentage in the fruit sorting method is low in terms of dimensions (Diezma-Iglesias et al., 2004). In Table 4, the variance analysis of the measured parameters is shown.

Table 5 shows the measured parameters for extracting the regression model of Fig. 7.

The variable entered into the regression Eq. is the core of the regression analysis, which is shown in Table 7. Eq. 5 shows the regression formula.

$$\mathbf{Y= a + b} \qquad (5)$$

Y: the predicted value of a dependent variable, a: width from the origin of the point of intersection of the regression line with the y-axis extracted from the table of regression coefficients, b: the slope of the line (unstandardized regression coefficient (B)) and x: different values of the independent variable (size).

In Table 7, the regression equetion. was calculated using the unstandardized coefficient column of Table 6 for percentage of crushing and distance. The values presented were for all three blocks.

It can be said that by increasing one unit of each independent variable, the dependent variable will increase by the amount of the written coefficient, or in other words, by increasing one unit of distance in each block, the first treatment will increase by 0.231, the second treatment by 0.124, and the third treatment by 0.356 standard deviations of healthiness. This increase is evident in the calculated values, resulting in a positive relationship.

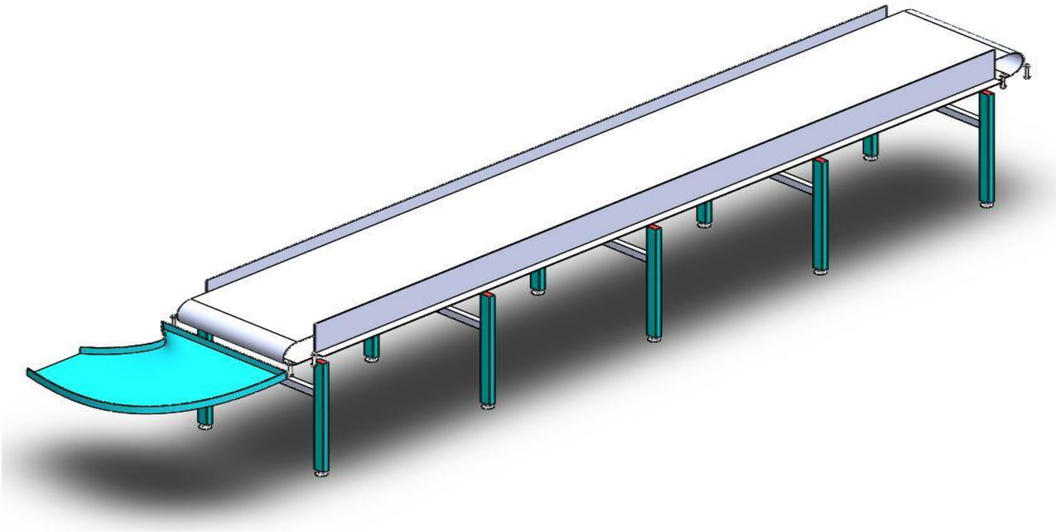

Fig. 5. Conveyor belt

Table 2. Measured parameters cherry tomato

Humidity	Density	Modulus of elasticity	Poisson coefficient	Adhesion	Surrender stress ratio	Internal friction valves (Drucker-Prager)	Dilation angle	Size
15%	0.015 g m^{-2}	2000Kpa	0.3	26.12Kpa	0.78	36	20	18-130 mm

Table 3. Data analysis results

Block 1 (Seline No.)			
Method	Treatment 1	Treatment 2	Treatment 3
Visual separation	35	35	30
Device separation	6	34	30
Number of errors	1	1	0
Error percentage	4%	4%	0%
Block 2 (Canyon number)			
Method	Treatment 1	Treatment 2	Treatment 3
Visual separation	36	36	35
Device separation	10	35	35
Number of errors	0	1	0
Error percentage	2%	2%	0%
Block 3 (Red number drawn)			
Method	Treatment 1	Treatment 2	Treatment 3
Visual separation	34	35	34
Device separation	33	33	32
Number of errors	2	1	1
Error percentage	3%	2%	1%

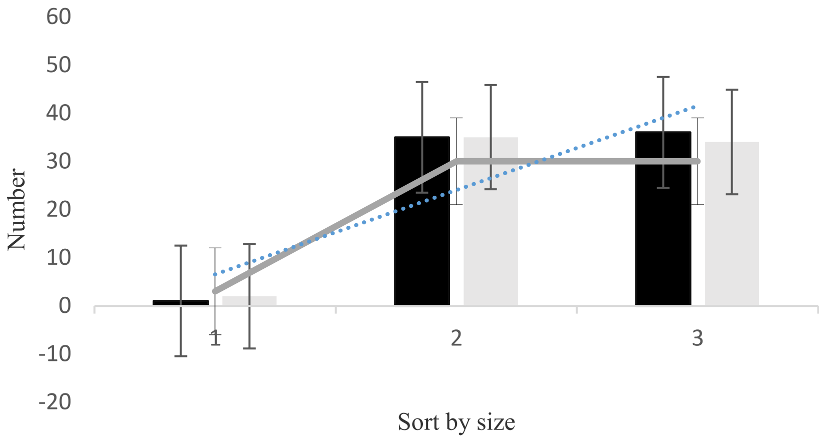

Fig. 6. Comparison of the sorter device and the manual method (actual measurement)

