Determining of some physical and mechanical properties for designing tomato fruits cutting machine

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Abstract: The present study aimed to determine some physical and mechanical properties of Nesma, Masa and 2020 tomato cultivars that are considered as a database for tomato cutting machine designing and development. The physical properties were studied the axial dimensions, average diameter, arithmetic diameter, geometric diameter, mass, density, surface area, packing coefficient, sphericity, and aspect ratio of the tomato fruits. The mechanical properties were studied the static coefficient of friction and the firmness. The results showed that the average value of axial dimensions, the high (*H*), largest diameter ($D_{max.}$), and lowest diameter (D_{min}.) of samples was 73.98, 69.26 and 61.03, 63.28, 59.89 and 53.32, and 70.99, 53.86 and 49.60 mm for cultivars of tomato fruits Nesma, Masa and 2020, respectively. The average value of arithmetic diameter, Geometric diameter of three cultivars of tomato were 69.26, 58.76, 58.11 and 67.69 , 58.52, 57.33 mm, respectively. And the mean value of mass and density were 181.74, 120.14, 109.96, and 0.991, 0.991, 0.972 g cm^{-3} respectively. While the mean value of the surface area, packing coefficient, sphericity, and aspect ratio were 144.61, 107.93, 103.65 cm^2, 0.533, 0.572, 0.562., 92.13%, 92.67%, 81.11%, and 94.48%, 94.99%, 76.39 % respectively for three. The lowest values of static coefficient of friction were 0.427, 0.266, 0.242 with plywood while the highest value was 0.566, 0.310, 0.388 with rubber of three cultivars respectively. And means values of the firmness were 4.70, 5.95, and 4.9 N cm^{-2} for three cultivars, respectively. The results obtained may be beneficial to developers and manufacturers of harvesting, transporting, handling, packing, sorting, grading, and cutting tomatoes for drying purposes.

Keywords: tomato fruits, sun drying, physical and mechanical properties, cutting machine

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1 Introduction

Egypt occupies the fifth center globally in the production of tomatoes, with an annual production volume of close to 7 million tons (FAO, 2020), but the tomato crop is exposed to loss in the harvesting and production stages and during processes of transporting and handling, as well as a significant loss in the level of product quality. Therefore, the sun drying of tomatoes is one of the technical solutions to reduce the losses in this strategic crop (Bahaa, 2020). One of the limiting factors that influence tomato's economic value is its relatively short shelf life caused by pathogen attack (Samuel and Orji, 2015), and due to different postharvest physiological, physical, and chemical changes that occur during storage (Fagundes et al., 2015). The production of dried tomato is proportional to the conditions of Egypt's weather in winter (Luxor and Aswan) and in summer (northern Egypt). The production period (sun drying) in Egypt can reach 8 months of the year, which is the longest period of production. The preferred varieties for drying are often the solid varieties at harvest and fully colored, which contain a large content of total solids. Most tomato

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drying projects lack the mechanization of cutting, the cutting is still done manually by women laborers, and lacks full information about the physical properties of the preferred tomato varieties for drying. Tomato fruit quality is substantially reduced by bruise damage, the occurrence of bruising depends on the direct mechanical damaging of the tomato and the subsequent action of cell wall-related proteins. The shape, color, size, texture, shelf life (maturity) and visual flaws are mainly inspected to evaluate the outside quality of ripe fruits (Naik and Patel, 2017). The physical properties of tomato are important to design the equipment for processing, transportation, sorting, separation, and storing. Designing such equipment without consideration of these properties may yield poor results. Physical and mechanical properties of agricultural materials are essential for the design of equipment for harvesting, handling, cleaning, separating, grading, processing, and storing. Therefore, specific knowledge is necessary for associating many problems with the design or development of a specific machine, and for the analysis of equipment and systems used to process food on a commercial production scale (Abd-Elhay, 2017). The physical and mechanical properties of tomato and revealed that moisture content and weight density of fruits decreased while loss and volume shrinkage increased with storage period (Varshney et al., 2007). The structural and geometrical properties of two tomato cultivars, namely Fenguan906 and Jinguang28, ware average height, diameter, arithmetic mean diameter, geometric mean diameter, surface area, volume, mass, bulk density, and porosity of tomato fruits (Li et al., 2011).

The objectives of this study are to determine some physical and mechanical properties of three varieties of tomato. To obtain information that could contribute database designing to the development and design of machinery for harvesting, sorting, grading, handling, and visualizing the appropriate design for the cutting machine of the tomato.

2 Material and methods

Three different cultivars of fresh tomato fruits are custom for sun drying were used in this study. The commercial F1 hybrid Nesma, Masa and 2020 of tomato (Solanum lycopersicom Mill.) (Importer Mecca TRADE Co. as PETO SEED product, USA). The fruits were obtained from the tomato sun drying project at Al-Qurnah Agricultural Secondary School (25 °43' 05.6" N 32 ° 37' 19.2" E) in Luxor Governorate, Egypt in February 2020 and kept inside polyethylene bags in a refrigerator at 4 ℃ prior to carrying out the measurements. The measurements and testing were carried out the day after the harvest in the Fac. of Agri. Eng., Al-Azhar U., Assiut branch (27 ° 12' 24.7" N 31 ° 09' 55.4" E). The moisture content of three varieties (Nesma, Masa and 2020) of tomatoes was determined by drying method in a hot air oven at 105 ℃ for 24 hours. This test was repeated six times.

