International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 7, 2019, pp.-8173-8178.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

MATHEMATICAL MODELLING OF SELECTED ENGINEERING PROPERTIES OF POMEGRANATE FRUITS (*Punica granatum* L.) cv. GANESH

SURESHKUMAR K.[1], PANDIARAJAN T.*[2], SUDAGAR I.P.[3] AND DURAISAMY M.R.[4]
[1,3]Department of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India
[2]Department of Processing and Food Engineering, Agricultural Engineering College & Research Institute, Kumulur, Tiruchirappalli, 621712, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India
[4]Department of Physical Sciences & Information Technology, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India
*Corresponding Author: Email - pantry_apk@yahoo.co.in

Received: March 28, 2019; Revised: April 11, 2019; Accepted: April 12, 2019; Published: April 15, 2019

Abstract: The mathematical modelling is used to predict some of the models along with their engineering properties of pomegranate fruits. The effects of engineering properties, which are important for designing of post-harvest handling and processing machineries. The moisture content of the pomegranate cv. Ganesh at wet basis was found to be arils (83%), peels (76%), and whole fruit (80%). With respect to moisture content, dimensional properties were categorised as like major diameter (length), intermediate diameter (width), minor (Thickness) diameter, geometric and arithmetic mean diameter, sphericity, surface area, projected area, weight, volume (oblate spheroid, ellipsoid shape), flakiness and elongation ratio of pomegranate cv. Ganesh found to be 79.56 mm, 76.08 mm, 76.18 mm, 77.22 mm, 77.27 mm, 0.97, 188.67 cm^2 and 60.90 cm^2, 253.65 g, 246.69 cm^3 and 469.86 cm^3, 1.00 and 1.05 respectively. The gravimetric properties of pomegranate *viz*., bulk density, true density, porosity and angle of repose were observed to an average values of 554 kg/m^3, 1030 kg/m^3, 46.77%, 49° respectively. The frictional properties of pomegranate were coefficient of friction, rolling angle and rolling resistance and the mean values for different surfaces like mild steel, stainless steel, aluminium, galvanised, rubber and card board was investigated. The mechanical property like firmness of the fruit was found to be 16.4 kg/cm^2. The frequency distribution of the major diameter, geometric mean diameter and the fruit mass/weight followed by normal distribution of Gaussian model. The maximum number of fruits were distributed with a frequency range of major diameter (75-85 mm), intermediate diameter (72.5-82.5 mm), and weight (200-300 grams). The different mathematical models like linear, logarithmic, exponential, polynomial and power models for some engineering properties were used, and their result shown the best suitable mass models, which helps in predicting the mass of pomegranate based on the estimated surface area of the pomegranate cv. Ganesh. The higher regression coefficient of best model R^2=0.93 and the corresponding equation $M= 71.667e^{0.0065Sa}$.

Citation: Sureshkumar K., *et al*., (2019) Mathematical Modelling of Selected Engineering Properties of Pomegranate Fruits (*Punica granatum* L.) cv. Ganesh. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 7, pp.- 8173-8178.

Academic Editor / Reviewer:

Introduction

Pomegranate (*Punica granatum* L.) botanically known as *balusta*. The fruit is considered as one of the 'old world' fleshy berry belonging to the family Punicaceae is a very popular tropical and sub- tropical commercially important non climacteric fruit crops of India. Pomegranate is originated from Iran and has been cultivated and naturalised over the entire Mediterranean region. About 60 % of pomegranate fruits contains edible portion and is highly valued for its medicinal properties and nutritional properties and has many health benefits. Owing to its low maintenance cost, potential-keeping quality, higher nutraceuticals composition. the popularity of pomegranate is increasing among growers and consumer worldwide [1]. India is one of the major country producing pomegranate and the total area under cultivation of pomegranate in India is 0.22 million ha, and production is around 2.8 million metric tons. Pomegranate is widely cultivated in states like Maharashtra, Karnataka, Tamil Nadu, Gujarat and Andhra Pradesh, Punjab, and Haryana. Major pomegranate varieties commercially cultivated in India are Ganesh, Musket, Alandi or Vadki, Paper Shelled, Spanish Ruby, Dholka and Muskati Red [2]. There is tremendous potential for export of pomegranate from India and its fact largest production in the world. To increase the exports is necessary to improve the quality at various stage for production, post-harvest, processing and handling, storage and till it reaches to the customers[3].

