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Physical Attributes and Modelling of Trans-Himalayan Seabuckthorn Berries

SWAPNIL G. JAISWAL[1]*, BHUSHAN R. DOLE[1], SANGRAM K. SATPATHY[1,2] and S.N. NAIK[1]

[1]Center for Rural Development and Technology, Indian Institute of Technology Delhi-110016, India.
[2]Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Post-Harvest Technology, Ranipool, Gangtok (Sikkim)-737135, India.

Abstract

Seabuckthorn is a highly perishable fruit found in trans-Himalayan region and North-Eastern part of India. It has enormous nutritional and medicinal properties. Physical attributes of fruits play an important role in the design of machines to meet various harvest and post harvest operations. In the present study properties like dimensions, true density, bulk density, sphericity, porosity and angle of repose were measured and correlated with the mass of the fruit. In addition linear, polynomial, quadratic, logarithmic and exponential models were used for mass and surface area. The length, diameter, thousand berry weight, geometric mean diameter, arithmetic mean diameter, surface area, aspect ratio, angle of repose, sphericity, porosity, true density, bulk density, moisture content were found in the range of 6.5-7.5, 4.74-6.28, 362.67-910.14, 5.49-6.99, 6.17-6.24, 76.87-154.76, 72.81-83.73, 3.59-6.82, 65.84-90.47, 17.05-60.07, 647.19-1399.24, 453.81-725.88, 84.53-87.34 respectively.Polynomial model was suited to be best for mass with length and diameter. Polynomial model between surface area and geometric mean diameter gave highest R^2 of 0.981.

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Keywords

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Physical properties,
Mass modelling,
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Introduction

Seabuckthorn is known as a new botanicals of upcoming era because of its medicinal and nutritional properties (Stobdan *et al.,* 2008). According to some researcher's prediction, seabuckthorn is the "next major health food fad." The nutritional and health potential of the fruit has been reviewed earlier in terms of nutraceutical and cosmoceutical applications (Bal *et al.,*2011). In India seabuckthorn is widely spread in the trans-Himalayan and North-East region (Figure 1). Economically the whole shrub of seabuckthorn is useful for the population living in the cold desert of Leh-Ladakh (Stobdan *et al.,*2012). Defence Institute of High Altitude Research (DIHAR) located in Leh-Ladakh has been working on seabuckthorn for their promotion, large scale cultivation and processing in order to develop this region economically by creating revenue and

CONTACT Swapnil G. Jaiswal swpnljaiswal320@gmail.com Center for Rural Development and Technology, Indian Institute of Technology Delhi-110016, India.

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livelihood for the local population. Unfortunately post-harvesting practices for the picking of fruit from the thorny branches are so much disappointing and no mechanical tool is available for the picking. Therefore cost of harvesting is increased due to manual hand picking (Stobdan *et al.,* 2012). In order to overcome this problem, it is necessary to develop mechanical tool which will enhance the safe and efficient picking without causing any damage to berries and branches of the shrub. Hence, study of physical properties of seabuckthorn berry is needed, which required for the design and development of suitable equipments for harvesting, post-harvest processing and material handling.

According to Khosnam *et al.,*(2007), measurement of physical properties of agricultural and horticultural products is an important tool in design of sorting, grading, conveying, processing and packaging system. In another study, length, width, thickness, mass, volume and projected area was found to be the most important parameters in the sizing system (Mohsenin *et al.,* 1986; Pelag and Ramraz, 1975; Khodabandhloo, 1999). Hence from the economic point of view, consumer prefers fruits and vegetable of uniform weight and size. Therefore study of relationship between weight and other sizing attributes is necessary (Storshine and Hamann, 1994). Shahbazi and Rahmati (2012), determine best (R^2=0.98) and worst (R^2=0.66) predicted mass model based on criteria projected area and thickness for fig fruit.Mass model based on volume was fitted perfectly with maximum coefficient (R^2=0.91) for two Iranian apples varieties (Chakespari *et al.,* 2010). Few researchers reported surface area based model for apple and nutmeg (Torabi *et al.,*2013; Lorestani *et al.,* 2013). Soltani *et al.,* (2011) developed model for banana fruit on the basis of geometrical attributes. Physical properties of other agricultural products were measured and reported by some other researcher; simarouba fruit and kernel (Dash *et al.,* 2008), jatropha seed (Garnayak *et al.,* 2008), yellow oleander fruit and kernel (Sahoo *et al.,* 2009), mahua flower (Patel *et al.,* 2011).