2.1 Tomato fruits physical properties

2.1.1 Axial dimensions

One hundred fresh tomato fruits were randomly selected for each of verity. three principal dimensions the height (*H*), the largest diameter ($D_{max.}$), and the smallest diameter ($D_{min.}$), where ($D_{max.}$ and $D_{min.}$) is a plane perpendicular to a polar axis as shown in Figure 1, this method has been successfully used in other fruits by several researchers (Li et al., 2011; Ghaffari et al., 2015), These dimensions were measured with a digital Vernier-caliper with an accuracy of 0.01 mm.

2.1.2 Average diameter

The average diameter was calculated by the arithmetic mean and geometric mean methods of the axial dimensions. The arithmetic means diameter (*Da*, in mm) and geometric mean diameter (D_g, in mm) of the tomatoes fruit were calculated using the following equations according to Karababa (2006) and Goyal et al. (2007):

$$D_a = (H + D_{max.} + D_{min.})/3 \quad (1)$$

$$D_g = (H \times D_{max.} \times D_{min.})^{\frac{1}{3}} \quad (2)$$

Where:

H= height (mm), $D_{max.}$ = width or maximum diameter (mm), and $D_{min.}$ = thickness or minimum diameter (mm).

2.1.3 Surface area

The surface area is defined as the outside total area of the fruit. The surface area of tomato fruits is a very important characteristic in determining both volumetric and gravimetric heat transfer coefficient and it is also useful for analyzing heat and moisture transfer during drying processes. The surface area of tomato fruits (S_A) in mm^2 was calculated by using the following equation according to Moradi et al. (2017).

$$S_A = \pi(D_g)^2 \quad (3)$$

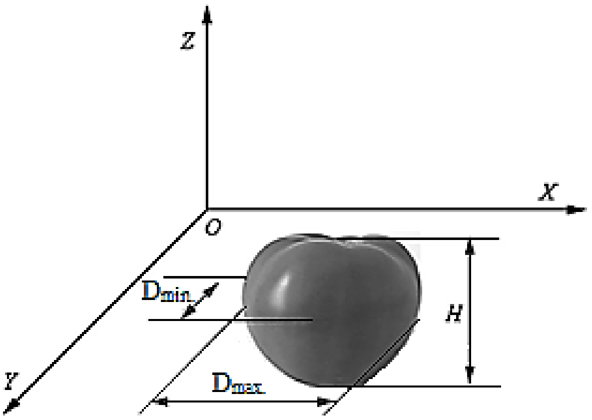


Figure 1 Tomato fruit axial dimensions

2.1.4 Sphericity and aspect ratio

The sphericity (S_p,%) was calculated by using the values of the geometric mean diameter and high from Equation 4, and the aspect ratio (R_a,%) which relates the fruit width to high of the fruits will be determined by Equation 5 according to Moradi et al. (2017).

$$S_p = (H \times D_{max.} \times D_{min.})^{\frac{1}{3}}/H \times 100 \quad (4)$$

$$R_a = D_{max.}/H \times 100 \quad (5)$$

2.1.5 Mass

Determine a single tomatoes fruit mass (g) for each variety separately using a digital electrical balance with an accuracy of 0.01 g.

2.1.6 Density

Density of tomato fruits was determined according to (Mahmoud and Elkaoud, 2019), and calculated by using the following equation.

$$\rho_d = M/V_c \quad (6)$$

Where:

ρ_d= relative density (kg m^{-3}), M = mass of the fruit (kg), and V_c= volume of the fruit (m^3).

2.1.7 Packing coefficient

The packing coefficient was defined by the ratio of the volume of fruits packed to the total and calculated by the Equation 7 according to Moradi et al. (2017).

$$\lambda = V_c/V_0 \quad (7)$$

Where:

λ = packing coefficient, V_c = volume of the fruit (mm^3), V_0 = volume of the box containing fruit (mm^3).

2.2 Mechanical properties

2.2.1 Coefficient of static friction

The static coefficient of friction of the fruits was determined with respect to each of the following four structural materials namely, stainless steel, plastic, rubber, and plywood with fruits parallel to the direction of motion. The fruits are placed as a group bonded together on a horizontal surface then the angle of inclination is gradually increased until the fruits begin sliding without rolling. For each fruit group of an average sample of 10, the friction was determined. The angle of inclination was read from a graduated scale and the coefficient of friction was taken as the tangent of this angle (Mahmoud and Elkaoud, 2019).

$$\mu = \tan\beta \quad (8)$$

Where:

μ = static coefficient of friction.

β = angle of inclination.

2.2.2 Firmness

Penetrometer, made in Italy, with an accuracy of (0.1 kg cm^{-2}) was used to determine the firmness of the three identified tomato varieties. Firmness was measured by applying pressure slowly in a direction perpendicular to the surface of the fresh fruit and then taking the indicator reading. The cylindrical probe with a circular edge, which had 0.6 cm diameter.

2.3 Regression models

Fruit volume can be estimated based on the arithmetic mean diameter which depended on independent variables of the three dimensions (H, $D_{max.}$ and $D_{min.}$), and mass of the fruit. Towards this end, MATLAB® 2019 (MathWorks Inc.) software. The model obtained with three variables for predicting the volume of tomato fruits was:

The overall model is based on the following equation:

$$V_{N.} = a_1 + b_1 M + c_1 D_a \quad (9)$$

$$V_{M.} = a_2 + b_2 M + c_2 D_a \quad (10)$$

$$V_{20.} = a_3 + b_3 M + c_3 D_a \quad (11)$$

Where:

$V_{N.}$, $V_{M.}$ and V_{20}. are volumes (cm^3) of tomato fruits for Nesma, Masa and 2020, respectively. While a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2 and c_3 are coefficients of regression, M is mass (g) of fruits, and D_a is arithmetic mean diameter (mm).