The engineering properties especially physical, mechanical, frictional properties of seeds, grains, fruits, nuts or kernels should be known in order to design or modify the equipment for conveying, sorting, grading, transfer, processing, packaging, storing, sizing, oil extraction, drying, and other useful engineering applications [4,5]. Plentiful researches have been investigated on physical, mechanical, frictional and chemical properties of agricultural and horticultural products but there is only limited published literature about physical and mechanical properties of fruits like pomegranate. The knowledge on the corresponding properties is also important for packaging, transportation and marketing of potential value of fruits such as pomegranate. Size and shape are very important for a separator grader and sorter that could be used to determine the lower size limits of conveyors. The characteristic dimensions allow a calculation of the surface area and volume of fruits, important aspects for modelling of drying and ventilation. Porosity affects the bulk density which is also a necessary factor to design a dryer, and conveyor and the true density is useful to design separation equipment [6]. The angle of repose and coefficient of friction are considered by engineers as important properties for the designing of seed containers and other storage structures and accessories. The static friction coefficient limits the maximum inclination angle of a conveyor and storage bin and the frictional properties of fruits are important for specific design problems of fruit handling machines where there is a relative movement of fruits and machine. The coefficient of friction of fruits with respect to material in contact has a significant effect on the skin injury caused to the fruits by machine while handling and transportation and the amount of power requirement for conveyor depends on the magnitude of the frictional force. Angle of repose is a useful parameter for the calculation of belt conveyor width and for designing the shape for storage [7]. Among the physical specifications of agricultural product: spatial dimension, geometric mean diameter, mass, volume, surface area, projected area, porosity, angle of repose, coefficient of friction have been determined by many researchers on dehusked coconut [8]; pomegranate cv. Eksinar variety [9]; orange [10]; pomegranate two cv. Hondosyal abad, Malas saveh [11]; sapota [12]; apricot [13] and the mechanical property especially rupture energy and firmness values have been founded [14]; [15]. The major moisture-dependent physical properties of biological materials are shape size, bulk density, true density, porosity, mass of fruits and friction against various surfaces. These properties have been studied for lily beans [28]. Narrow research has been conducted on the engineering properties and mathematical modelling on particularly Ganesh variety of pomegranate fruit. The main objective of this study was to investigate some engineering properties like moisture content, linear dimensions, geometric and arithmetic mean diameter, sphericity, surface and projected area, weight, volume (oblate spheroid ellipsoid shape), flakiness and elongation ratio, bulk density, true density, porosity, angle of repose, coefficient of friction, rolling angle and rolling resistance against different surfaces, firmness of the pomegranate cv. Ganesh were discussed and frequency distribution, the best mathematical mass model will be developed.

Materials and Methods

Sample procurement and its Moisture content on wet basis

Pomegranate cv. Ganesh is used in this study obtained from commercial market at Coimbatore is used for the study was carried out the experiment at Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The moisture content of the samples was determined by hot air oven at 105 ± 1ºC for 24 h [16]. Each sample was replicated three times and the mean moisture content of the pomegranate arils peels and whole fruit was found as 83%, 76% and 80% respectively.

Dimensional Properties

To determine the dimensions of the pomegranate 143 fruits were selected randomly from the bulk sample. Dimensional properties of fruits geometric mean diameter (DG) and arithmetic mean diameter (DA), sphericity (φ), Surface area (S), projected area (P), Flakiness ratio (FR) and elongation ratio (ER) was calculated based on the length, width and thickness were determined by [Eq 1-7] [17].

$$DG = \sqrt[3]{LWT} \quad (1)$$

$$DA = \frac{L+W+T}{3} \quad (2)$$

$$\varphi = \frac{\sqrt[3]{LWT}}{L} \times 100 \quad (3)$$

$$\mathrm{S} = \pi(\mathrm{DG})^2 \quad (4)$$

$$P = \pi LW/4 \quad (5)$$

$$FR = \frac{Thickness\ of\ the\ fruit}{Width\ of\ fruits} \quad (6)$$

$$ER = \frac{Length\ of\ the\ fruit}{Width\ of\ fruits} \quad (7)$$

The volume pomegranate oblate spheroid (Vosp) and ellipsoid (Vellip) was obtained by the [Eq-8 and 9] [15].

$$Vosp = \frac{\pi\, L(W+T)^2}{24} \quad (8)$$

$$Vellip = \frac{\pi\,(LWT)}{6} \quad (9)$$

Gravimetric property

Bulk density of pomegranate was determined by using the relationship between mass and volume of fruits including its pore space [9] by filling an empty cylinder of predetermined weight and volume and dropping pomegranates from a constant height of 24.5 cm and diameter of cylinder 21.5 cm, striking off the top level and weighted. The measurement was replicated ten times and then the mean values was recorded and expressed as kg/m^3.

$$Bulk\ density = \frac{Mass\ (kg)}{Volume\ (m^3)} \quad (10)$$

True density of pomegranate was determined by water displacement method [18] in a graduated cylinder. In case a fruit floated, the fruit was gently with the help of a 2 mm diameter glass rod and expressed as kg/m^3.

$$True\ volume = \frac{Mass\ of\ displaced\ water\ (kg)}{Density\ of\ water\ (\frac{kg}{m^3})} \quad (11)$$

By knowing the mass of pomegranate fruits in air and the true volume, the true density was obtained as the ratio between the mass of pomegranate fruit in air to its true volume.

$$\rho_t = \frac{W_a}{V_a} \quad (12)$$

Where,

ρ_t = True density of pomegranate kg/m^3,

W_a = Mass of pomegranate in air, kg, and

V_a = True volume of pomegranate, m^3.

