Available at www.sciencedirect.com

INFORMATION PROCESSING IN AGRICULTURE 5 (2018) 185–198

journal homepage: www.elsevier.com/locate/inpa

Sunflower petals: Some physical properties and modeling distribution of their number, dimensions, and mass

Amir Hossein Mirzabe [a,*], *Golam Reza Chegini* [b], *Javad Khazaei* [b]

[a] *Department of Mechanical Engineering of Biosystems, Faculty of Agricultural Engineering and Technology, College of Agriculture & Natural Resources, University of Tehran, Tehran, Iran*

[b] *Department of Mechanical Engineering of Biosystems, College of Aboureihan, University of Tehran, Tehran, Iran*

A R T I C L E I N F O

Article history:
Received 7 December 2017
Received in revised form
15 March 2018
Accepted 15 March 2018
Available online 22 March 2018

Keywords:
Sunflower (*Helianthus annus* L.) petal
Picking force
Image processing
Fibonacci sequence
Lucas sequence

A B S T R A C T

Sunflower petal is one of the parts of the sunflower which has drawn attention and has several applications these days. These applications justify getting information about physical properties, mechanical properties, drying trends, etc. in order to design new machines and use new methods to harvest or dry the sunflower petals. For three varieties of sunflower, picking force of petals was measured; number of petals of each head was counted; unit mass and 1000-unit mass of fresh petals were measured and length, width, and projected area of fresh petals were calculated based on image processing technique; frequency distributions of these parameters were modeled using statistical distribution models namely Gamma, Generalized Extreme Value (G. E. V), Lognormal, and Weibull. Results of picking force showed that with increasing number of days after appearing the first petal on each head from 5 to 14 and decreasing loading rate from 150 g min^{-1} to 50 g min^{-1} values of picking force were decreased for three varieties, but diameter of sunflower head had different effects on picking force for each variety. Length, width, and number of petals of Dorsefid variety ranged from 38.52 to 95.44 mm, 3.80 to 9.28 mm and 29 to 89, respectively. The corresponding values ranged from 34.19 to 88.18 mm, 4.28 to 10.60 mm and 21 to 89, respectively for Shamshiri variety and ranged from 44.47 to 114.63 mm, 7.03 to 20.31 mm and 29 to 89 for Sirena variety. Results of frequency distribution modeling indicated that in most cases, G. E. V and Weibull distributions had better performance than other distributions.

1. Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil seed crops due to its high amount of unsaturated fatty acids [1,2]. Sunflower originated in North America and was probably first introduced to Europe through Spain, and spread through Europe as a curiosity until it reached Russia where it

* Corresponding author.
E-mail addresses: a_h_mirzabe@alumni.ut.ac.ir (A.H. Mirzabe), chegini@ut.ac.ir (G.R. Chegini), jkhazaei@ut.ac.ir (J. Khazaei).
Peer review under the responsibility of China Agricultural University.
https://doi.org/10.1016/j.inpa.2018.03.002
2214-3173

was readily adapted and where it is cultivated more than any other country in the world. It was selected in Russia in 1860 for its oil. Attempts were conducted to produce hybrid varieties with more oil content; as a result, the oil content of seeds has increased from 28% to 50% [3].

The area under sunflower has increased more than 15 times during the last fifteen years, indicating strong motivation of the farmers [4]. Although food consumption of the seeds and oil extraction from the seeds are the main reasons of cultivation of sunflower [3], the other parts of sunflower have many applications; for example in some areas, after harvesting sunflower, farmers grind the remained sunflower stems and spread them on the farms as an organic fertilizer. However, sunflower can be consumed wholly by ruminants and no part of sunflower is poisonous.

Sunflower petals are one of the most important parts of the sunflower that have several applications. Petals are often brightly colored or unusually shaped to attract pollinators. The sunflower petals can be made into an infusion that can be used in the bath as soap and often used for their decorative element in crafts such as candles, paper making, potpourri, and dye. Sunflower petals can be used as food ingredient in soups, salads or as a garnish for cakes and cookies to add color and flavor to recipes.

Moreover, dried sunflower petals are a great ingredient for herbal tea blending. Sunflower petals were used as herbal teas in Iranian and Chinese ancient medicine to heal wounds, accelerate childbirth, lower blood pressure and strengthen the stomach. Tendency towards traditional medicine has increased all around the world. Along with this tendency, consumption of herbal teas is prevalent in many countries. One of these herbal teas that recently has become prevalent in Iran, is sunflower petal herbal tea so much that, according to local farmers reports, many people refer to farmers to buy sunflower petals.

One important aspect of each agricultural product and its manufacturing process is economic issues. We compare amount and price of harvested sunflower seed and dried harvested sunflower petal. We realized revenue arising from the sunflower petal is remarkable and even there is no big difference between revenue arising from the sunflower petal and sunflower seed. However, this revenue justifies the production, drying and selling sunflower petals, as well as research on medicinal and chemical properties of sunflower petals and also on methods of harvesting and drying them.

In the first step, we must be able to harvest the petals. In order to harvest the petals we must design and build up a new harvester. The physical and mechanical properties of agricultural products are useful parameters in the design of handling and processing equipment. Size and shape are important for designing the related handling, separating, and sorting machines [5]. Also, picking force is a necessary parameter to estimate power consumption of harvester machines. Therefore, to design a new harvester for sunflower petals we need to know physical and mechanical properties of sunflower petals like picking force, mass, size, shape, etc.

To the best knowledge of the authors of this paper, there are lots of scientific publications on physical, mechanical, and chemical properties of the sunflower seeds [6–11] but there is no published literature on physical properties of the sunflower petals.

Therefore, the aims of present study were to measure sunflower head diameter (SHD), unit mass of petals, and 1000-unit mass of petals, count number of petals of each sunflower head (SH), determine relation between SHD and number of petals, calculate length, width, and projected area of the petals based on image processing technique. Also, effect of loading rate (in two levels 50 and 150 $g\,min^{-1}$), sunflower head diameter (in three levels 10, 20, and 30 cm), and number of days after appearing the first petal on each head on picking force of petals from their head (in four levels: 4, 8, 11, and 14 days) were investigated. In addition, Gamma, Generalized Extreme Value, Lognormal, and Weibull were used to model frequency distribution of sunflower head diameter, number of petals of each head, length, width, and unit mass of the petals.

2. Materials and methods

2.1. Materials

Three varieties of sunflower were used in the present research, namely Dorsefid, Shamshiri and Sirena, which are widely cultivated in Iran. The Dorsefid, Shamshiri and Sirena varieties are native of Iran. The three varieties were planted on April 27th, 2012 in research farms of university of Tehran, located on Pakdasht, Tehran province, Iran with a longitude of 35.47°N, a latitude of 51.67°E, average annual Precipitation 110 mm, height above the sea level of 1025 m, average annual temperature of 18.0 °C (Shahid Beheshti University of Medical Sciences, 2016; The Ministry of Agriculture Jihad of Iran, 2016). Data collection was carried out in late July and early August, when sunflower petals were mature and fresh.

2.2. SH diameter and number of petals

From each variety, 50 sunflower heads were selected randomly. First, sunflower head (SH) diameter was measured based on image processing technique. For measuring of each SH, several diameters were measured in different directions, and the maximum value was selected. Then numbers of petals for each SH were counted. Correlation between SH diameter and number of petals was investigated to see whether with increasing the maximum diameter, the number of petals also increase.

2.3. Dimensions of petals

In order to measure the petals length, width and projected area, for each variety, sunflower petals were carefully and randomly manually harvested (sunflower heads were cut by knife). The petals were immediately transported to laboratory. Bulk samples were selected randomly and the unwanted debrides and materials were removed from bulk sample of petals. Length, width and projected area were measured based on image processing technique.

2.4. Image processing set up

The image processing set up consisted of a camera (Canon, IXY 600F, Japan) with 3X IS lens capable of filming up to 120 frames per second (fps) and 12.1 megapixels, with a USB connection, four white-colored fluorescent lamps (32 W) and a computer (DELL, INSPIRON 1558, CHINA) equipped with MATLAB R2012a software package [12,13]. The camera was mounted on an image processing box (Fig. 1).