3 Results and discussion

Results summary of some physical and mechanical properties of three cultivars of tomato were determined and presented in Table 1 and Table 2. All properties were measured at a constant moisture content d.b.,% to fresh tomato fruits. The average moisture content of the tomato fruits Nesma, Masa and 2020 was determined as a 62.57%, 68.58% and 69.36% respectively.

3.1 Physical properties of the fruits

3.1.1 Axial dimensions

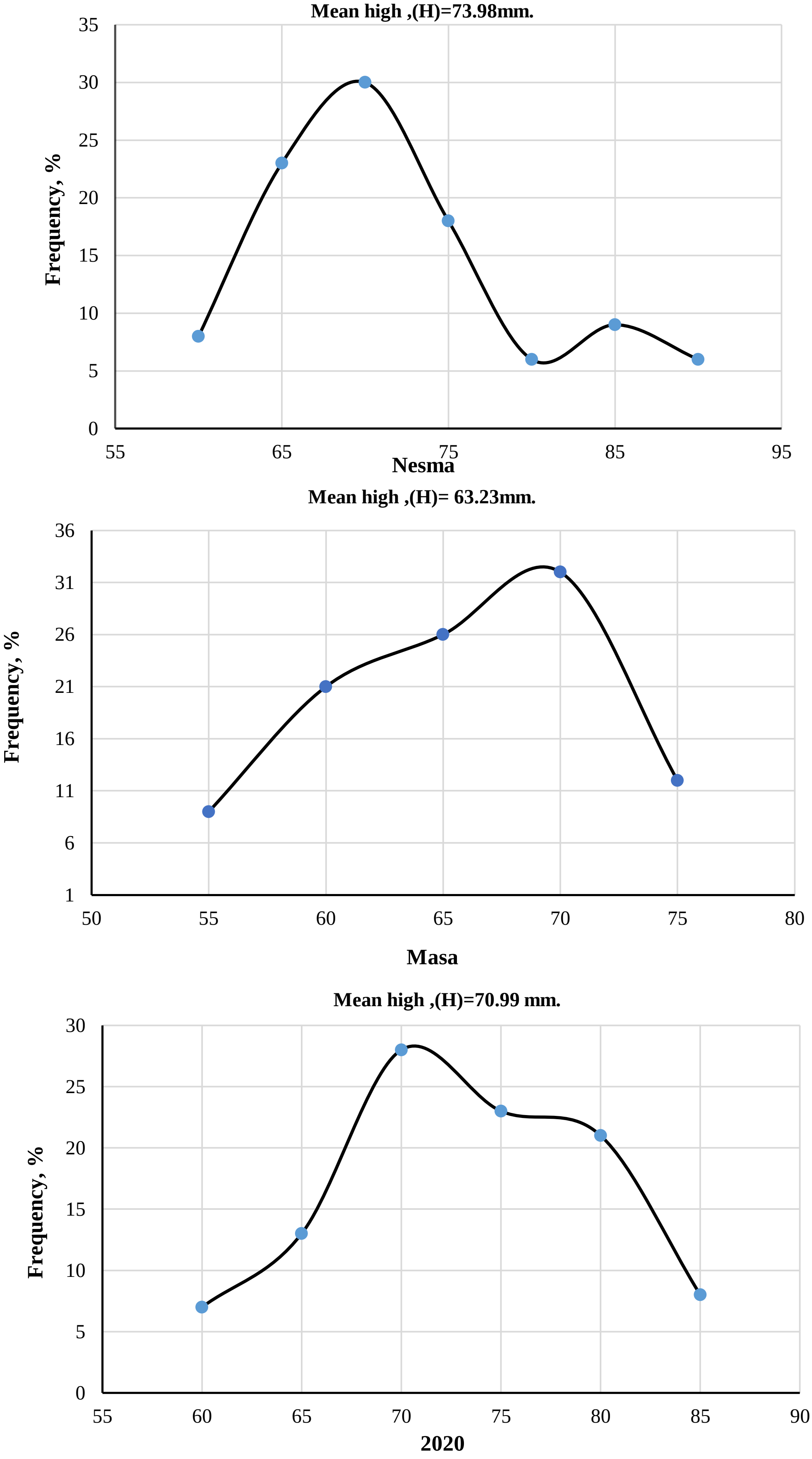
Determining the physical properties of tomato samples are presented in Table 1. The value of maximum, minimum, and average high (H) of samples was 94.80, 60.42 and 73.98 ± 8.97 mm, 70.53, 54.82 and 63.28 ± 5.18 mm, and 80.74, 58.66 and 70.99 ± 6.78 mm for cultivars of tomato fruits Nesma, Masa and 2020, respectively. As noted, the value of maximum, minimum, and average largest diameter (D_{max}.) of samples 87.88, 60.00 and 69.26 ± 6.45 mm, 67.16, 49.80 and 59.89 ± 4.19 mm, and 60.31, 47.53 and 53.86 ± 3.98 mm for cultivars of tomato fruits Nesma, Masa and 2020, respectively. While the value of maximum, minimum, and average lowest diameter (D_{min}.) of samples was 75.88, 55.00 and 61.03 ± 4.59 mm, 61.85, 44.88 and 53.32 ± 4.36 mm, and 60.10, 45.75 and 49.60 ± 3.07 mm for cultivars of tomato fruits Nesma, Masa and 2020, respectively.