Porosity

The porosity ε of the fruits was calculated with the help of its bulk and true density, by [Eq-13] [17].

$$\varepsilon = (1 - \frac{\rho_b}{\rho_t}) \quad (13)$$

Angle of repose

Angle of repose is the angle made by the heap of the materials and its (horizontal surface) base of the cone made by the heap. It is related to the density, surface area and shapes of the particles and the coefficient of friction of the material is gravity dependent [19].

$$\theta = tan^{-1}(H/R) \quad (14)$$

Where,

θ = Angle of repose, degree

H= Height of the heap in cm and

R= Radius of the cone base in cm.

Frictional properties

Coefficient of friction

Coefficient of friction may be defined as the frictional force acting between surfaces in contact and sample at rest. The apparatus used to determine the coefficient of friction of pomegranate consisted of frictionless pulley fitted on a frame with bottomless rectangular having loading pan, and a test surface.

The bottomless container placed on the test surface was filled with known weight of pomegranates, and the weight was added in the loading pan until the container began to slide. The weight of the fruits and weights added on the pan represent the normal force (N) and lateral force (F), respectively [18]. The coefficient of friction was calculated as given below and expressed in decimal.

$$\mu = tan^{-1}({}^{F}/_{N}) \quad (15)$$

Where,

μ = Coefficient of friction

F= Frictional force, kg

N= Normal force, kg

Rolling angle

The rolling angle of fruits was measured with rolling angle measuring apparatus. This apparatus consisted of two parallel rods with grooves fitted to a frame, flat surface and protractor with angles ranging from 0-90 degrees. The fruits were placed on a horizontal surface and the angle of inclination gradually increased until the fruits began to roll. The rolling angle was measured for fifty samples at both maximum and minimum stable positions.

Rolling resistance

Rolling friction is when a body (such as a ball, tire, or wheel) rolls on a surface the force resisting motion. When the fruit rolls on a surface the force resisting motion is termed as rolling friction.

Rolling friction is generally considered less than sliding friction. The rolling resistance for fifty samples was calculated using following formula, and expressed in kg/cm [18].

$$R = F_r \times \frac{W}{r} \tag{16}$$

$$F_r = \tan\varphi \tag{17}$$

Where,

ϕ = Rolling angle, degree

R= Rolling resistance, kg/cm

F_r= Coefficient of rolling friction, decimal

W= Weight of fruits, kg

r = Radius of fruit, cm

It is very important frictional property useful in the design and selection of materials and used for designing feeding tray, hopper, deck, rolling bed, etc. it is calculated using the value of rolling angle.

Mechanical property

Firmness or rupture force

Firmness of the fruit was measure at 23°C using a drill mounted penetrometer (digital force gauge 0-500 N/cm^2). For firmness measurements, the apparatus was directly penetrated the external surface. Three measurements were made per fruit at right angles to each other on paired areas on the equatorial of the fruit, reported [9].

Statistical Analysis

The Data was analysed statistically, using SPSS 16.0 software and MS Excel for determine the descriptive statistics, frequency distributions and mathematical mass modelling of pomegranate cv. Ganesh.

Result and Discussion

A summary of descriptive statistics of the various physical dimensions of pomegranate cv. Ganesh shown in [Table-1]. The mean value of major diameter, intermediate diameter, minor diameter of the fruits at moisture content 80% (w.b) was 79.55 mm, 76.08 mm, 76.18 mm respectively. The arithmetic mean, geometric mean diameter of fruits was 77.27 mm, 77.22 mm respectively. Which was found to be higher than the values obtained for pomegranate cv. Eksinar variety 62.4 (L), 76.9 (W), 71.8 (T) mm and 70.1 (Gm) mm respectively [3] and nearest higher values reported [15] the pomegranate two cultivars Hondos yar abad (77.24 (L), 83.71 (W), 82.88 (T) mm, 81.22mm (Gm) and Malas saveh (78.16 (L), 85.37 (W), 84.42 mm (T) and 79.02 mm (Gm) and also higher values than apricot fruit with spatial dimensions of 46.68 (L), 40.43 (W), 36.73 (T) mm and 41.15 mm (Gm) [7].