In order to calibrate the image processing system, two different methods including chess board plate (or primary calibration) and three metal spheres (or real time calibration) were used. For primary calibrating, a 8×8 chess board plate with black and white squares was used. Intersections of black and white squares were 115 points. By knowing coordinates of the points in image (by counting number of the pixels between these points) and also by knowing coordinates of the points on the chess board (knowing dimensions of squares), root mean square method was used for 115 points and the convert matrix between real world and image world was obtained. In order to do secondary calibration, three spheres in three specific positions were used. The spheres were placed on the perimeter of the circle with radius of 150 mm (which every petal was placed in its center). The angle between the spheres was 120°. Actually, secondary calibration was used to increase the accuracy of the image processing system.

Each sunflower petal was placed at the center of the camera's field of view and three metal spheres with the same and identified diameters were put at the side (three different and specific positions) of the sunflower petal (Fig. 1).

In the first step of processing, one RGB color images were captured from up view of the petals and the RGB color space images of calluses were converted into eight-bit gray-scale level.

In the second step of processing, the threshold technique was performed to isolate each object from its background. Eight-bit gray-scale intensity represents 256 different shades of gray from black to white (from 0 to 255). The eight-bit gray-scale images were digitized to binary image by using binary transformation on the basis of all the pixels with a brightness level equal to the average of the brightness levels of the three channels [12,13].

In the third step of processing, the threshold values of the sunflower petals were determined experimentally. The holes and noise of binary images were filled by morphological closing and opening. From the gray-scale image of Dorsefid variety, pixel values less than 145 were converted to 0 (black), and the values higher than 145 were converted to 255 or white. The threshold levels of the Shamshiri and Sirena varieties gray-scale image were chosen as 149 and 156, respectively. The threshold levels (145, 149, and 156) were determined experimentally [13,14]. The pixels with value of 255 showed the sunflower petals, and the pixels with value of 0 showed the remainder. The holes and noise of binary images were filled by morphological closing and opening [15].

Examples of the original, gray-scale, binary and boundary images of a sunflower petal and different steps of processing are shown in Fig. 2. The number of pixels representing the length (L) and width (W) of the petals and was also measured on the captured images using MATLAB R2012a software package.

In each photo, the number of the pixels in two perpendicular axes were counted for each sphere. After that, by knowing the diameter of the spheres, the number of the pixels in each millimeter was counted. Then for each sunflower petal, the number of the pixels in two perpendicular axes which had the maximum number of the pixels (length and width) were calculated. At the final step, the number of the pixels of the petal was multiplied by the number of the pixels in each millimeter and length and width of each petal were calculated.

Projected area of each petal was calculated (projected area of spheres equals 3.1415 R^2, R is the radius of the spheres and was measured by digital micrometer with an accuracy of 0.01 mm) using Eq. (1):

$$\text{Projected area of the petal} = \text{Number of pixels of petal} \times \frac{\text{Projected area of the sphere}}{\text{Number of pixels of sphere}} \quad (1)$$

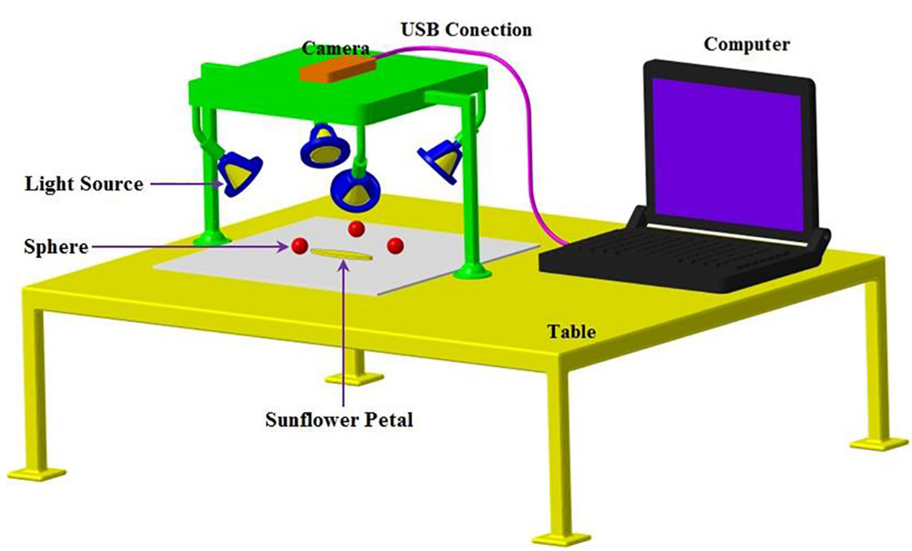

Fig. 1 – Experimental set up was used to image processing.

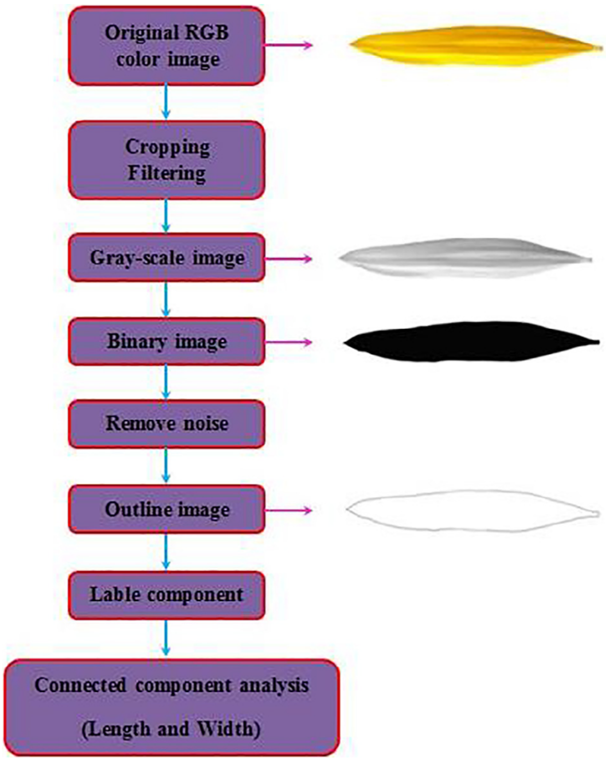

Fig. 2 – Image processing steps to measure length and width of sunflower petal.

For each photo all the above steps were done manually to calculate length, width and projected area.

2.5. *Unit mass and 1000-unit mass*

In order to measure the unit mass and 1000-unit mass of three varieties, after harvesting, sunflower petals transported to laboratory and the unwanted materials were removed from bulk sample of petals. At first mass of the each petal was measured using digital balance with an accuracy of 0.0001 g (KERN, JAPAN, ALT 160-4B). To calculate the 1000 petal mass, 100 petals were randomly selected from the bulk sample; the mass of 100 petals were measured and multiplied by 10 to determine 1000-unit mass. Measuring the 1000-unit mass was done with 5 repetitions.

2.6. *Picking force*

At the first sight, designing a vacuum harvester seems a great idea to pick sunflower petals. However, in order to design a harvester to pick sunflower petals, based on any possible methods, we need to know amount of picking force of petals. In order to measure the sunflower petals' picking force, a set up portable to the farm was designed and built. The portable set up worked based on water displacement method as follow:

The water is sucked out of the reservoir using a water pump. The water pump was driven by an electromotor working with 3.5 v DC power. The water was pumped to the flow control valve. By regulating the flow rate of the flow control valve, the loading rate was regulated and water enters the off-on valve. Water was come out of off-on valve and enters a plastic beaker, which was connected to a clamp with a string. The clamp held the sunflower petal. The plastic beaker and the clamp were made so that their mass was equal.

The water entered the beaker until the petal was picked. As soon as the petal was picked, the off-on valve stopped the water flow. In order to measure picking force, mass of the water in beaker was measured. Value of picking force was equal to value of mass of water in the beaker. Mass of the water was measured using digital balance with an accuracy of 0.01 g (KERN, Japan, PLS 360-3).

To study the effect of the sunflower head size on picking force, the head diameter of each sunflower was measured and SHs were divided into three different categories, based on their diameters. If the diameter of SH ranged from 5 to 15 cm, it was named small SH; if the diameter of SH ranged from 15 to 25 cm, it was named medium SH; f the diameter of SH ranged from 25 to 35 cm, it was named big SH. From each variety, 10 sunflower heads with diameter of 10, 20, and 30 were selected randomly.

The effect of loading rate on picking force at two levels (50 and 150 g min^{-1}) was examined. In order to change the loading rate, the water flow was changed. Also, the effect of time on picking force was investigated at 4 levels 5, 8, 11, and 14 days after appearing of the first petal in each sunflower head. In order to get the best intervals we did some pretests. We wanted to determine the effect of the time when the petals are fresh and also the difference between levels be clear. So, based on the results of the pretests and suitable interaction between freshness of petals and clear differences for picking force in each level with the other levels, the levels were selected.