Table 1 Physical properties of three cultivars of tomatoes (Sample size 100 fruits)

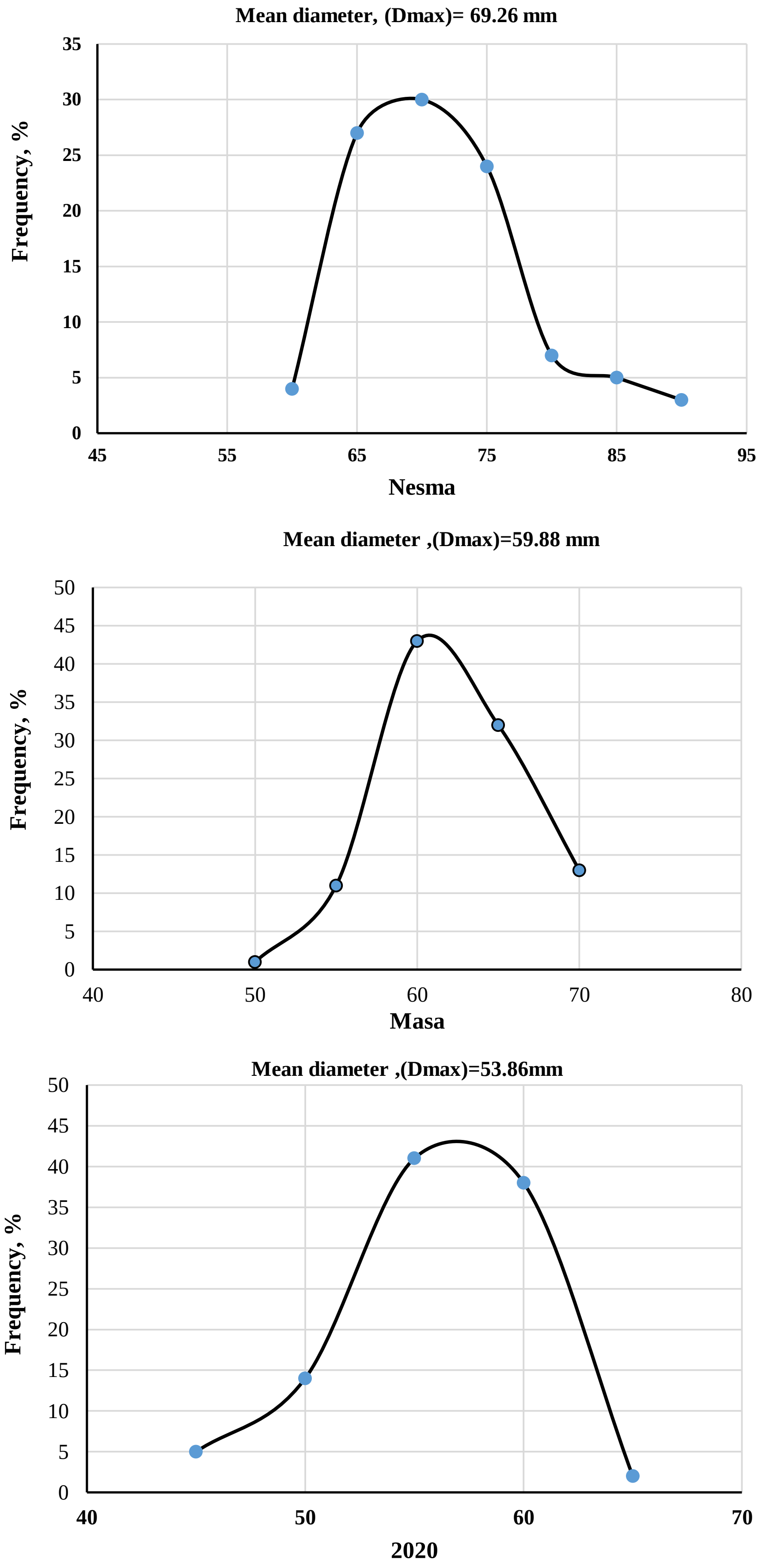
Properties		Nesma			Masa			2020		
		Max.	Min.	Mean ± SD	Max.	Min.	Mean ± SD	Max.	Min.	Mean ±SD
Axial dimensions, (mm)	L	94.80	60.42	73.98 ±8.97	70.53	54.82	63.28 ±5.18	80.74	58.66	70.99 ±6.78
	$D_{max.}$	87.88	60.00	69.26 ±6.45	67.16	49.80	59.89 ±4.19	60.31	47.53	53.86 ±3.98
	$D_{min.}$	75.88	55.00	61.03 ±4.59	61.85	44.88	53.32 ±4.36	60.10	44.75	49.60 ±3.7
Arithmetic mean diameter, mm	D_a	84.91	59.77	68.04 ±5.04	65.54	50.04	58.76 ±3.53	66.32	50.36	58.11 ±3.84
Geometric mean diameter, mm	D_g	84.65	59.68	67.69 ±4.89	65.49	49.90	58.52 ±3.52	65.79	50.02	57.33 ±3.73
Equivalent diameter, mm	D_e	84.77	59.75	67.3 ±7.18	65.50	50.38	58.769 ±4.7	65.52	50.08	57.827 ±4.405
Aspect ratio	R_a	114.40	67.64	94.48 ±10.49	111.62	74.93	94.99 ±7.36	92.85	59.49	76.39 ±7.64
Sphericity, (%)	S_p	100.48	74.71	92.13 ±6.57	100.12	79.54	92.67 ±4.84	90.19	70.36	81.11 ±4.97
Surface area, cm^2	S_a	225.03	111.85	144.61 ±21.45	134.66	78.17	107.93 ±12.86	135.91	78.57	103.65 ±13.51
Mass, gm	M	295.80	101.66	181.74 ±33.34	155.0	77.45	120.14 ±23.75	152.44	70.56	109.96 ±20.1
Density	ρ	0.996	0.984	0.991 ±0.002	0.994	0.987	0.991 ±0.002	0.985	0.686	0.972 ±0.029
Packing coefficient	P_a	0.555	0.511	0.533 ±0.014	0.588	0.543	0.572 ±0.015	0.576	0.544	0.562 ±0.012