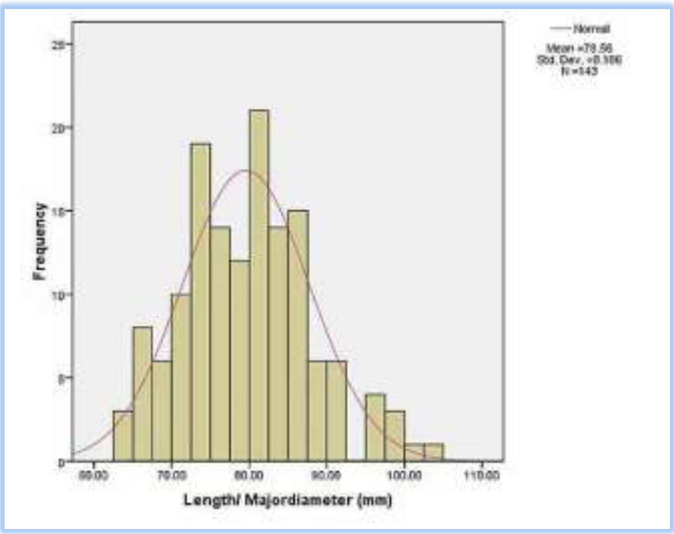

Fig-1 Frequency distribution of 143 pomegranate fruit with major diameter

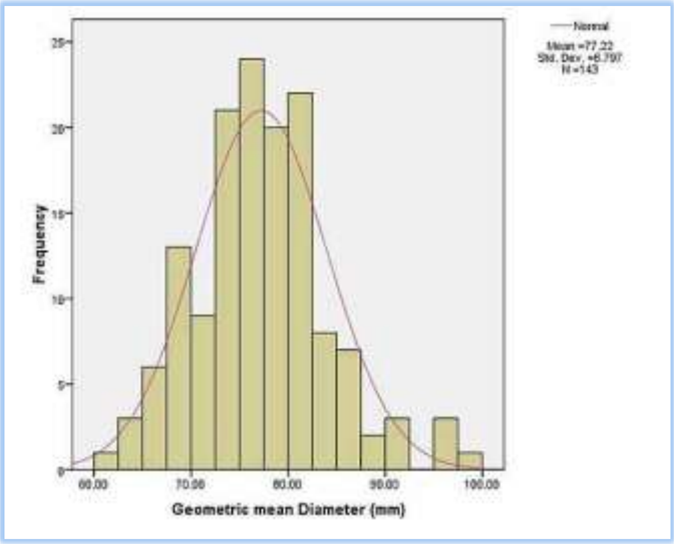

Fig-2 Frequency distribution of 143 pomegranate fruit with geometric mean diameter

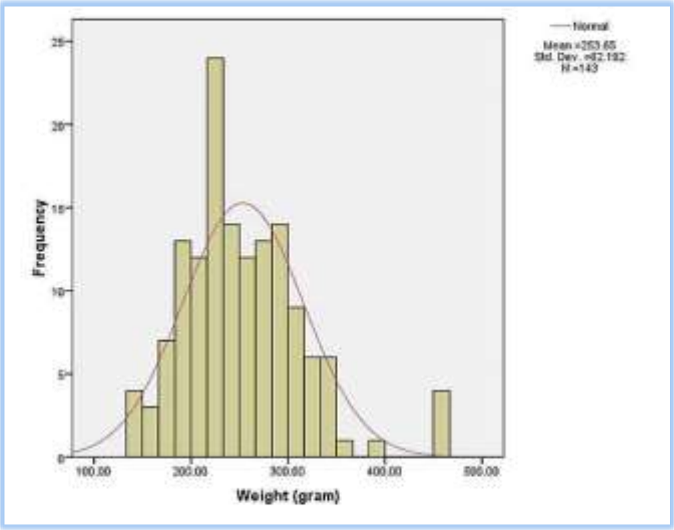

Fig-3 Frequency distribution of 143 pomegranate fruit with weight/mass

The lower values of the coconut fruit reported [1] with dimensions of 99.2 (L), 92.5 (W), 89.5 (T) mm and 92.9 mm (Gm). The importance of these and other characteristics attributes of spatial dimensions in determining the aperture size of machines particularly separation of materials, was discussed [20,21]. The mean fruit mass of pomegranate cv. Ganesh was 253.65 gram which is higher than compared with pomegranate fruit cv. Eksinar (206.4 g) reported [9]; and also higher values for oranges reported the values of pomegranate two cultivars Hondos yar abad (295.29 g) and Malas saveh (316.57 g) and also higher value pomegranate cv.Rubby (321.50 gram) as reported [22]. While the corresponding values for volume and spatial dimensions of eight cultivar of pomegranate from Croatia country [23]. The Sphericity, surface area, projected area, volume of oblate spheroid , volume ellipsoidal, Flakiness, elongation ratio of the fruits was 0.97, 188.67 cm^2, 60.89cm^2, 246.68 cm^3, 469.86 cm^3, 1.00, 1.05 respectively, and the results were compared with lower values of surface area (154.96 cm^2), volume (211.7 cm^3), pomegranate cv. Eksinar variety and respectively, reported [9], and also closer values reported [15] sphericity, volume for pomegranate two cultivars Hondos yar abad (0.96, 239.46 cm^3,) Malas saveh (0.91, 374.5 cm^3) respectively. Which was found to be the lower values of Sphericity, surface area, projected area, volume, for melon seeds (0.36, 25.47 mm^2, 22.31 mm^2, 12.17 mm^3) and kernels (0.37, 22.44 mm^2, 20.04 mm^2, 10.06 mm^3) respectively. Flakiness of pomegranate cv. Ganesh compared with lower values found to be melon seeds (0.22) and kernels (0.21), elongation values higher for melon seeds (2.11) and kernels (2.0) discovered.