2.7. *Statistical analysis*

Statistical indices including maximum, minimum, average, and standard deviation for two principal dimensions, dimensional properties and unit mass of petals were calculated using Microsoft Office Excel 2010. The skewness and kurtosis were calculated using the following Eqs. (2) and (3) as reported by [13,16], respectively:

$$Skewness = \frac{n}{(n-1)(n-2)} \sum_{i=1}^{n} \left(\frac{x_i - x_{avg}}{\delta} \right)^3 \tag{2}$$

$$Kurtosis = \left\{ \frac{n(n-1)}{(n-1)(n-2)(n-3)} \sum_{i=1}^{n} \left(\frac{x_i - x_{avg}}{\delta} \right)^4 \right\} - \frac{3(n-1)^2}{(n-2)(n-3)} \tag{3}$$

where n is the number of occurrences, δ is standard deviation, x_{avg} is mean petals size, x_i is midpoint of each class interval in metric. Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution. Two times of standard errors of skewness (SE_S) and kurtosis (SE_K) for a normal distribution are equal to [17,18]:

$$SE_S = \sqrt[2]{\frac{6n(n-1)}{(n-2)(n+1)(n+3)}} \tag{4}$$

$$SE_K = (2 \times SE_K)\sqrt[2]{\frac{(n^2-1)}{(n-3)(n+5)}} \tag{5}$$

where n is number of occurrence; in the present study for all the parameters n was equal to 50. So, in order to calculate the values of SE_S and SE_K, 50 replaces in Eqs. (4) and (5) and values of SE_S and SE_K were obtained 0.0337 and 0.663, respectively. If for each parameter the result of this division is between $-2 < Skewness/SE_S < +2$, it can suggest that population data are neither positively or Negatively skewed. If for each parameter the result of this division is between $-2 < Kurtosis/SE_K < +2$, it can suggest that population data are neither positively or negatively kurtosis.

2.8. Modeling of dimensional properties and mass

Dimensions, mass, and dimensional properties can be determined for a single petal, grain, fruit, nut or kernel, but values of these properties differ for each individual seed. Normally, we are not interested to know the properties of each individual seed, but description of the frequency distributions of the dimensions, mass and physical properties of the whole sets of the seeds is needed for designing agricultural machinery [5]. There are many researches on modeling the properties of agricultural products based on statistical distributions [19–21].

Number, length, width, and mass of petals and SH diameter distributions were modeled with four probability density functions. These functions were: (1) Gamma, (2) Generalized Extreme Value (G.E.V), (3) lognormal and (4) Weibull. The probability density function and cumulative frequency for Gamma, Generalized Extreme Value, Lognormal, and Weibull distribution are described in Table 1 [5,20–22].

In fact, a probability distribution is characterized by location, scale, and shape parameters. These parameters are typically used in modeling applications. The effect of the location parameter is to translate the graph, relative to the standard normal distribution. That is, a location parameter simply shifts the graph left or right on the horizontal axis. The effect of the scale parameter is to stretch out the graph. The effect of a scale parameter greater than one is to stretch the probability density function. The greater the magnitude, the greater the stretching. The effect of a scale parameter less than one is to compress the probability density function. The compressing approaches a spike as the scale parameter goes to zero. A scale parameter of 1 leaves the probability density function unchanged (if the scale parameter is 1 to begin with) and non-positive scale parameters are not allowed. Shape parameter is any parameter of a probability distribution that is neither a location parameter nor a scale parameter (nor a function of either or both of these only, such as a rate parameter). Such a parameter must affect the shape of a distribution rather than simply shifting it (as a location parameter does) or stretching it (as a scale parameter does).

In fact, if P(x) is a density function for a characteristic of a petals sample, then:

$$\int_a^b P(x)dx = \left\{ \begin{array}{l} \textit{Fraction of petals} \\ \textit{sample for which} \\ a \leqslant x \leqslant b \end{array} \right\} \tag{6}$$

In Eq. (6), if P(x) is interpreted as a probability density function, then the right hand of the equation will be equal to the probability that $a \leqslant x \leqslant b$ [23]. We also know that for any density function:

$$\int_{-\infty}^{+\infty} P(x)dx = 1 \tag{7}$$

Furthermore, the cumulative distribution function for the seeds characteristic is defined as [23]:

$$P(t) = \int_{-\infty}^{t} P(x)dx \tag{8}$$

The adjustable parameters for each probability density function were calculated using the commercial spreadsheet package of Easy Fit 5.5. Kolomogrov-Smirnov methods were used for comparing of all probability density. The test is based on the vertical deviation between the observed cumulative density function and estimated cumulative density function based on the Eq. (9):

$$Ks = \max[s(x) - f(x)] \tag{9}$$

where S(x) is the cumulative frequency distribution observed and F(x) is the probability of the theoretical cumulative frequency distribution. In this equation, small values of the test statistics Ks indicate a better fit. Also the Kolmogorov-Smirnov index for each probability density function was calculated using the commercial spreadsheet package of Easy Fit 5.5.

Table 1 – The probability density function and cumulative frequency for Gamma, Generalized Extreme Value, lognormal and Weibull distribution.

Name	Probability density function	Cumulative frequency function
Gamma	$f(x) = \frac{(x-\delta)^{\varepsilon-1}}{\sigma^\varepsilon \Gamma(\varepsilon)} \exp\left(-\frac{x-\delta}{\sigma}\right)$	$F(x) = \frac{\Gamma_{(x-\delta)/\sigma}(\varepsilon)}{\Gamma(\varepsilon)}$
Generalized Extreme Value	$f(x) = \frac{1}{\psi}\left[1+\xi\left(\frac{x-\mu}{\psi}\right)\right]^{(-1/\xi)-1} \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\psi}\right)\right]^{-1/\xi}\right\}$	$F(x) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\psi}\right)\right]^{-1/\xi}\right\}$
Lognormal	$f(x) = \left(\frac{1}{(x-\theta)\tau\sqrt{2\pi}}\right) \exp\left(-\frac{1}{2}\left(\frac{\ln(x-\theta)-\lambda}{\tau}\right)^2\right)$	$F(x) = \phi\left(\frac{\ln(x-\theta)-\lambda}{\tau}\right)$
Weibull	$f(x) = \frac{\gamma}{\beta}\left(\frac{x-\alpha}{\beta}\right)^{\alpha-1} \exp\left(-\left(\frac{x-\alpha}{\beta}\right)^{\gamma}\right)$	$F(x) = 1 - \exp\left(-\left(\frac{x-\alpha}{\beta}\right)^{\gamma}\right)$

3. Results and discussions

3.1. *Dimensional properties*

Statistical indices (maximum, minimum, average, standard deviation, skewness and kurtosis) for number of petals, unit mass of petals, length of petals, width of petals and SHs diameter of Dorsefid, Shamshiri and Sirena varieties are shown in Table 2.

The length, width and thickness are important in designing of separating, harvesting, sizing and grinding machines [24,25]. Length and width of Dorsefid variety ranged from 38.52 to 95.44 mm and 3.80 to 9.28 mm, respectively. Length and width of Shamshiri variety were ranged from 34.19 to 88.18 mm and 4.28 to 10.60 mm, respectively. The corresponding values for Sirena variety were found to be 44.47 to 114.63 mm and 7.03 to 20.31 mm, respectively.

The projected area is an important parameter to determine aerodynamic properties. Projected area of petals was calculated based on image processing technique and obtained results of three varieties are shown in Table 2. Projected areas of petals of Dorsefid, Shamshiri and Sirena varieties were ranged from 111.93 to 695.59 mm^2, 252.32 to 1782.36 mm^2 and 116.00 to 734.100 mm^2, respectively (Table 2).

A comparison between length, width and projected area of the sunflower petal of the three varieties shows that mean value of length, width and projected area of Sirena variety were more than the other varieties; while length, width and projected area of Dorsefid variety were the least (Table 2).

Skewness and kurtosis are the two statistical indices calculated so that the reader would better understand the probability density distribution data. The first usually noticed about a distribution's shape is whether it has one mode (peak) or more than one. If it's unimodal (has just one peak), like most data sets, the next thing noticed is whether it is symmetric or skewed to one side. If the bulk of the data is at the left and the right tail is longer, the distribution is skewed right or positively skewed; if the peak is toward the right and the left tail is longer, the distribution is skewed left or negatively skewed (see to the Table 2). For all the varieties, all the characteristics have no significant positively or negatively kurtosis problem. Also, all the characteristics except projected area of Sirena variety and the number of petals of Shamshiri variety, have no significant positively or negatively skewness problem.