Figure 2 showed that the frequency distribution curves of dimensions (H, $D_{max.}$, and $D_{min.}$) measured for one hundred samples of each cultivar for three cultivars of tomato fruits. The highest frequencies of high (H) of samples were 23%,32% and 28% at (65 – 70 mm), for three cultivars of tomato fruits Nesma, Masa and 2020 respectively, the highest frequencies of largest diameter ($D_{max.}$) of samples were 30% at (65 – 70 mm), 43% at (55 – 60 mm) and 41% at (50 – 55 mm), for cultivars of tomato fruits Nesma, Masa and 2020 respectively, and the highest frequencies of lowest diameter ($D_{min.}$) of samples were 53% at (55 – 60 mm), 39% at (50 – 55 mm) and 58% at (45 – 50 mm), for cultivars of tomato fruits Nesma, Masa and 2020, respectively.

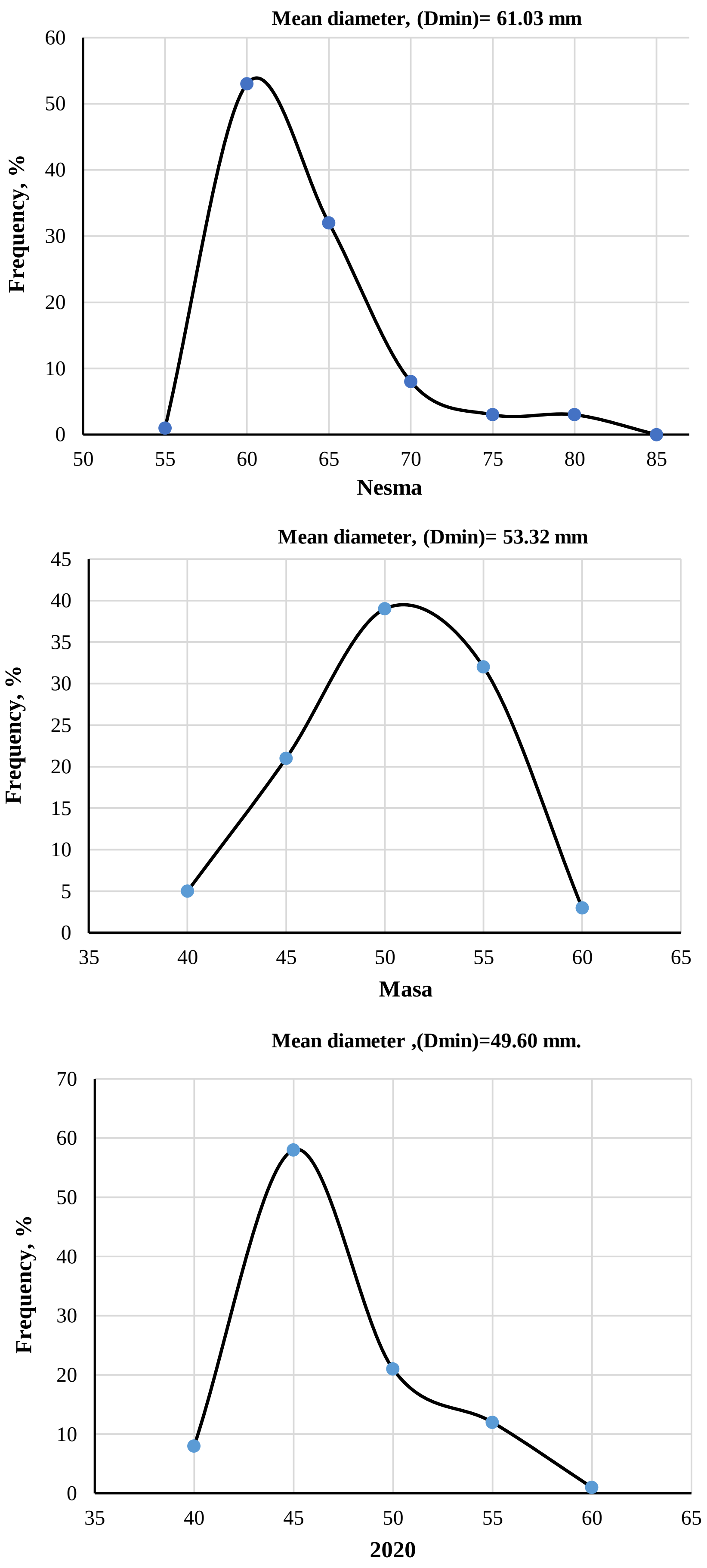
The shapes of curves are semi-normal distribution for high (H) for Nesma, Masa and 2020, normal distribution for largest diameter ($D_{max.}$) for Nesma, Masa and 2020, and the shapes of curves are semi-normal distribution for lowest diameter ($D_{min.}$) Nesma and 2020, while normal distribution for Masa cultivar.



(a) High (*H*, mm)



(b) Largest diameter (D_{max}., mm)



(c) Lowest diameter (D_{min}., mm) for three cultivars of tomato fruits Nesma, Masa and 2020

Figure 2 Frequency distribution curves of dimensions, and

3.1.2 Average diameter

From Table 1, the values of arithmetic mean diameter (D_a) ranged from 55 to 75.88 mm with a mean value of 61.03 ± 7.18 mm for Nesma cultivar, the values of arithmetic mean ranged from 50.04 to 65.54 mm with a mean value of 58.76 ±3.53 mm for Masa cultivar and ranged from 50.36 to 66.32 mm with a mean value of 58.11 ±3.84 mm for 2020 cultivar.