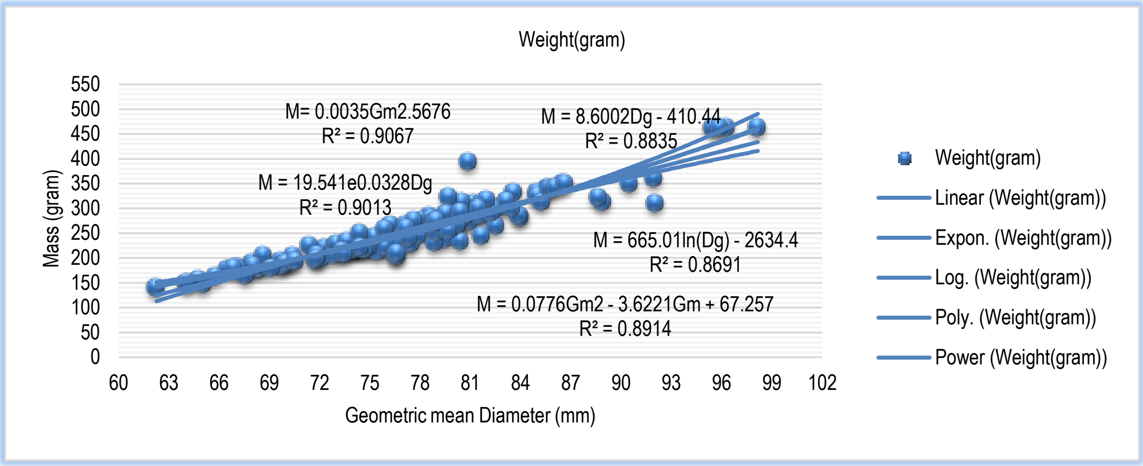

Fig-4 Mass model with geometric mean diameter

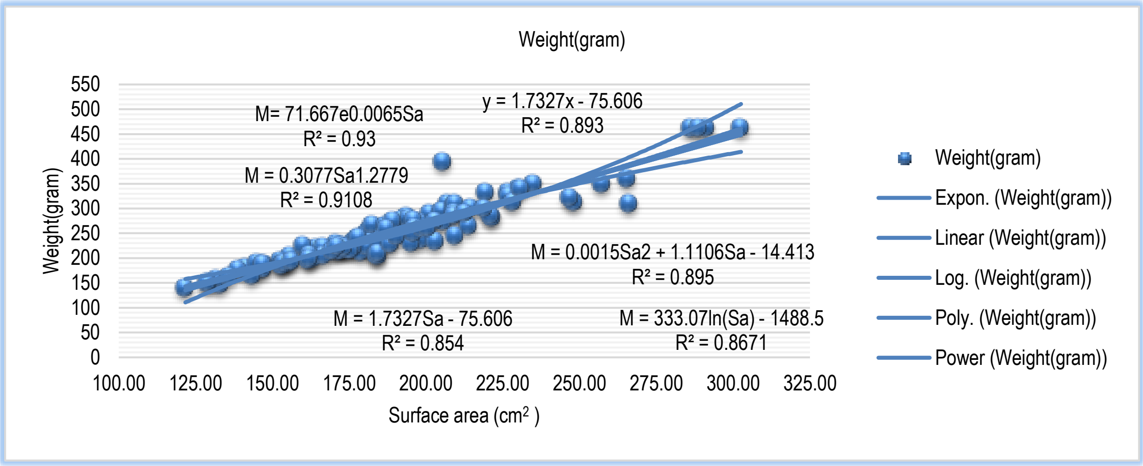

Fig-5 Mass model with Surface area

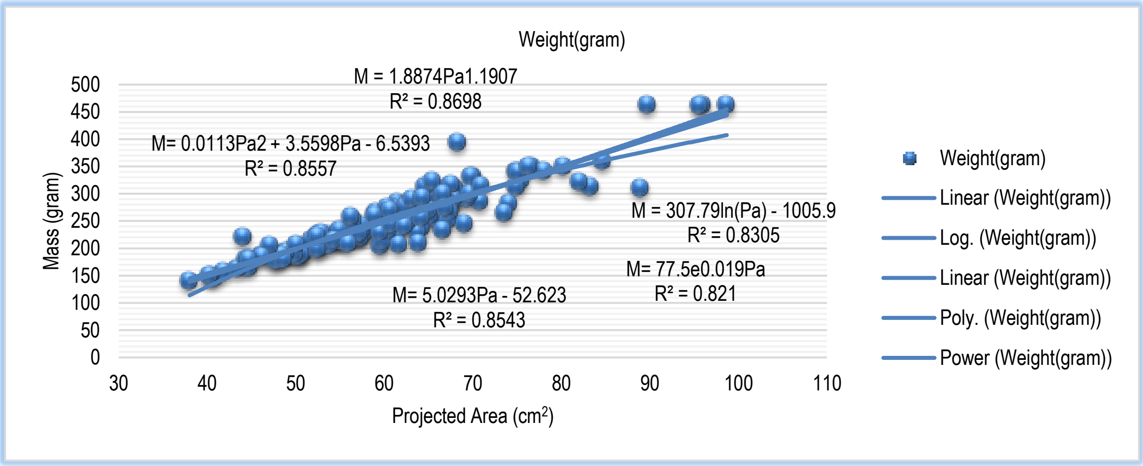

Fig-6 Mass model with Projected area

The bulk density, true density, porosity, angle of repose of pomegranate fruits was 554, 1030 kg/m^3, 46.77%, 490 respectively. Which was found to be the corresponding values bulk density (440kg/m^3), true density (1030 kg/m^3), and porosity (51%) were obtained for orange cv. Tomson, reported [24]. These properties and all useful for separation and transportation of the pomegranate fruit particularly for machine designing purpose [25]. The mechanical property like the mean value of firmness was 16.4 kgf/cm^2 which was compared with the average values of firmness six cultivar for Egyptian pomegranate reported [26]. The coefficient of friction, rolling angle, rolling resistance of the pomegranate fruits against different surfaces shown in [Table-2]. The maximum coefficient of friction fruits was found in mild steel (0.71) followed by aluminium (0.7), galvanised iron GI (0.66), stainless steel SS (0.63), card board (0.59), rubber (0.56) respectively and lower as compared to corresponding co efficient of friction reported [9] for cv. Eksinar pomegranate, and [1] for dehusked coconut. The rolling angle of pomegranate was in maximum stainless steel (15°) followed by mild steel, GI, rubber, card board and aluminium. The rolling resistance of fruits was found maximum in stainless steel (1.97 kgf/cm) followed by rubber, card board, GI, aluminium and mild steel respectively.

Frequency distribution of Geometric dimensions and weight

The frequency distribution of major diameter (length), geometric mean diameter and weight/mass of the pomegranate cv. Ganesh showed a normal distribution and followed a Gaussian model [Fig-1, 2, 3].