3.2. *Number of petals*

The number of petals of Dorsefid, Shamshiri and Sirena varieties were ranged from 29 to 89, 21 to 89, and 29 to 89, respectively. Correlation between number of sunflower petals and sunflower head diameter for three varieties are shown in Fig. 3. Results indicated that with increasing SH diameter, number of sunflower petals increases. Dependence of Dorsefid, Shamshiri and Sirena varieties' number of petals on sunflower head diameter is described by linear equation that follows, respectively (N_p is number of petals and the equations were obtained based on linear regression method):

$$N_P = 0.4713SH_D - 21.0120, \quad R^2 = 0.9313$$

$$N_P = 0.5329SH_D - 26.7870, \quad R^2 = 0.9024$$

$$N_P = 0.3729SH_D - 4.0384, \quad R^2 = 0.8550$$

The Fibonacci sequence has been observed widely throughout the structures of living organisms in the natural world, from the geometrical distribution of leaves on plant stems to the spiral of nautilus shells. Even the ratios of the different sizes of many organisms of physical structures tend to follow Fibonacci sequences or its derivation into two

Table 2 – Statistical indices for number of petal, length of petal, width of petal, unit mass of petal and sunflower head diameter of the three varieties of sunflower.

Variety	Parameter	Max	Min	Mean	Skewness	Kurtosis
Dorsefid	N_P	89.00	29.00	54.06 ± 14.69	0.30*	−0.22*
	M_P	0.2318	0.0789	0.1473 ± 0.04	0.14*	−0.89*
	SHD	221.00	100.00	159.28 ± 30.08	0.07*	−0.43*
	L_P	95.44	38.52	67.03 ± 13.45	−0.26*	−0.16*
	W_P	9.28	3.70	6.53 ± 1.31	−0.24*	−0.06*
	P_{AP}	695.59	111.93	357.06 ± 134.89	0.28*	0.00*
Sirena	N_P	89.00	29.00	54.36 ± 13.46	0.19*	0.80*
	M_P	0.3198	0.0973	0.1964 ± 0.05	0.30*	−0.41*
	SHD	238.00	100.00	156.60 ± 33.37	−0.06*	−0.51*
	L_P	114.63	44.47	80.03 ± 15.88	−0.27*	0.09*
	W_P	20.31	7.03	12.69 ± 3.01	0.42*	−0.29*
	P_{AP}	1782.36	252.32	827.20 ± 337.83	0.73**	0.48*
Shamshiri	N_P	89.00	21.00	48.06 ± 16.77	0.71**	−0.10*
	M_P	0.1888	0.0406	0.1222 ± 0.03	−0.14*	−0.67*
	SHD	210.00	88.00	140.44 ± 29.88	0.46*	−0.16*
	L_P	88.18	34.19	61.53 ± 12.29	−0.28*	−0.02*
	W_P	10.60	4.28	7.42 ± 1.48	−0.21*	−0.08*
	P_{AP}	734.10	116.00	372.25 ± 140.19	0.31*	0.08*

* and ** indicated respectively a distribution with no significant and significant positively or negatively Skewness or Kurtosis.

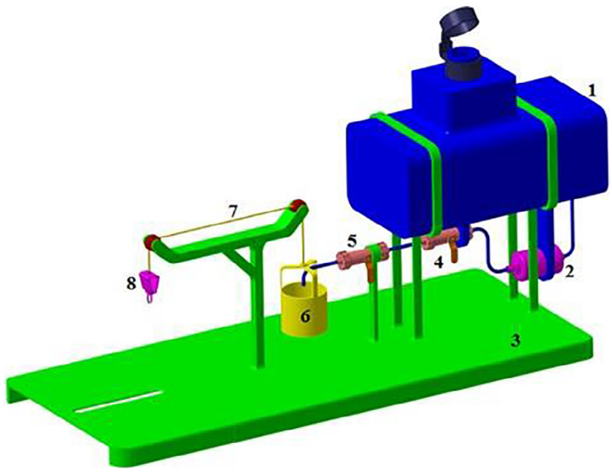

Fig. 3 – Experimental set up that was used to measure the picking force of sunflower petals. 1: reservoir, 2: water pump, 3: frame, 4: flow control valve, 5: off-on valve, 6: plastic beaker, 7: string, 8: clamp.

dimensions as the golden spiral. The sequence of the Fibonacci numbers are: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144 … and generally:

$$F_{n+2} = F_n + F_{n+1} \quad n = 0, 1, 2, 3, 4, 5, \ldots \tag{10}$$

While other studies of sunflowers found that Fibonacci sequences occur in around 90% of seed heads, this new study found some flowers that display newer pattern. Using the Fibonacci recurrence relation and different initial conditions, we are able to construct new number sequences [26]. For instance, let L_n be the n^{th} term of sequence with $L_1 = 1$, $L_2 = 2$, and in general:

$$L_n = L_{n-1} + L_{n-2} \; n \geqslant 3 \tag{11}$$

The resulting sequence 1, 3, 4, 7, 11, 18, 29, 47, 76, 123 … is called the Lucas sequence [26] (see Fig. 4).

The sunflower seed pattern used by the National Museum of Mathematics contains many spirals. If you count the spirals in a consistent manner, you will always find a Fibonacci number. Sunflower seed pattern motivated us to investigate matching number of sunflower petals to Fibonacci and Lucas sequences. Results of this work indicated that number of

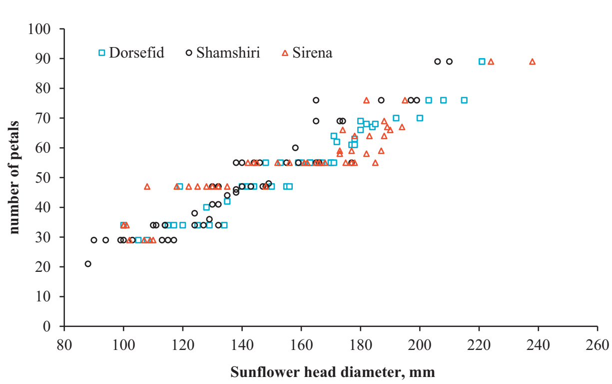

Fig. 4 – Correlation between number of sunflower petals and sunflower head diameter.

counted petals of Dorsefid variety equals to one number of Lucas and Fibonacci series in 32 and 40% of cases. Results indicated that number of counted petals of Shamshiri variety equals to one number of Lucas and Fibonacci series in 38 and 38% of all cases. The corresponding value for Sirena variety was found to be 28 and 42%, respectively.

3.3. *Unit mass*

Unit mass of Dorsefid variety, at 80.05% (d.b) moisture content, were ranged from 0.0789 to 0.2318 g. The corresponding values for Shamshiri and Sirena varieties, at 80.15% (d.b) and 80.82% (d.b) moisture content were found to be 0.0406 to 0.1888 g and 0.973 to 0.3198 g, respectively (Table 2). 1000-unit mass of Dorsefid, Shamshiri and Sirena varieties, at 80.05, 80.15 and 80.82% (d.b) moisture content, were found to be 144.2582, 122.6128 and 198.6842 g, respectively.

A comparison between unit mass of the three varieties shows that mean value of unit mass of Sirena variety was greater than the other varieties; while unit mass of Shamshiri variety was the least (Table 2). When the unit mass of one variety is greater than the other varieties, it is obvious that 1000-unit mass of the variety will be greater than the other varieties; the obtained results of three varieties confirm that 1000-unit mass of Sirena variety is greater than the Dorsefid and Shamshiri varieties.