While the values of the geometric mean diameter (D_g, ranged from 59.68 to 84.65 mm with a mean value of 67.59± 4.89 mm for Nesma cultivar, from 49.90 to 65.49 mm with a mean value of 58.52 ±3.52 mm for Masa cultivar, and from 50.02 to 65.79 mm with a mean value of 57.33 ± 3.73 mm for 2020 cultivar. The obtained results of the axial dimensions, arithmetic mean diameter and geometric mean diameter are important to determine the range of clearance or size of handling mechanism and dimensions of the cutting knife in the cutting machines of tomato fruits.

3.1.3 Sphericity (S_p%)

The high sphericity of tomato fruit is indicative of the tendency of the shape towards a sphere. Largest values of sphericity 100.40%, 100.12% and 90.19% for tomato fruits Nesma, Masa and 2020 respectively, while lower values of sphericity 74.71%, 79.54% and 70.36% for cultivars Nesma, Masa and 2020, respectively. The mean values of 92.13% ±6.57%, 92.67% ±4.84% and 81.11% ±4.97% for cultivars Nesma, Masa and 2020 respectively as shown in Table 1 and Figure 3 indicates that the most frequent percent 37%, 36%, and 37% of tomatoes fruits in the sample were at the range of sphericity 95%-100%, 90%-95%, and 80%-85% for cultivars of Nesma, Masa and 2020, respectively. These results indicate that the tomato fruits tend to have a spherical shape with a high percentage and fruits of Nesma and Masa cultivars are approximately equal in the percentage of sphericity, while the 2020 cultivar is lower in the percentage of sphericity ones with about 11% from the other two cultivars.

3.1.4 Aspect ratio

The mean values were found to be 94.48% ± 10.49%, 94.99% ± 7.36% and 76.39% ± 6.46% for Nesma, Masa and 2020 cultivars respectively based on the means largest diameter. Taken along with the high aspect ratio, it may be deduced that the tomato fruit will rather roll than slide on their flat surfaces (Ghaffari et al., 2015). However, the aspect ratio value is being close to the sphericity values may also mean the tomato fruit will undergo a combination of rolling and sliding action on their surfaces (Oyelade et al., 2005).

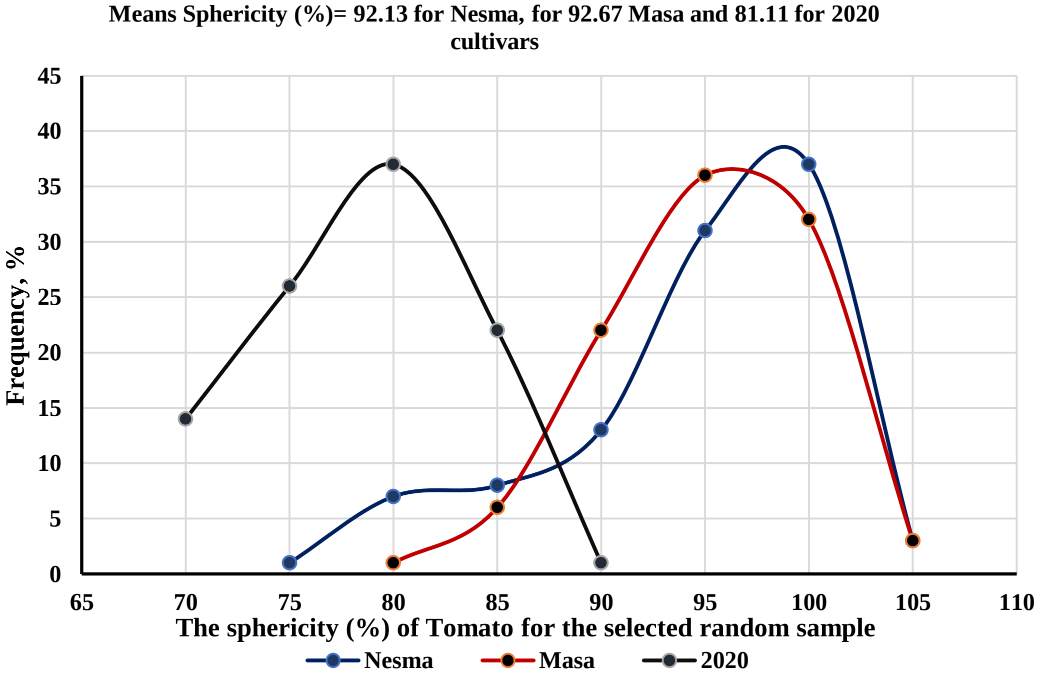


Figure 3 Frequency distribution curves of the (sphericity,%) for three cultivars of tomato fruits Nesma, Masa and 2020

