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Comparative study of physical properties of Nutmeg (*Myristica fragrans* Houtt.) of different varieties

S Yamagar and Siddhi Borkar

Abstract
The physical and engineering properties of Nutmeg are important for developing harvesting, and different process equipment machineries, for its mass handling and storage. Keeping this in view, a study was undertaken to determine physical and engineering properties Nutmeg of different varieties viz., Konkan Sugandha, Shrimanti and Vishwashri respectively. The average length, breadth and thickness of Nutmeg were found to be 65.99, 54.41 and 46.07 mm for Konkan Sugandha; 57.21, 50.19 and 43.43 mm for Konkan Shrimanti and 60.30, 45.11 and 38.61 mm for Konkan Vishwashri respectively. Whereas the average sphericity and size or equivalent diameter were o.82 and 54.88 mm for Konkan Sugandha; 0.87 and 49.94 mm for Konkan Shrimanti; 0.78 and 47.18 mm for Konkan Vishwashri respectively. The unit volume, surface area and projected area of the Nutmeg were found to be 86.57 cc, 23.57 cm^2 and 94.63 cm^2 for Konkan Sugandha; 65.25 cc, 19.61 cm^2 and 78. 37 cm^2 for Konkan Shrimanti; 55.00 cc, 69.94 and 17.50 cm^2 for Konkan Vishwashri respectively. The bulk density of matured Nutmeg fruit (Cv Konkan Vishwashri) was found to be 0.58 g/cc.

Keywords: nutmeg, physical properties, engineering properties

Introduction
Nutmeg belongs to the family *Myristicaceae* which is a small group comprising 16 genera and about 380 spices. It is an important tree spice which produces two different spices namely Nutmeg and mace. It is mainly distributed to the low land tropical forests of the world. Nepal, Bhutan, Grenada, Sri Lanka, Malaysia, Indonesia and Guatemala are major Nutmeg growing regions. Guatemala is world's largest producers of Nutmeg (24,000 MT) which contributes 32.44 per cent of the world's total production. In India, it has occupied an area of about 19,670 ha with an annual production of 18,070 MT. It is grown in Tamil Nadu, Kerala, Karnataka, Assam, Andhra Pradesh, Konkan region in Maharashtra and Goa (Anonymous 2016) [2]. The female Nutmeg tree starts fruiting from sixth years, till the peak period is reached after 20 years.

Physical and engineering properties such as length, breadth and thickness of fruit also weight of fruit, nut mace and pericarp, shape, equivalent diameter, sphericity, unit volume, surface area, projected area, and bulk density etc. are essential information in the design of equipment for handling, processing and storing of the Nutmeg. In recent years, physical and mechanical properties of seeds have been reported by many researchers. The physical properties have been studied for various types of seeds, such as locust bean seed (Ogunjimi *et. al*., 2002) [8] and (Bulent *et al*., 2006) [4].

Hence, a study was undertaken to determine some physical properties, and of fully matured Nutmeg fruit required for development of harvesting, handling, storing and process equipment. The experiment of measurement of physical properties and engineering properties of fully matured fruits was carried out at Department of Horticulture, College of Agricultural, Dr. BSSKKV, Dapoli, Dist. Ratnagiri (Maharashtra), India.

Materials and Method
Determination of physical properties of Nutmeg
The Nutmeg Cv Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri were used for the experiment. The Nutmeg has three different parts viz., nut, mace and pericarp. The physical properties of Nutmeg fruits were measured in the laboratory of AICRP on Spices,

Department of Horticulture, College of Agriculture, Dapoli. The fully matured fruits were selected randomly. The physical properties of matured Nutmeg fruit measured dimensions like length, breadth, and thickness using Vernier caliper (Range 0 to 30 cm and least count 0.01 mm).

Fruit length
The length of sampled fruits from stalk base to the apex of fruit was measured with the help of Vernier caliper (Range 0 to 30 cm and least count 0.01 mm) in cm to find mean length as shown in plate 1.

Fruit breadth
The maximum linear distance between two sides of the fruits was considered as the breadth and was measured with the help of Vernier caliper (Range 0 to 30 cm and least count 0.01 mm) in cm to find mean breadth.