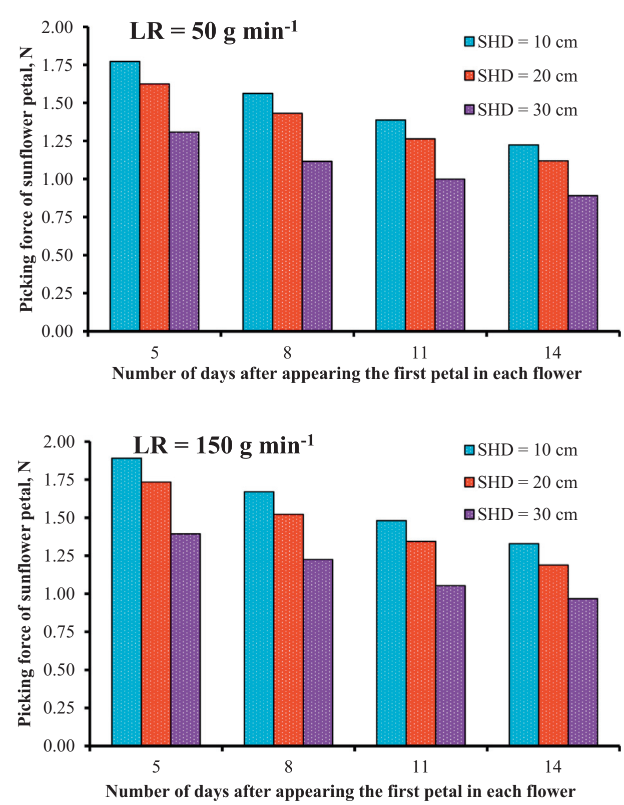

Fig. 5 – Effect of loading rate (LR), sunflower head diameter (SHD) and number of days after appearing the first petal in each flower on picking force of sunflower petal (PFSP) of 'Dorsefid' variety.

3.4. *Picking force*

The results of PFSP of Dorsefid variety are shown in Fig. 5. The results indicated that in all cases, with increasing the number of days from 5 to 14 days, values of PFSP decreased from 1.772 to 1.223, 1.624 to 1.119, and 1.308 to 0.890 N, respectively, when the loading rate was 50 g min^{-1}. The corresponding values for loading rate of 150 g min^{-1} were 1.891 to 1.329, 1.743 to 1.188, and 1.393 to 0.967 N, respectively. Also, the results of Dorsefid variety showed that in all cases with increasing loading rate, PFSP increased. Moreover, results showed that with increasing SHD, value of PFSP decreased.

The results of PFSP of Shamshiri variety are illustrated in Fig. 6. The results showed that in all cases, with increasing the number of days from 5 to 14 days, values of PFSP decreased from 2.308 to 1.514, 2.376 to 1.663, and 1.561 to 1.059 N, respectively, when the loading rate was 50 g min^{-1}. The corresponding values for loading rate of 150 g min^{-1} were 2.440 to 1.616, 2.618 to 1.812, and 1.673 to 1.144 N, respectively. Also, the results showed that in all cases with increasing loading rate PFSP increased. Moreover, results showed that with increasing SHD from 10 to 20 cm and increasing SHD from 30 to 20 cm value of PFSP increased.

The results of PFSP of Sirena variety are illustrated in Fig. 7. The results indicated that in all cases, with increasing the number of days from 5 to 14 days, values of PFSP decreased from 2.440 to 1.877, 2.777 to 2.181, and 3.096 to 2.407 N, respectively, when the loading rate was 50 g min^{-1}. The corresponding values for loading rate of 150 g min^{-1} were 2.605 to 2.131, 2.983 to 2.415, and 3.330 to 2.671 N, respectively. Also, the results of Sirena variety indicated that in all cases, with increasing loading rate, PFSP increased. Moreover, results showed that with increasing SHD, value of PFSP increased.

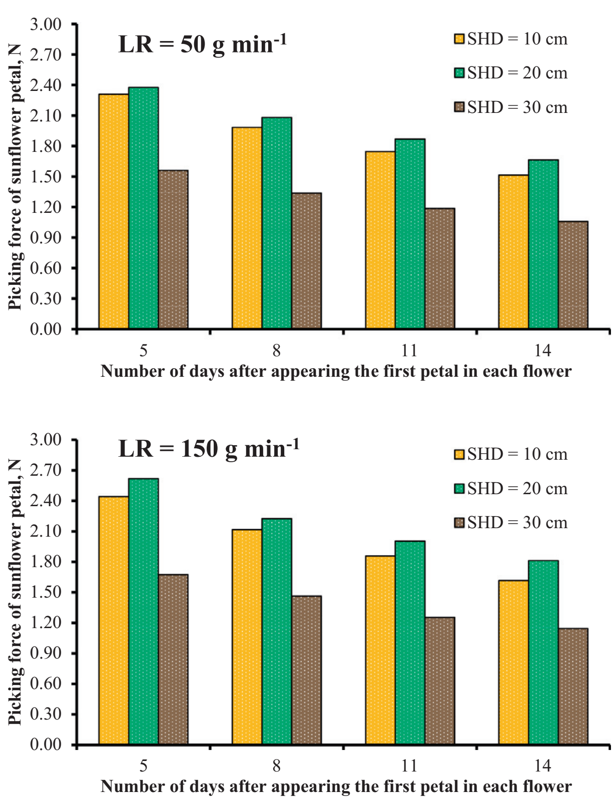

Fig. 6 – Effect of loading rate (LR), sunflower head diameter (SHD) and number of days after appearing the first petal in each flower on picking force of sunflower petal (PFSP) of 'Shamshiri' variety.

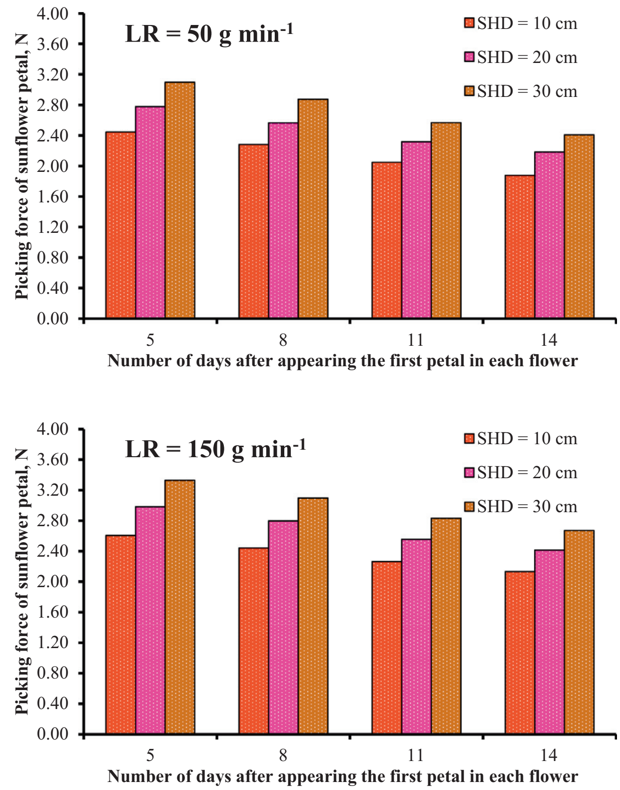

Fig. 7 – Effect of loading rate (LR), sunflower head diameter (SHD) and number of days after appearing the first petal in each flower on picking force of sunflower petal (PFSP) of 'Sirena' variety.

3.5. *Distribution modeling*

Number, length, width and mass of petals and SH diameter distributions were modeled using the Gamma, Generalized Extreme Value (G. E. V), Lognormal, and Weibull probability density functions distribution; the results for Dorsefid, Shamshiri and Sirena varieties are shown in Tables 3, 4 and 5, respectively.

Results of Dorsefid variety showed that to model the number, mass and length of the petals, G. E. V distribution had the best performance, while to model the width of the petals and SHs diameter, Weibull distribution had the best performance. Also to model the mass, length and width of the petals, Gamma distribution had the worst performance (Table 3).

Results of Shamshiri variety showed that to model the number, length and width of the petals, Weibull distribution had the best performance, while to model the unit mass of petals and SH diameter, G. E. V and Lognormal distributions had the best performances, respectively (Table 4). Also to model the mass, length and width of the petals, Gamma distribution had the worst performance.

Table 3 – Constant coefficients and capability of models to fit the dimensional data, number of petal, unit mass of petal of the Dorsefid variety.