Table 4. Analysis of variance of the evaluated parameters (visual separation, device separation, number of errors and percentage of errors)

Sources of changes	Average of Squares			
	Device separation	Visual separation	Number of errors	Percentage of errors
Block	9.45**	368.96^{ns}	1	80*
Treatment 1	9.45**	3.84*	1	60*
Treatment 2	9.45**	6.93*	1	70*
Treatment 3	9.45**	4.15*	0	80*
Error	9.45	63.45	0.5	9.6
Coefficient of variation	10	9	0.5	13

ns, *, **: non-significant and significant at the five and one percent levels, respectively.

Table 5. Reading of measured parameters

Correlation percentage of crushing percentage	Correlation of distance between fruits in terms of size	The average percentage of health	Average hole spacing	The average value of the crushing percentage	Average size	Treatment
0.211	0.670	65	125.29	30	91.66	1
0.465	0.618	70	83.53	32	97.52	2
0.611	0.600	80	100.63	33	130.66	3

Fig. 8 shows the designed overview of the device.

Many postharvest characteristics of cherry tomatoes, such as shelf life and edible quality, depend on the time of harvest (Elbatawi., 2008). Therefore, if it is possible to determine the quality of the fruit, it is possible to indirectly predict the time of harvest (Elbatawi., 2008). Common methods for examining the internal quality of fruits include: visual, sensory, measurement, or destructive methods (Cheng & haugh., 1994). So the evaluation of color, shape, size, and mechanical firmness has been studied in various studies (Lalam et al., 2025). Because the shape and size of fruits and vegetables change during the growth period, examining the changes in these parameters is considered one of the simplest methods for measuring the quality of the product.

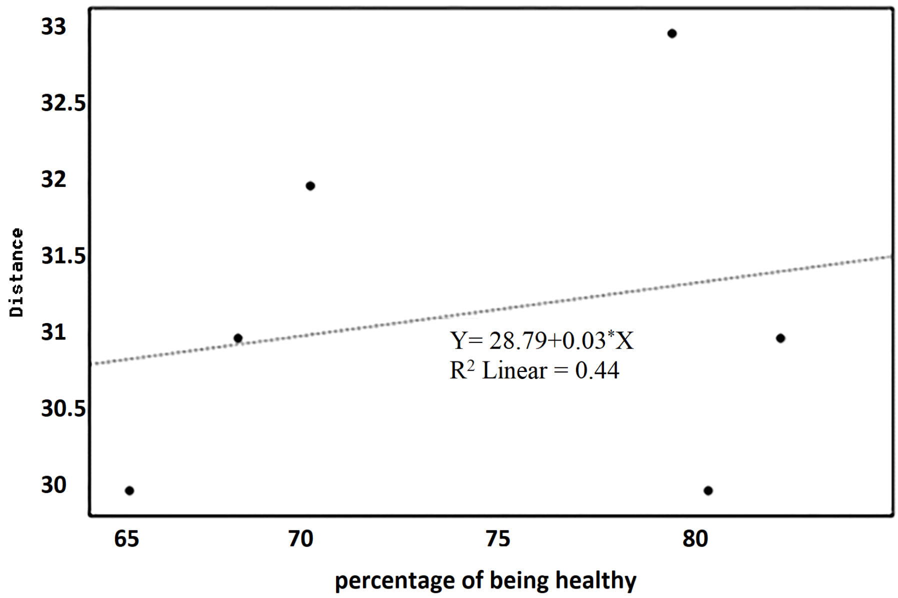

Fig. 7. Regression model and correlation between crushing percentage and distance

Table 6. Significance of regression coefficients

Treatment	Model	Non-standard coefficient		Standardized coefficient
		B	Std. error	Beta
1	Fixed value	0.544	0.118	0.465
	Crushing percentage	0.231	0.198	
2	Fixed value	0.673	0.061	0.495
	Crushing percentage	0.124	0.188	
3	Fixed value	0.534	0.095	0.573
	Crushing percentage	0.356	0.294	

Table 7. Regression formula and values

Block	Formula	Calculated value
1	$Y=0.534+(0.231)^*X$	0.623
2	$Y=0.673+(0.124)^*X$	0.667
3	$Y=0.534+(0.356)^*X$	0.583

4.1. Modeling

The Drucker-Prager behavioral model (Fig. 9a) compared to the Mohr-Coulomb model (Fig. 9b) had a good fit with the experimental data with a coefficient of determination of 85%.