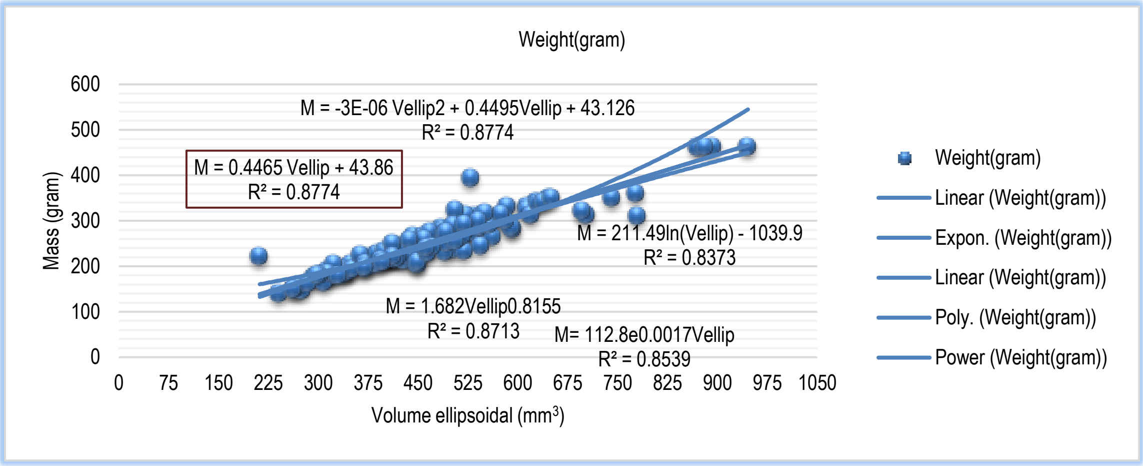

Fig-7 Mass model with volume ellipsoidal

Table-1 *Engineering properties pomegranate (Ganesh) fruits, descriptive statistics*

	Mean	Std. Deviation	N
Length (mm)	79.558	8.18583	143
Width (mm)	76.0785	6.81262	143
Thickness (mm)	76.175	6.55494	143
Weight (gram)	2.54E+02	62.1918	143
Arithmetic mean Diameter (mm)	77.2705	6.81072	143
Geometric mean Diameter (mm)	77.2187	6.79723	143
Sphericity (decimal)	0.9726	0.03551	143
Surface area (cm^2)	1.89E+02	33.70356	143
projected area (cm^2)	60.8979	11.42981	143
Volume oblate spheroid (cm^3)	2.47E+02	67.41647	143
Volume ellipsoid (cm^3)	4.70E+02	130.46956	143
Flakiness ratio (decimal)	1.0023	0.03792	143
Elongation ratio (decimal)	1.0462	0.06176	143
Bulk density (kg/m^3)	554	24.15	50
True density (kg/m^3)	1030	83.86	50
Porosity (%)	46.77	2.6001	50
Angle of repose (degree)	49	3.742	----
Firmness test (kgf/cm^2)	16.4	1.78065	50

Table-2 *Coefficient of friction, rolling angle and rolling resistance of fruits*

Different surfaces	Coefficient of friction	Rolling angle (degree)	Rolling resistance (kgf/cm)
Mild Steel	0.71	14.8	1.45
Stainless Steel	0.63	15	1.97
Aluminium	0.7	11.6	1.51
Galvanised Iron sheet	0.66	12.7	1.57
Rubber	0.56	12.2	1.84
Card Board	0.59	12	1.82

143 fruits samples were taken for study, and the maximum and minimum major, geometric mean diameter of the fruits to be same as 110 mm and 60 mm respectively. The frequency of major diameter and geometric mean diameter were found to range between 75-85 mm and 72.5-82.5 mm respectively. The maximum and minimum weight of fruit was 500 g and 100 g respectively and the corresponding frequency distribution of maximum number of fruits according to weight/mass of fruits the values ranging from 200-300 g and its followed by normal distribution in Gaussian model.