Parameter	Distribution name	Shape parameter	Scale parameter	Location parameter	Kolmogorov Smirnov index	Rank
Number of petals	Gamma	16.489	3.615	5.552	0.1380	3
	G. E. V	−0.190	13.895	48.272	0.1279	1
	Lognormal	0.140	4.631	−49.581	0.1412	4
	Weibull	2.163	33.714	24.178	0.1334	2
Mass of petal	Gamma	15.503	0.010	−0.011	0.0858	4
	G. E. V	−0.227	0.039	0.132	0.0773	1
	Lognormal	0.112	−1.043	−0.207	0.0857	3
	Weibull	2.141	0.090	0.067	0.0844	2
Length of petal	Gamma	141.940	1.140	−94.681	0.1065	4
	G. E. V	−0.400	14.181	63.032	0.0787	1
	Lognormal	0.035	5.948	−316.120	0.1023	3
	Weibull	4.505	57.236	14.828	0.0818	2
Width of petal	Gamma	147.130	0.108	−9.485	0.0961	4
	G. E. V	−0.391	1.370	6.136	0.0873	3
	Lognormal	0.037	3.578	−29.287	0.0774	2
	Weibull	4.362	5.424	1.590	0.0740	1
Sunflower head diameter	Gamma	79.962	3.370	−110.240	0.0641	3
	G. E. V	−0.282	30.434	148.530	0.0595	2
	Lognormal	0.051	6.361	−420.100	0.0668	4
	Weibull	2.875	87.550	81.292	0.0596	1

Table 4 – Constant coefficients and capability of models to fit the dimensional data, number of petal, unit mass of petal of the Shamshiri variety.

Parameter	Distribution name	Shape parameter	Scale parameter	Location parameter	Kolmogorov Smirnov index	Rank
Number of petals	Gamma	3.251	9.474	17.257	0.1093	2
	G. E. V	−0.009	13.636	40.313	0.1155	3
	Lognormal	0.413	3.619	7.496	0.1161	4
	Weibull	1.765	31.831	19.738	0.1047	1
Mass of petal	Gamma	108.120	0.003	−0.239	0.0701	4
	G. E. V	−0.330	0.036	0.110	0.0478	1
	Lognormal	0.037	0.067	−0.813	0.0658	3
	Weibull	3.988	0.133	0.002	0.0606	2
Length of petal	Gamma	148.86	1.020	90.488	0.1092	4
	G. E. V	−0.412	12.950	57.972	0.0890	2
	Lognormal	0.029	6.041	−358.84	0.1046	3
	Weibull	4.623	53.655	12.501	0.0874	1
Width of petal	Gamma	151.880	0.120	10.865	0.1057	4
	G. E. V	0.359	1.529	6.952	0.0845	2
	Lognormal	0.034	3.755	35.352	0.1005	3
	Weibull	4.199	5.943	2.019	0.0842	1
Sunflower head diameter	Gamma	9.306	9.809	49.158	0.0663	3
	G. E. V	−0.118	26.971	127.710	0.0655	2
	Lognormal	0.207	4.939	−2.209	0.0618	1
	Weibull	2.117	67.402	80.692	0.0699	4

Results of Sirena variety indicated that to model the unit mass, length and width of the petals, Weibull distribution had the best performance, while to model the number of petals and SH diameter, G. E. V distribution had the best performance (Table 5). Also to model the number of the petals, unit mass of the petals, length of the petals and SHs diameter, Gamma distribution had the worst performance.

In order to determine the best distribution, we used the results in Tables 3–5. Based on the Kolomogrov-Smirnov index, we ranked the distributions for each parameter of each

Table 5 – Constant coefficients and capability of models to fit the dimensional data, number of petal, unit mass of petal of the Sirena variety.

Parameter	Distribution name	Shape parameter	Scale parameter	Location parameter	Kolmogorov Smirnov index	Rank
Number of petals	Gamma	75.687	1.545	−62.678	0.1968	4
	G. E. V	−0.264	12.719	49.719	0.1851	1
	Lognormal	0.052	5.551	−203.430	0.1896	2
	Weibull	2.922	40.465	18.192	0.1915	3
Mass of petal	Gamma	16.779	0.013	−0.017	0.0465	4
	G. E. V	−0.172	0.045	0.175	0.0411	2
	Lognormal	0.148	−1.061	−0.153	0.0453	3
	Weibull	2.383	0.130	0.081	0.0400	1
Length of petal	Gamma	155.42	1.291	−120.770	0.1155	4
	G. E. V	−0.405	16.629	75.391	0.1007	2
	Lognormal	0.032	6.215	−420.310	0.1057	3
	Weibull	4.528	68.260	17.715	0.0856	1
Width of petal	Gamma	9.972	0.955	3.167	0.0596	3
	G. E. V	−0.122	2.743	11.403	0.0576	2
	Lognormal	0.202	2.669	−2.037	0.0636	4
	Weibull	2.263	7.188	6.319	0.0572	1
Sunflower head diameter	Gamma	73.693	3.979	−136.560	0.1303	4
	G. E. V	−0.402	35.366	146.670	0.0917	1
	Lognormal	0.045	6.593	−574.340	0.1249	2
	Weibull	2.924	97.499	69.768	0.1268	3

variety. Then we comprised the rank of the distributions. For easy comparison between three varieties, probability and cumulative density distributions of number of petals, mass of each petal, length of each petal, and length of each petal seeds mass are shown in Figs. 8 and 9, respectively. In sum, in order to model the number of petals and mass of each petal, Generalized Extreme Value distribution had the best performance (see Tables 3–5). Also, totally, in order to model the length and width of each petal, Weibull distribution had the best performance. So, we decided to illustrate probability density distributions of number of petal and mass of each petal that were modeled by Generalized Extreme Value distribution and also, illustrate probability density distributions of length and width of each petal that were modeled by Weibull distribution.

Fig. 8 shows that there was a large overlap between the probability density distributions of number of petals of Shamshiri and Sirena varieties and they are same. But, for mass of each petal, length of each petal, and width of each petal, there is more similarity between Dorsefid and Shamshiri varieties. The more overlap between different varieties in each diagram means the average of parameter (number, mass, length, and width) of different varieties are close to each other.

Fig. 9 shows for all parameters (number, mass, length, and width) values of mean of Sirena variety's data are more than the other varieties while, in most cases (for number, mass, and length) values of mean of Shamshiri variety's data are lower than the others.

4. Discussions

A comparison between three varieties showed that in all cases, values of PFSP of Sirena and Shamshiri varieties are highest and lowest values, respectively. Also, results of three varieties showed that with increasing the number of days from 5 to 14 days and decreasing loading rate from 150 to 50 g min^{-1}, values of PFSP decreased. Furthermore, diameter of sunflower head had different effects on PFSP for each variety.

The effect of loading rate and moisture content (in our study moisture content is equivalent to number of days after appearing the first petal in each flower) on picking and cutting force of agricultural crops was also reported by previous researchers. Shearing properties of sugarcane (*Saccharumofficinarum* L.) stems at five moisture content levels, three shearing speed and at ten positions on the stem were investigated [27]. Their results of ANOVA analysis indicated that effect of the shearing rate was significant at 1% probability level. Shearing strength and specific shearing energy increased with increasing shearing rate and so shearing strength and specific shearing energy decreased when the stem moisture content decreased.

Shahbazi & Nazari Galedar, [28] determined bending stress, Young's modulus, shearing stress, and shearing energy of safflower (*Carthamustinctorius* L.) stalk as a function of moisture content and stalk region were determined by Shahbazi & Nazari Galedar, [28]. Their results indicated that shearing strength and shearing energy increased with increasing in stem moisture content. Also, Hassan-Beygi et al. [29] mentioned that with increasing tension rate, the required tensile strength per unit, area of saffron stalk increased significantly.

Results of modeling showed that whenever skewness and kurtosis had negative values, Generalized Extreme Value and Weibull distribution had good performance, while Gamma distribution had poor performance to model the data. Also whenever skewness had positive value and kurtosis a