Few studies has been carried out in the past on the physical properties of berries by Jarcau M., (2012) and Dwivedi *et al.,*(2005). But, no such studies related to mass modelling of seabuckthorn have been reported. The aim of the present study was to develop most desirable model on the basis of measured physical properties for predicting berries masson the basis of dimensions and surface area. In this study the correlation of various physical properties with respect to mass of the fruit has been studied. It also provides important information for researcher, horticultural product processor and food processor to design harvesting and processing tools.

Materials and Methods

Seabuckthorn berries were collected from the research farm of the Defence Institute of High Altitude Research (DIHAR) located in Leh-Ladakh. The berries were packed in polythene bags and transported to IIT, Delhi in ice containers. The berries were stored in the laboratory in deep freezer at - 25 °C before start of the experiments. The principal dimensions, i.e. length (L) and diameter (D) of a hundred randomly selected seabuckthorn berries were measured by using a digital Vernier calliper of 0.01 cm least count (Fig. 1). From the principal dimensions, the geometric mean diameter (D_g) was calculated and is expressed as size. Berry mass was measured by using an electronic balance of 0.001 g sensitivity. To determine the 1000 berry mass, 100 randomly selected berries were weighed and extrapolated. The volume and true density of fruits and seeds were measured by liquid displacement method and toluene was used as the liquid. Porosity of bulk materials was calculated from bulk and true densities using their ratio in percentage (Mohsenin, 1986). The berry volume was measured using a 500 mL measuring cylinder. Arithmetic mean(D_a) was calculated by dividing the diameter of all samples with the number of samples taken. The true density was calculated as the ratio of berry mass by volume. The seed to pulp ratio was also calculated from the berry and seed masses. The oil was extracted from pulp using solvent extraction method (soxhlet). The size, sphericity (φ), surface area (S), porosity (ϵ), bulk density and true density were computed using the following equations 1-5 (Kingsly *et al.,* 2006; Topuz *et al.,* 2005):

$$D_g = (L \times D^2)^{1/3} \quad ...(1)$$

$$\varphi = (D/L)^{2/3} \quad ...(2)$$

$$S= \pi L^{2/3}D^{4/3} \quad ...(3)$$

$$\varepsilon= \rho t- \rho b/\rho t * 100 \quad ...(4)$$

$$Da= 1/n^* \sum_{i=1}^{n} Xi \quad ...(5)$$

Modelling of Seabuckthorn Fruit

In the present study all physical parameters based on mass and surface area were studied to develop models. Five models system namely linear (6), power (7), polynomial (8), exponential (9) and logarithmic (10) were used to predict best model for seabuckthorn fruit.

$$a = k_1b + k_2 \quad ...(6)$$

$$a = k_1b^{k2} \quad ...(7)$$

$$a = k_1 + k_2b + k_3b^2 \quad ...(8)$$

$$a = k_1e^{k2b} \quad ...(9)$$

$$a = k_1\ln (b) + k_2 \quad ...(10)$$

Where, 'a' is dependent variable for mass (M) and Surface area (S) determination

b is independent variable for physical characteristics

k_1, k_2, k_3 are regression coefficient

Statistical Analyses

MS-office (excel spreadsheet) was used to analyse physical property data. All values are reported in the form mean ± SD. Statistical analyses for correlation between physical properties and regression modelling was done by using the same software.