Mathematical mass modelling with four parameters (Geometric mean diameter, surface area, projected area and volume)

Mass model with geometric mean diameter

Among the five mass models (linear, Logarithmic, exponential, polynomial and power models) measurements of four diameters like (major intermediate, minor, geometric and arithmetic diameter). Geometric mean diameter was found higher R^2 (0.9067) by power model equation followed by exponential, and polynomial Shown [Fig-4]. While the one dimensional models were selected as the best suitable mass model with Geometric mean diameter by power model in nature, eq.18. which was found to be best mass model for the pomegranate two cultivars like Malas saveh and Hondos, reported, as for geometric mean diameter with respect to mass model of both variety exponential in nature. The corresponding mass model equation for Malas and Hondos variety were $M=15.52e^{0.0037}$ (Dg), R^2=0.96 and $M=17.296e^{0.0347}$ (Dg), R^2=0.95 respectively.

$M= 0.0035Gm^{2.5676}$ ($R^2 = 0.9067$) (18)

Mass model with Surface Area

While the five mass models (linear, Logarithmic and exponential, power and polynomial) measurements, for Surface area was higher R^2 (0.93) values founded by exponential model equation followed power and polynomial equations shown in [Fig-5]. Hence, the best appropriate mass model corresponding with surface area of pomegranate cv. Ganesh by exponential in nature e.q., 19.

$M= 71.667e^{0.0065Sa}$($R^2 = 0.93$) (19)

Mass model with Projected Area

The linear, Logarithmic, exponential, power and polynomial which the corresponding measurements for projected area was higher regression coefficient R^2 (0.8698) values founded by power model equation followed polynomial and linear Shown [Fig-6]. and also the best suitable mass model corresponding with projected area by power in nature E.q 20. The mass model equations M=1.098(PC)1.273, R^2= 0.97 recommended for sizing kiwi fruits based on projected area was reported [27] where PC respect to projected area. As so far compared with mass model for pomegranate cv. Malas, Hondos variety with projected area, and the best mass model with higher regression coefficient of two cultivars reported.

$M = 1.8874Pa^{1.1907}$ ($R^2 = 0.8698$) (20)

Mass model with volume

All along with the five mass models which was measurements for volume ellipsoidal the higher R^2 (0.8774) values found by Linear and polynomial model Equation shown in [Fig-7]. Because the best suitable mass model corresponding with volume ellipsoidal, linear and polynomial in nature. E.q 21,22. Which was compared with pomegranate two varieties for corresponding two volumes (oblate spheroid, ellipsoidal), reported for best predicted mass model.

$M= 0.4465\ Vellip + 43.86$ $R^2 = 0.8774$ (21)

$M = -3E\text{-}06\ Vellip2 + 0.4495Vellip + 43.126$ $R^2 = 0.8774$ (22)

The overall mass model corresponding with four condition the higher regression coefficient of popular variety (Pomegranate cv. Ganesh - India) were founded surface area have higher R^2 (0.9310) followed by Geometric mean diameter R2 (0.9067), volume R^2 (0.8774) and projected area R^2 (0.8678). Hence, compared with the overall predicted the mass model suitable for surface area with exponential in nature.

Which was found to be the best suitable mass models with volumes had good relationship between them and higher regression coefficient R^2=0.97 for projected area and followed by specific dimensions of two cultivars of pomegranate reported [15], and also compared with orange cv. Tomson the best mass model for polynomial three order function with the mean diameter of orange [24] and higher regression coefficient of polynomial model R^2 (0.99).

Conclusion

Understanding of this research, popular pomegranate (cv. Ganesh) fruit contained average values of moisture content 80% (w.b). The corresponding moisture content of fruits have the mean values of all dimensional properties, gravimetric properties, frictional properties and mechanical property were investigated. Which are essential for designing post- harvest processing machineries for sorting, grading, packaging and transportation of fruits. The frequency distribution of the major, geometric mean diameter and the fruit mass/weight followed by the normal distribution of Gaussian model. The maximum number of fruits frequency distributed along with the major, intermediate, and weight of the fruits were founded 75- 85mm, 72.5-82.5 mm and 200-300 grams respectively. In these distributions of cultivars which help the marketing growth of fruits. Finally, found the best suitable mathematical mass model for pomegranate (*cv*. Ganesh) for corresponding four parameters like major diameter, Geometric mean diameter, surface area, projected area, volume of ellipsoidal. The mathematical mass models needed for make sizing and weighing mechanisms and create more effective and potential for marketing values of fruits. The result shown the best suitable mass model and the higher regression coefficient was R^2 =0.93, corresponding equation is $M= 71.667e^{0.0065Sa}$ which could predict the weight of the pomegranate (*cv*. Ganesh) based on the estimated surface area of the fruits.