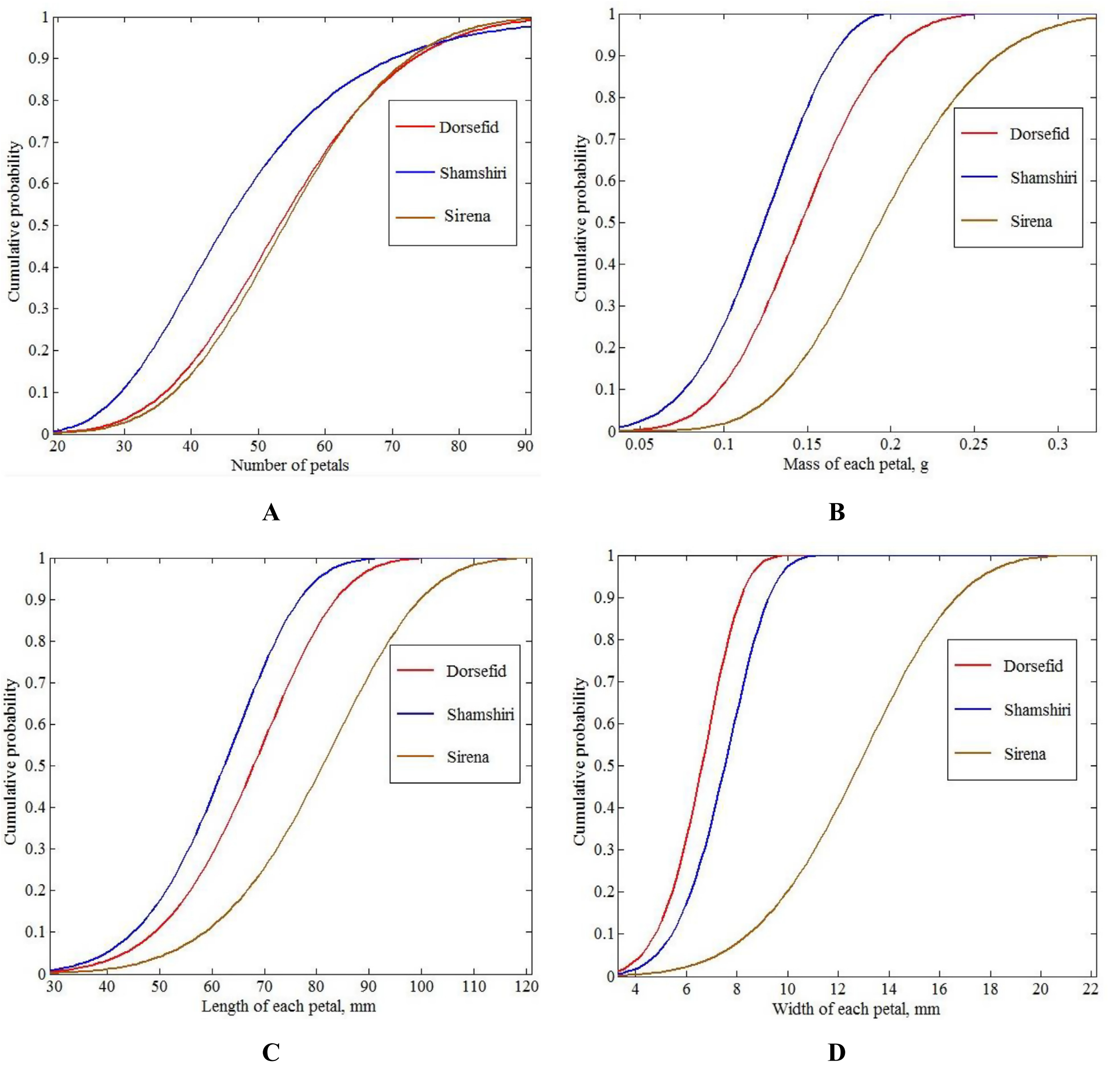

Fig. 8 – Probability density distribution of sunflower petals for the three varieties (A) number of petals on each SH modeled by Generalized Extreme Value distribution, (B) mass of petal modeled by Generalized Extreme Value distribution, (C) length of petal modeled by Weibull distribution, (D) width of petal modeled by Weibull distribution.

negative value, G.E.V and Weibull distributions showed good performance; while Gamma and lognormal distributions had poor performance to model data.

Khazaei et al. [5] modeled mass and size distributions of two varieties of sunflower seeds and kernels using the Log-normal, normal and Weibull distributions. They cited that when skewness had a positive value, Log-normal distribution was the best and normal distribution was the worst model for data prediction. Mirzabe et al. [23] modeled distance between adjacent sunflower seeds on sunflower head of three varieties using the Lognormal, normal and Weibull distributions. They cited that whenever skewness and kurtosis had negative value, Weibull distribution was the best fit one.

Skewness and kurtosis are two statistical indices calculated (based on Eqs. (2) and (3)) so that the reader would better understand the probability density distributions. The first thing usually must be noticed about a distribution's shape is whether it has one mode (peak) or more than one. If it's unimodal (it has just one peak), like most data sets, the next thing noticed is whether it is symmetric or skewed to one side. If the bulk of the data is at the left and the right tail is longer, the distribution is skewed right or positively skewed (see Fig. 8 and Table 2); if the peak is toward the right and the left tail is longer, the distribution is skewed left or negatively skewed [30].

Kurtosis is a measure of whether the set of the data are peaked or flat relative to a normal distribution, that is data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails [30]. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak (see Fig. 8 and Table 2).

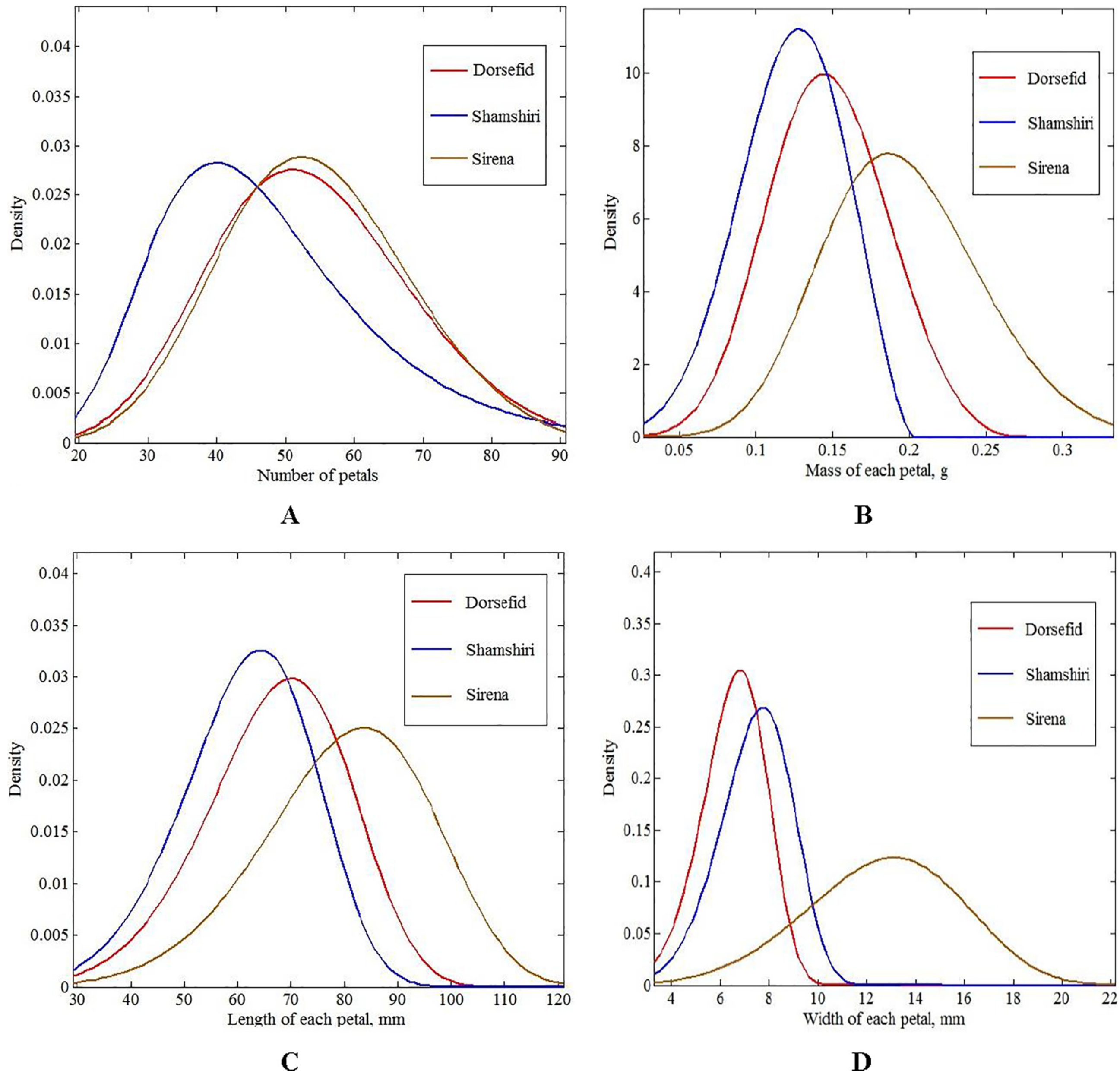

Fig. 9 – Cumulative probability distribution of sunflower petals for the three varieties (A) number of petals on each SH modeled by Generalized Extreme Value distribution, (B) mass of petal modeled by Generalized Extreme Value distribution, (C) length of petal modeled by Weibull distribution, (D) width of petal modeled by Weibull distribution.