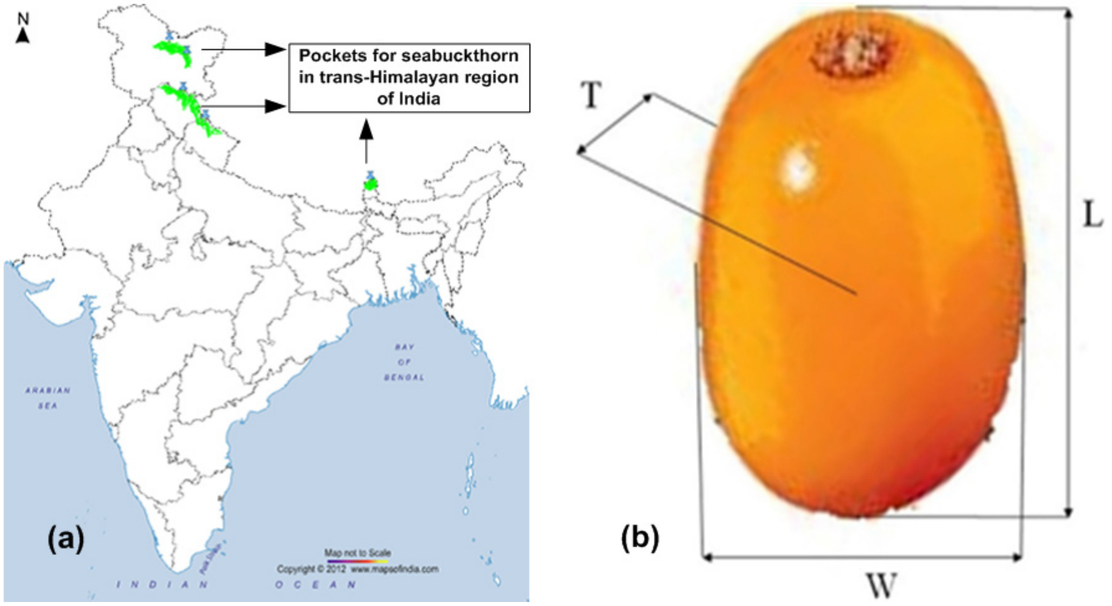


Fig.1: (a) Different pockets (Ladakh, Himachal Pradesh and Sikkim) for seabuckthorn in trans-Himalayan part of India (b) Dimensions of seabuckthorn berry fruit, L: length, W: width, T: thickness

Result and Discussion

The average, minimum, maximum and standard deviation values of the studied physical parameters are given in Table-1. All the measurements of physical parameters were taken on fresh weight basis. The length, diameter, thousand berry weight, geometric mean diameter, arithmetic mean diameter, surface area, aspect ratio, angle of repose, sphericity, porosity, true density, bulk density, moisture content were found in the range of 6.5-7.5, 4.74-6.28, 362.67-910.14, 5.49-6.99, 6.17-6.24, 76.87-154.76, 72.81-83.73, 3.59-6.82, 65.84-90.47, 17.05-60.07, 647.19-1399.24, 453.81-725.88, 84.53-87.34 respectively. Due to variation in dimensions and mass in fruit, some major difference was observed in the measured values of thousand berry weight, surface area, angle of repose, sphericity, porosity, true density, bulk density. Hence, relation between mass and other physical parameters (true density, bulk density, sphericity, porosity, surface area and angle of repose) were also studied in order to observe coefficient of determination (R^2) and best suited equation.

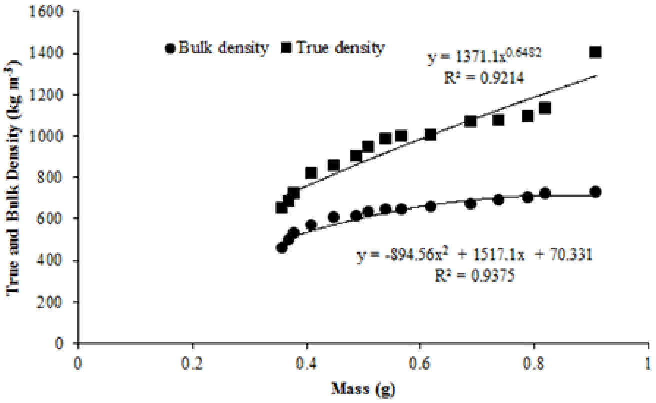
Some other physicochemical parameters namely percent seed, percent pulp, pulp to seed ratio and percent oil were also determined which is important from the economic point of view. Extraction of oil from pulp was carried out by solvent extraction method. Two hour extraction procedure was followed by using hexane and ethanol as extraction solvent in 1:1 ratio. 3.6 % yield of oil was obtained on fresh weight basis. In earlier report range of percent of oil yield from pulp and seed was reported to be 1.5-3.5 and 9.9-19.5 respectively (Stobdan *et al.,* 2008).