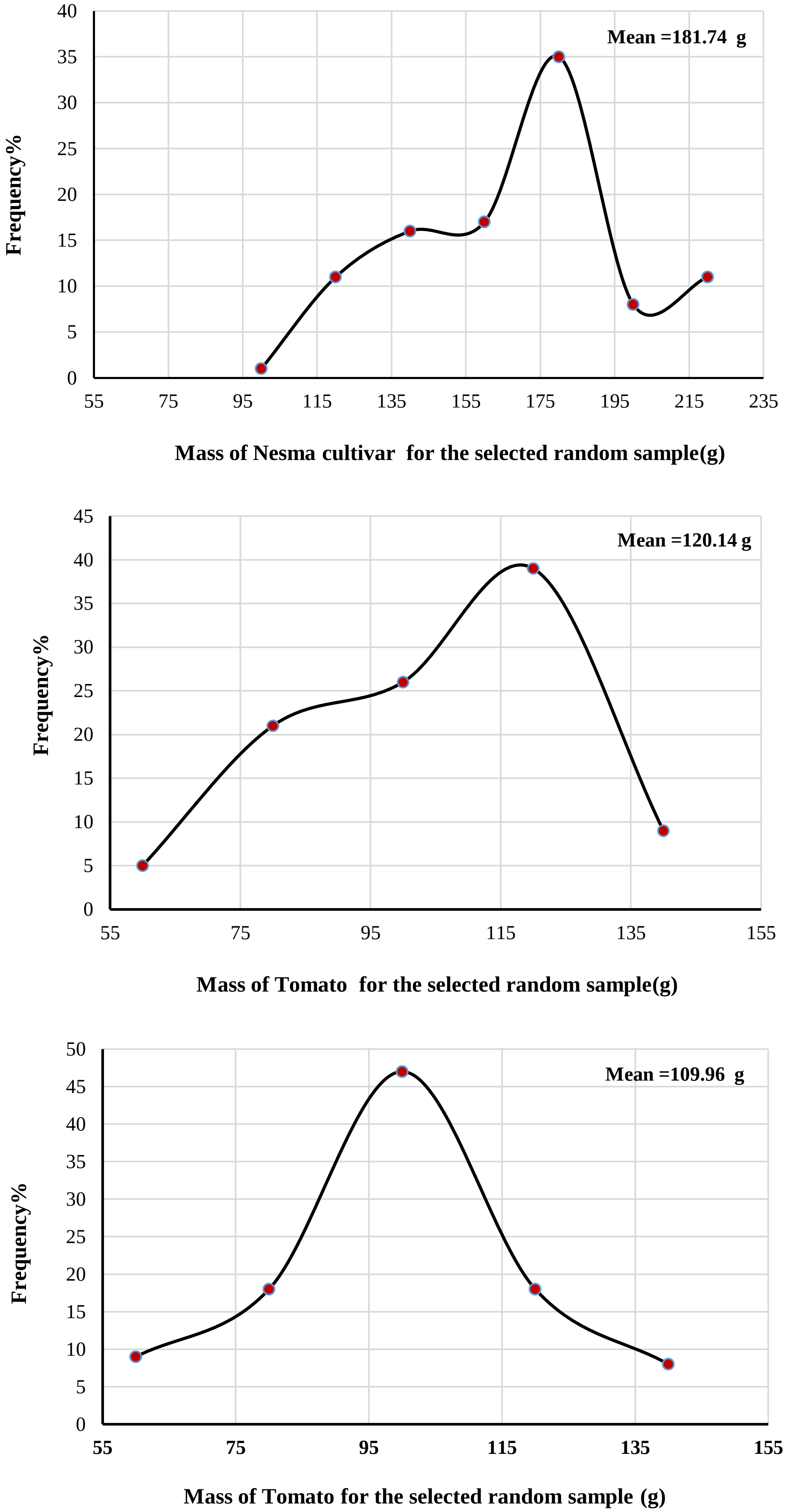


Figure 4 Frequency distribution curves of the (Mass, gm) for three cultivars of tomato fruits Nesma, Masa and 2020

3.1.5 Mass of the fruits

In Table 1 and Figure 4, these results showed that the values of individual fruits masses ranged from 101.66 to 295.8 g with a mean value of 181.74 ± 33.34 g, from 77.45 to 155.0 g with a mean value of 120.14 ±23.75 g, and from 70.56 to 152.44 g with a mean value of 109.96 ±20.10 g mass, for cultivars of Nesma, Masa and 2020, respectively. The most frequent percent 35%, 29% and 47% of tomatoes fruits in the sample had 180 – 200, 120 – 140 and 100 – 120 g mass, for cultivars of Nesma, Masa and 2020, respectively.

3.1.6 Density of the fruits (ρ, g cm^{-3})

In Table 1 shows the mean values of the density fruits, it has been observed that the density of the three cultivars tomato fruits approaches the density of water. Means value of density was about 0.991± 0.002, 0.991 ±0.002 and 0.972 ±0.029 g cm^{-3} for Nesma, Masa and 2020 cultivars, respectively.

3.1.7 Packing coefficient

In Table 1 the results shown that the packing coefficient of Nesma, Masa and 2020 cultivars were 0.625, 0.575 and 0.562, respectively.

3.2 Mechanical properties

Table 2 show the values of the coefficient of friction ranged from 0.466 to 510, 0.249 to 0.306 and 0.268 to 0.325 with mean values of 0.488 ±0.018, 0.277 ±0.016 and 0.30 ±0.018 for Nesma, Masa and 2020 cultivars, respectively with stainless steel (304) structural surfaces. While the values of the coefficient of friction ranged from 0.510 to 0.601, 0.287 to 0.344 and 0.364 to 0.424 with mean values of 0.566 ±0.027, 0.310 ±0.018 and 0.388 ±0.021 for Nesma, Masa and 2020 cultivars, respectively with rubber structural surfaces. And the values of the coefficient of friction ranged from 0.404 to 0.466, 0.213 to 0.325 and 0.194 to 0.287 with mean values of 0.427 ± 0.023, 0.266 ± 0.040 and 0.242 ± 0.032 for Nesma, Masa and 2020 cultivars respectively with plywood structural surfaces.

The results indicated that the means values of the firmness were 4.70 ±0.35, 5.95 ±0.60 and 4.9 ±0.59 N cm^{-2} for Nesma, Masa and 2020 cultivars, respectively.