Fig. 9 shows that the significance of the designed interval is 85%.

5. Conclusions

The results show that the most basic way to increase product quality is to separate them in terms of their dimensions; therefore, the best method for dimensional separation is to use a dimensional sorter device that is designed and manufactured with the above materials. The results of this research can be used for tomato processing for

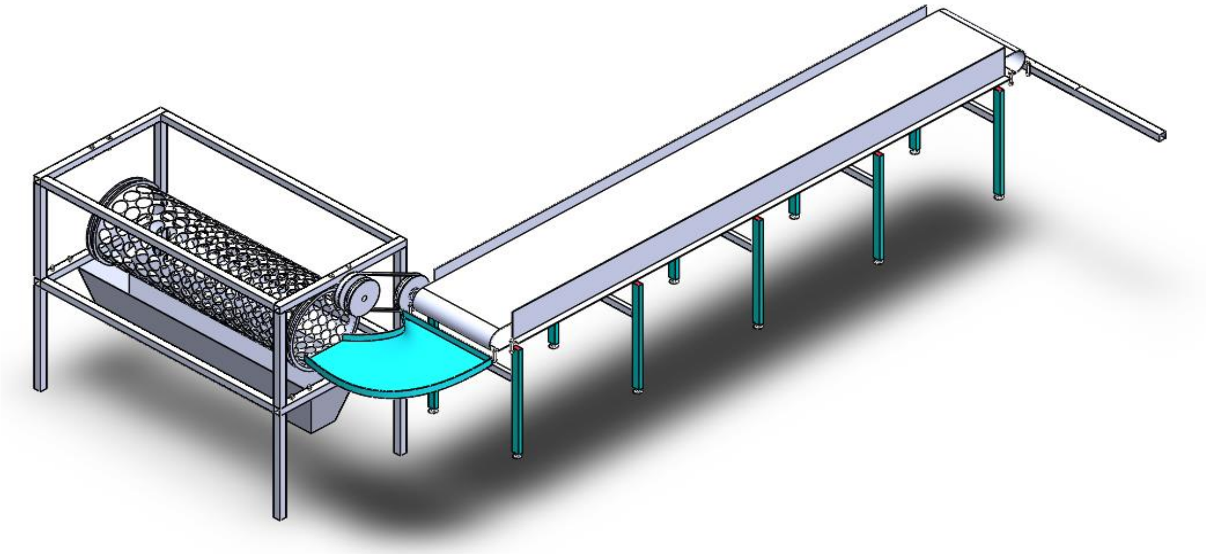

Fig. 8. Designed view of the device

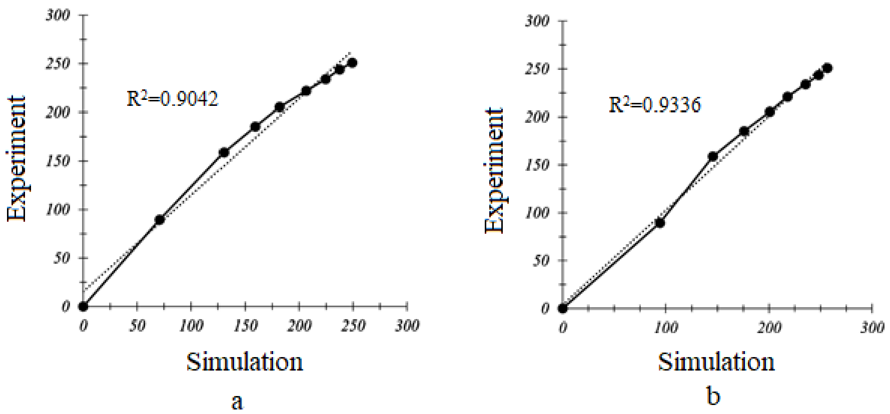

Fig. 9. Coefficient of Explanation A) Drucker-Prager Model B) Mohr-Coulomb Model

food industry factories. The results of this research can also be an introduction to the design and manufacture of similar devices. Among the methods for quality measurement of agricultural products, the dimensional separation method is a low-cost and acceptable method for the beginning of the process of increasing product quality. This increases the accuracy of other methods (spectrometry, non-destructive methods, etc.) for increasing product quality, and it is also better than other methods in terms of non-destructiveness, low cost, etc., and can be disseminated for sorting various agricultural products. Sepehr et al. (2022) confirmed this block-sorting method. After performing the sorting operation by machine, we found that there was an error of 4% in box one, 4% in box two, and 0% in box three. By repeating this operation daily for a month, an error rate of 11% was obtained, which indicates an acceptable value for the sorting operation by the manufactured machine, which was also confirmed by Balestani et al. (2012). This value can be minimized by eliminating the causes of the error, and as a result, this device can be used for sorting cherry tomatoes with a high degree of reliability and high speed (89% resolution). The modeling behavior model with 85%.

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