5. Conclusions

Result of this study indicated that with increasing SH diameter, number of sunflower petals increases. Unit mass of Dorsefid, Shamshiri, and Sirena varieties, at 80.05, 80.15, and 80.82% (d.b) moisture content, ranged from 0.0789 to 0.2318 g, 0.0406 to 0.1888 g and 0.973 to 0.3198 g, respectively. 1000-unit mass of Dorsefid, Shamshiri and Sirena varieties, at 80.05, 80.15 and 80.82% (d.b) moisture content, were found to be 144.2582, 122.6128 and 198.6842 g, respectively.

For all the varieties, all the characteristics have no significant positively or negatively kurtosis problem. Also, all the characteristics except projected area of Sirena variety and number of petals of Shamshiri variety, have no significant positively or negatively skewness problem.

Frequency distribution of sunflower head diameter, number of petals of each head, length, width, unit mass, and projected area of the petals of three varieties were modeled using four continues statistical distributions, namely Gamma, Generalized Extreme Value, Lognormal and Weibull. Results of frequency distribution modeling indicated that in most cases G. E. V and Weibull distributions had the best performance.

Also, economic analysis showed that harvest of sunflower petals is a reasonable process because its revenue is remarkable and even it can be equal to the revenue from the sale of seeds, themselves. Therefore, an economic analysis justifies

the production, harvesting, drying and selling sunflower petals, as well as research on medicinal and chemical properties of sunflower petals and also on methods of drying them.

Conflict of interest

The authors declare that there is no conflicts of interest.

Acknowledgements

The authors would like to thank the University of Tehran for providing technical support for this work. The authors would also like to thank Ms. Zohre Torki, and Ms. Fateme Jafari for their technical help and support while doing this research. The authors would also like to thank Mohammad Hassan Torabi for his support in editing the language of the paper.

Appendix

F_n	the nth term of Fibonacci sequence
K_s	Kolmogorov-Smirnov index
L_n	the nth term of Lucas sequence
L_p	length of petal, mm
LR	loading rate, g min^{-1}
n	number of occurrence
N_p	number of petals
P_{Ap}	projected area of petal,
$PFSP$	picking force of sunflower petal, N
SE_K	standard errors of kurtosis
SE_S	standard errors of skewness
SH	sunflower head
SHD	sunflower head diameter, cm
W_p	width of petal, mm
x_{avr}	mean of data
x_i	midpoint of each class interval
α	location parameter in Weibull distribution
β	scale parameter in Weibull distribution
Γ	Gamma function
γ	shape parameter in Weibull distribution
δ	location parameter in Gamma distribution
ε	shape parameter Gamma distribution
θ	location parameter in lognormal distribution
λ	scale parameter in lognormal distribution
μ	location parameter in G. E. V distribution
ξ	shape parameter in G. E. V distribution
σ	scale parameter in Gamma distribution
τ	shape parameter in lognormal distribution
ψ	scale parameter in G. E. V distribution

REFERENCES

[1] Darvishzadeh R, Pirzad A, Hatami-Maleki H, Poormohammad-Kiani S, Sarrafi A. Evaluation of the reaction of sunflower inbred lines and their F1 hybrids to drought conditions using various stress tolerance indices. Spanish J Agric Res 2010;8(4):1037–46.

[2] Razi H, Assad MT. Evaluating variability of important agronomic traits and drought tolerant criteria in sunflower cultivars. JWSS-Isfahan Univ Technol 1998;2(1):31–44.

[3] Mirzabe AH, Chegini GR, Khazaei J, Massah J. Design, construction and evaluation of preliminarily machine for removing sunflower seeds from the head using air-jet impingement. Agric Eng Int CIGR J 2014;16(1):294–302.

[4] Goel AK, Behera D, Swain S, Behera BK. Performance evaluation of a low-cost manual sunflower thresher. Indian J Agric Res 2009;43(1):37–41.

[5] Khazaei J, Jafari S, Noorolah S, Nagatsuka T, Ninomiya S. Lognormal vs. Normal and Weibull distributions for modeling the mass and size distributions of sunflower seeds and kernels. In: World conf. agric. inf. IT, n.d., p. 91–105.

[6] Halder S, Gupta K. Effect of storage of sunflower seeds in high and low relative humidity on solute leaching and internal biochemical changes. Seed Sci Technol 1980;8(3):317–21.

[7] Gupta RK, Das SK. Physical properties of sunflower seeds. J Agric Eng Res 1997;66(1):1–8.

[8] Gupta RK, Das SK. Friction coefficients of sunflower seed and kernel on various structural surfaces. J Agric Eng Res 1998;71(2):175–80.

[9] Gupta RK, Das SK. Fracture resistance of sunflower seed and kernel to compressive loading. J Food Eng 2000;46(1):1–8.

[10] Gupta RK, Arora G, Sharma R. Aerodynamic properties of sunflower seed (*Helianthus annuus* L.). J Food Eng 2007;79(3):899–904.

[11] Prasad VSS, Gupta SD. Applications and potentials of artificial neural networks in plant tissue culture. In: Plan tissue cult. eng., Springer; 2008. p. 47–67.

[12] Mansouri A, Fadavi A, Mortazavian SMM. Effects of length and position of hypocotyl explants on *Cuminum cyminum* L. callogensis by image processing analysis. Plant Cell Tissue Organ Cult 2015;121(3):657–66.

[13] Mansouri A, Mirzabe AH, Ráufi A. Physical properties and mathematical modeling of melon (*Cucumis melo* L.) seeds and kernels. J Saudi Soc Agric Sci 2017;16(3):218–26.

[14] Koc AB. Determination of watermelon volume using ellipsoid approximation and image processing. Postharvest Biol Technol 2007;45(3):366–71.

[15] Li Y, Dhakal S, Peng Y. A machine vision system for identification of micro-crack in egg shell. J Food Eng 2012;109(1):127–34.

[16] Lucian C. Geotechnical aspects of buildings on expansive soils in Kibaha, Tanzania; 2008.

[17] Tabachnick BG, Fidell LS. Using multivariate statistics. 3rd ed. New York: Harper Collins; 1996.

[18] Matalas NC. Probability distribution of low flows. US Government Printing Office; 1963.

[19] Bart-Plange A, Baryeh EA. The physical properties of Category B cocoa beans. J Food Eng 2003;60:219–27.

[20] Nanang DM. Suitability of the Normal, Log-normal and Weibull distributions for fitting diameter distributions of neem plantations in Northern Ghana. For Ecol Manage 1998;103(1):1–7.

[21] Gorgoso JJ, González JGÁ, Rojo A, Grandas-Arias JA. Modelling diameter distributions of Betula alba L. stands in northwest Spain with the two-parameter Weibull function. For Syst 2007; 16(2):113–23.

[22] Bhunya PK, Berndtsson R, Ojha CSP, Mishra SK. Suitability of Gamma, Chi-square, Weibull, and Beta distributions as synthetic unit hydrographs. J Hydrol 2007;334(1):28–38.

[23] Mirzabe AH, Khazaei J, Chegini GR. Physical properties and modeling for sunflower seeds. Agric Eng Int CIGR J 2012;14(3):190–202.

[24] Pradhan RC, Naik SN, Bhatnagar N, Vijay VK. Moisture-dependent physical properties of jatropha fruit. Ind Crops Prod 2009;29(2):341–7.

[25] Sahay KM, Singh KK. Unit operations of agricultural processing. Vikas Publishing House Pvt. Ltd.; 1996.

[26] Koshy T. Fibonacci and Lucas numbers with applications, vol. 51. John Wiley & Sons; 2011.

[27] Hemmatian R, Najafi G, Hosseinzadeh B, Tavakkoli Hashjin T, Khoshtaghaza MH. Experimental and theoretical investigation of the effects of moisture content and internodes position on shearing characteristics of sugar cane stems. J Agric Sci Technol 2012;14(5):963–74.

[28] Shahbazi F, Nazari Galedar M. Bending and shearing properties of safflower stalk. J Agric Sci Technol 2012;14 (4):743–54.

[29] Hassan-Beygi SR, Ghozhdi HV, Khazaei J. Picking force of saffron flower and shear strength of saffron stalk. Electron J Polish Agric Univ 2010;13(1):1–10.

[30] Mirzabe AH, Taheri M, Pouyesh A, Bavani NB. Moisture content on some engineering properties of celery (*Apium Graveolens* L) seeds. Agric Eng Int CIGR J 2016;18(2):243–59.