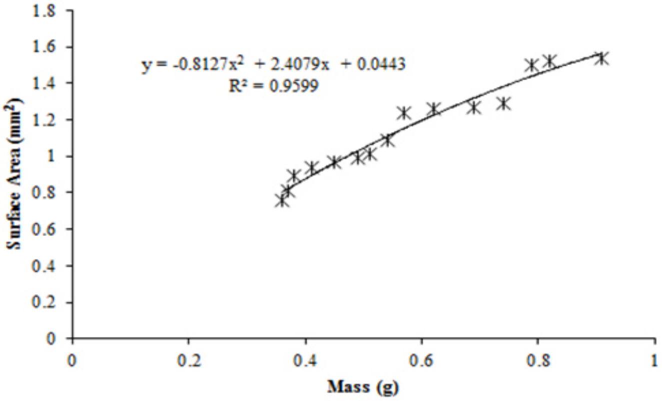
Variation of Physical Properties

Seabuckthorn is a highly perishable and delicate fruit due to its soft texture. Its physical parameter like diameter is greatly affected by than length, which is in agreement to previous reports (Jarcau M., 2012). Mass is an equally important factor with moisture which play an important role in post-harvest processing of fruits and vegetables. Present study includes the effect of mass on some important physical characteristics as shown in figure 2. Sphericity and porosity results show that as the mass increases sphericity and porosity increases. Polynomial equations 11 and 12were fitted best for sphericity and porosity with highest R2 0.971 and 0.960 respectively.