Table 2 Mechanical properties of three tomatoes cultivars (Sample size 100 fruits)

Properties		Nesma			Masa			2020		
		Max.	Min.	Mean ±SD	Max.	Min.	Mean ±SD	Max.	Min.	Mean ±SD
Coefficient of static friction	S.S. (304)	0.51	0.47	0.018± 0.488	0.31	0.25	0.016± 0.277	0.32	0.27	0.018± 0.30
	Rubber	0.60	0.51	0.027± 0.566	0.34	0.29	0.018± 0.310	0.42	0.36	0.032± 0.388
	Plywood	0.47	0.40	0.023± 0.427	0.32	0.21	0.04± 0.266	0.29	0.19	0.032± 0.242
Firmness, (N/ cm^2)	Fa	4.97	4.27	0.35± 4.7	6.67	5.53	0.6± 5.95	5.30	4.17	0.59± 4.9

The equations were calculated using the stepwise method and based on independent. mass and arithmetic diameter are the two independent variables that estimate fruit volume.

The volume model of tomato fruits based on measured mass and arithmetic diameter was given as a linear form the following equations.

$$\mathrm{V}_{N.} = -0.6833 + 1.008\, M + 0.01465\, D_a$$

$$R^2 = 0.9798 \qquad (13)$$

$$\mathrm{V}_{M.} = 1 + M - 1.077 \times 10^{-15}\, D_a$$

$$R^2 = 0.9899 \qquad (14)$$

$$\mathrm{V}_{20.} = -4.923 + 1.024\, M + 0.9517\, D_a.$$

$$R^2 = 0.9352 \qquad (15)$$

Measuring the actual volume takes a long time, and therefore the volume of the fruits can be predicted based on obtained volume modeling equations for cultivars of Nesma, Masa, and 2020.

3.2.4 Application of the theory to the design of the tomato's fruits cutting machine

The physical and mechanical properties were studied for three tomatoes cultivars are used for open sun drying tomatoes, with the aim of a useful and vision suitable design for tomato cutting machine to two halves for purpose of drying as follows:

a. The conveyor belt:

- The width of the conveyor belt must not be less than the largest diameter of a tomato fruit 87.88 mm for the Nesma variety.

- Designing the conveyor so that it can bear the appropriate number of tomatoes, considering the largest mass of tomato fruits, which was 295 grams for Nesma cultivar.

- Direct the fruits at the end of the conveyor belt towards the axis of cutting disc knives, to ensure that they are cut to two similar halves.

- Based on the results values of the aspect ratio, the fruits of the Nesma and Masa of the cultivar can be placed on the conveyor belt in a vertical position, while the fruits of 2020 are placed in a horizontal position.

b. barrier of the conveyor belt:

The barrier must be designed according to the maximum height for tomato cultivars, which was 94.80 mm for Nesma cultivar, taking into consideration the position fruits are placed on the conveyor belt (vertical or horizontal).

c. The cutting disk:

The radius of the disc cutting knife must be greater than the maximum height of the tomato fruit (it is 94.80 mm for Nesma cultivar). The clearance between the disc knife edge and the conveyor belt may be 2-4 mm, which gives the optimum cut of the fruits without damaging the conveyor belt.

4 Conclusion

Overall results of this research may be concluded as follows:

The maximum, minimum, and average of high (H) were 94.80, 60.42 and 73.98 mm, 70.53, 54.82 and 63.28 mm, and 80.74, 58.66, and 70.99 mm for three cultivars (Nesma, Masa, and 2020) of tomato, respectively.

The maximum, minimum and average of largest diameter (D_{max}.) were 87.88, 60.00 with average 69.26 mm, 67.16, 49.80 with average 59.89 mm, and 60.31, 47.53 with average 53.86 for three cultivars (Nesma, Masa and 2020) of tomato, respectively.

The maximum, minimum and average of lowest diameter (D_{min}.) were 75.88, 55.00 with average 61.03 mm, 61.85, 44.88 with average 53.32 mm, and 60.10, 45.75 with average 49.60 mm for three cultivars (Nesma, Masa and 2020) of tomato, respectively.

Approximately equal cultivar of Nesma and Masa in the percentage of sphericity with a means value of 92.13% and 92.67% respectively, while the 2020 cultivar is lower in the percentage of sphericity with about 11% from the other two cultivars.

The mean values of individual fruits mass were 181.74, 120.14, and 109.96 g for three cultivars (Nesma, Masa and 2020) of tomato, respectively.

The lowest value means of the coefficient of static friction was 0.242 with plywood surface while the highest value means was 0.566 with stainless steel structural surface for Nesma and 2020 cultivars, respectively.

The means value of density was about 0.991, 0.991 and 0.972 g cm^{-3} for Nesma, Masa and 2020 cultivars, respectively.

The Means values of the firmness was 4.70, 5.95 and 4.9 N cm^{-2} for Nesma, Masa and 2020 cultivars, respectively.

These results can be used to suggest a suitable design machine cutting tomato machine for the open sun drying purposes. They can be also applied in the harvesting, handling, transportation, grading, and sorting packing processes related to these cultivars.

The volume modeling equations can be justified for all cultivars of Nesma, Masa, and 2020 of tomato fruits based on mass and arithmetic diameter was given as linear equations are the following: $\mathrm{V}_{N.} = -0.6833 + 1.008\,M + 0.01465\,D_a., \mathrm{V}_{M.} = 1 + M - 1.077 \times 10^{-15}\,D_a$, and $\mathrm{V}_{20.} = -4.923 + 1.024\,M + 0.9517\,D_a.$, for cultivars of Nesma, Masa, and 2020, respectively.

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