Application of research: The mathematical modelling is very much essential to predict some of the models along with their engineering properties of pomegranate fruits. The effects of engineering properties, which are important useful for designing of post-harvest handling and processing machineries.

Acknowledgement / Funding: Authors are thankful to Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India.

***Chairperson of research: Dr T. Pandiarajan**
University: Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu
Research project name: M.Tech Thesis- Development of weight grader with singulating feed conveying mechanism for pomegranate (*Punica granatum* L.) cv. Ganesh

Author Contributions: All authors equally contributed.
Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: The sample were collected from commercial market at Coimbatore

Cultivar / Variety name: Pomegranate (*Punica granatum* L.) cv. Ganesh

Conflict of Interest: None declared
Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] www.nhb.com
[2] Venkatesha H., Y.S.N. (2016) *International Journal of Multidisciplinary Research and Development*, 3(1), 356-359.
[3] Prasad R. N., Chandra R., & Teixeira da Silva J. (2010) *Fruit Veg. Cereal Sci. Biotechnol*, 4, 88-95.
[4] Moustafa S. M. (1971) *Transactions of the ASAE*, 14(3), 549-0553.
[5] Khojastehpour M. (1996) *Design and construction of poptato sorting machine according to Iran condition, M. Sc. Thesis faculty of Bio-system Engineering. University of Tehran*.
[6] Sologubik C., Campañone L. A., Pagano A. M., & Gely M. (2013) *Industrial Crops and Products*, 43, 762-767.
[7] Sirisomboon P., Kitchaiya P., Pholpho T. & Mahuttanyavanitch W. (2007) *Biosystems engineering*, 97(2), 201-207.
[8] Monicka A.A., Pandiarajan T., Ganapathy S., Rani C. I., Sathy R. (2017) *Journal of Agricultural Engineering*, 54(4), 36-42.
[9] Celik A. & Ercisli S. (2009) *Int. Agrophysics*, 23(3), 295-298.
[10] Nivrutti G.N. (2010) *Ph.D thesis (Agricultural Processing and Structures) submitted to the Post-Graduate School, Indian Agricultural Research Institute, New Delhi*.
[11] Wetzstein H.Y., Zhang Z., Ravid N. & Wetzstein M.E. (2011) *HortScience*, 46(6), 908-912.
[12] Ali S., Mandhar, Ganachari A., Ambrish, Nidoni U., Udaykumar & Ananthacharya. (2010) *International Journal of Engineering Science and Technology*, Vol. 2 (12),7555-7561.
[13] Hazbavi I. (2013) *Agricultural Engineering International: CIGR Journal*, 15(4), 288-292.
[14] Ekrami-Rad N., Khazaei J. & Khoshtaghaza M.H. (2011) *International journal of food properties*, 14(3), 570-582.
[15] Mansouri Y., Khazaei J., Hassan Beygi S. & Mohtasebi S. (2010) *Journal of Food Processing Technology*, 1, 1-4.
[16] Suthar S.H., Das S.K. (1996) *Journal of Agricultural Engineering Research*, 65(1), 15-22.
[17] Mansouri A., Hossein A. & Ra A. (2015) *Journal of the Saudi Society of Agricultural Sciences*, doi: 10.1016/j.jssas.2015.07.001.
[18] Sahay K.M. & Singh K.K. (2001) *Unit Operations of Agricultural Processing, 2/e, ISBN: 9788125911425, Vikas Publishing House Pvt. Ltd., India*
[19] Kleinhans M., Markies H., De Vet S. & Postema F. (2011) *Journal of Geophysical Research: Planets*, 116(E11).
[20] Mohsenin N.N. (1980) *New York: Gorden and Breach Science Publishers.*
[21] Omobuwajo T., Sanni, L., & Olajide, J. (2000) *Journal of Food Engineering*, 45(1), 43-48.
[22] Fawole O. A., & Opara U. L. (2013) *Scientia Horticulturae*, 150, 37-46.
[23] Radunić M., Špika M. J., Ban S. G., Gadže J., Díaz-Pérez J. C. & MacLean D. (2015) *Food chemistry*, 177, 53-60.
[24] Sharifi M., Rafiee S., Keyhani A., Jafari A., Mobli H., Rajabipour A., & Akram A. (2007) *International Agrophysics*, 21(4), 391.
[25] Omobuwajo, T., Ikegwuoha, H. Koya O., & Ige M. (1999) *Journal of Food Engineering*, 42(3), 173-176.
[26] Ismail O.M., Younis R.A. & Ibrahim A. (2014) *African Journal of Biotechnology*, 13(2).
[27] Lorestani A. N. & Tabatabaeefar A. (2006) *International Agrophysics*, 20(2), 135.
[28] Suganya P. and Kailappan R. (2013) *International journal of recent Scientific Research*, 4(11), 1835-1838.