$$y = -80.48x^2 + 140.31x + 28.179 \quad ...(11)$$

$$y = -15.72x^2 + 87.436x - 6.7964 \quad ...(12)$$





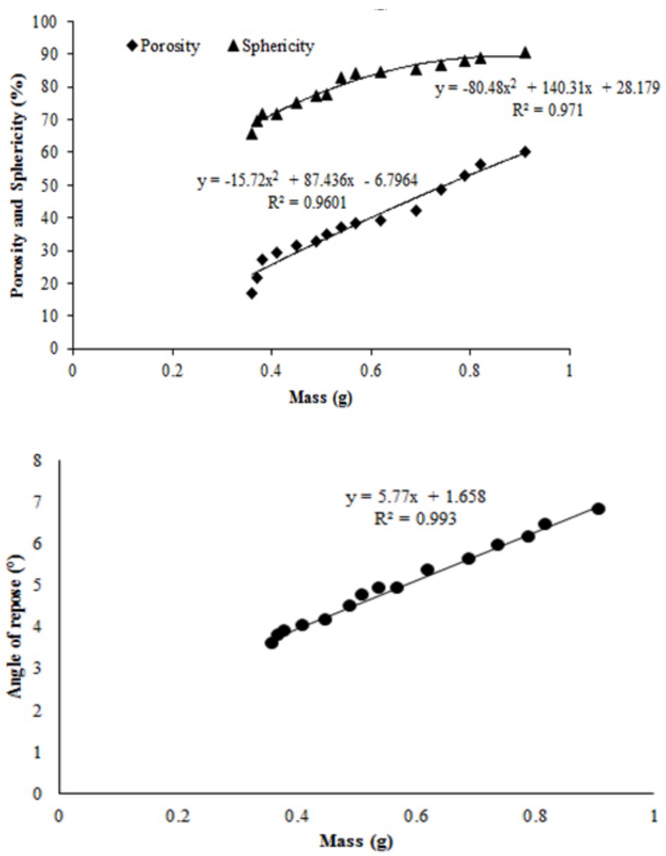


Fig. 2: Effect of mass on various physical parameters

Table 2: Modelling based on mass

Sr. No.	Models	Relation	Best suited Model	R^2	RSE
1	$M= k_1L + k_2$	$M= 0.51L – 2.96$	Exponential	0.987	0.035
2	$M = k_1D + k_2$	$M = 0.39D – 1.57$	Polynomial	0.980	0.028
3	$M = k_1L + k_2D + k_3$	$M = 0.26L + 0.18D – 2.12$	Polynomial	0.997	0.024
4	$M = k_1D_g + k_2$	$M = 0.39D_g – 1.78$	Polynomial	0.988	0.027
5	$M = k_1S + k_2$	$M = 139.01S – 34.01$	Exponential	0.963	5.554

Values for true and bulk density was also found to be directly proportional with the increasing mass. Logarithmic and polynomial equation with highest R^2 0.915 and 0.937 was found to be fitted best for true and bulk density respectively (Eq.13 and 14).

$$y = 608.92\ln(x) + 1313.3 \quad ...(13)$$

$$y = -894.56x2 + 1517.1x + 70.331 \quad ...(14)$$

results for angle of repose was linearly correlated with mass while polynomial relation was found between mass and surface area as shown in following equation 15 and 16. R^2 recorded for equation 11 and 12 were 0.993 and 0.959 respectively. Strong correlation with highest coefficient of determination was observed between mass and angle of repose, whilemass and true densities were found to be poorly correlated.

$$y = 5.77x + 1.658 \quad ...(15)$$

$$y = -0.8127x^2 + 2.4079x + 0.0443 \quad ...(16)$$

Modelling Based on Mass and Surface Area

Model was prepared based on mass using dimensions of the seabuckthorn fruit like length, diameter, geometric mean and surface area (Meisami-asl *et al.,* 2009). The developed models are shown in Table-2. The best among the 5 models prepared was the polynomial model with R^2 of 0.997 and RSE of 0.024. This model indicates strong effect of length and diameter on the mass of berries. Among the single variable regression models, the polynomial model between mass and geometric meanhad highest R^2(0.988) and RSE of 0.027. Surface area based model with respect to dimensions and mass were developed and shown in Table 3. The best model among the single and multiple regression model was the polynomial model between surface area and geometric mean diameter giving highest R^2 = 0.981 and RSE = 4.38.

Table 3: Modelling based on surface area

Sr. No.	Models	Relation	Best suited Model	R^2	RSE
1	$S= k_1L + k_2$	S = 70.24L – 378.3	Power	0.948	6.53
2	$S = k_1D + k_2$	S = 59.34D – 205.5	Polynomial	0.947	5.86
3	$S = k_1L + k_2D + k_3$	S = 29.53L + 34.76D -288.53	Exponential	0.979	5.79
4	$S = k_1D_g + k_2$	$S = 57.9D_g – 236.3$	Polynomial	0.981	4.38
5	$S = k_1M + k_2$	S= 145S + 31.1	Polynomial	0.932	5.42

Conclusion

The shape of seabuckthorn berry was found to be somewhat ovoid. 3.6 % of oil yield was obtained from seabuckthorn berry pulp.

Correlation between mass and other physical attributes (true density, bulk density, sphericity, porosity and angle of repose) were studied. Sphericity, porosity and bulk density varied with fruit mass and followed polynomial regression equations. However, angle of repose and true density wererelated to mass in linear and logarithmic equations respectively.

In modelling study, 5 mass based model were studied and the polynomial model was best suited with highest R^2 = 0.997 and RSE = 0.024. This model indicates strong correlation between length and diameter on the mass of berries.

The best model among the single and multiple regression model was the polynomial model between surface area and geometric mean diameter giving highest R^2 = 0.981 and RSE = 4.38.

This study concludes that mass model is fitted best from economic point of view for further study.

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