Plate 1: Measurement of length, breadth and thickness of fruit with the help of Vernier caliper.

Plate 2: Weight of fully matured Nutmeg fruit

Fruit thickness
The minimum linear distance between two sides of the fruits was considered on the thickness and was measured with the help of Vernier caliper (Range 0 to 30 cm and least count 0.01 mm) in cm to find mean thickness

Weight of fruit
Individual freshly harvested fruit was weighed on electronic balance (Range 0 to 2 kg and least count 0.1 g) in g to find mean fruit weight and moisture content of fruit was found out on wet basis in per cent by oven dry method (plate 2).

Weight of nut
The weight of above selected nuts was measured on electronic balance (Range 0 to 2 kg and least count 0.1 g) in g to find mean weight of nut and found out the moisture content of nut on wet basis in per cent by oven dry method.

Weight of mace
The mace was separated from the fruit and weighed individually on electronic balance (Range 0 to 2 kg and least count 0.1 g) in g to find mean weight of mace and moisture content was found out on wet basis in per cent by oven dry method.

Weight of pericarp
The weight of pericarp was calculated by subtracting the weight of Nutmeg fruit and weight of nut and mace for the respective fruits and recorded in g and found out the moisture content of pericarp on wet basis in per cent on oven dry method.

Determination of engineering properties of Nutmeg
The following engineering properties viz., size or equivalent diameter or geometric mean diameter, sphericity, unit volume, projected area, surface area and bulk density were determined with the help of different formulae as follows. The three different crop varieties were selected for measurement of engineering properties viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The above mentioned engineering properties of Nutmeg fruit were determined in Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Dapoli during last week of August 2017.

Size or equivalent diameter or geometric or mean diameter
Size or equivalent diameter is the geometric mean of the three dimensions viz., length, breadth and thickness (Mohsenin,

1950) [7]. The size was calculated by using following relationship.

$$\emptyset = 3\sqrt{LBT} \quad \ldots\ldots\ldots (1)$$

Where,

$\emptyset$ = Size or equivalent diameter, mm
L = Length (Major diameter), mm
B = Breadth (intermediate diameter), mm
T = Thickness (minor diameter), mm

Sphericity

The shape of Nutmeg kernel resembles like that of ellipsoid. The volume of the solid was assumed as equal to the volume of the triaxial ellipsoid with intercept L, B, T and that the diameter of the circumscribed sphere is the longest intercept (L) (Mohsenin, 1950) [7]. The degree of sphericity was determined with the help of following formula.

$$S = \sqrt[3]{LBT}/L \quad \ldots\ldots\ldots\ldots (2)$$

Where,
S= Sphericity, %
L = Length (Major diameter), mm
B = Breadth (intermediate diameter), mm
T = Thickness (minor diameter), mm
Also, Sphericity = Geometric mean diameter/Major Diameter

Unit volume

Unit volume of individual seeds was determined from the values of L, B and T using the formula proposed by Miller, 1987.

$$V = \pi\frac{LBT}{6} \quad \ldots\ldots (3)$$

Where,
L = Length (Major diameter), mm
B = Breadth (intermediate diameter), mm
T = Thickness (minor diameter), mm
V= Unit volume, mm^3

Projected area

The projected area of fruit was found out by equation proposed by Li *et al*., (1998) [5]. This was investigated by using unit volume above as,

$$A_p = kV^{2/3} \quad \ldots\ldots (4)$$

Where,
A_p = projected area, mm^2
V = unit volume,
(k= constant =1.21)

Surface area

The surface area of Nutmeg fruit was calculated with the help of the formula given by Li *et al*., (1998) [5].

$$A_s = (36\ \pi)^{1/3}\times(V)^{2/3} \quad \ldots\ldots\ldots\ldots (5)$$

Where,
A_s = Surface area, mm^2
V = unit volume

Bulk density

Bulk density was determined by filling a specific mass of sample in known volume of rectangular box. The sample was weighed which required for filling the box. The bulk density of nutmeg fruit expressed as below (Mohsenin, 1950) [7],

Bulk density = weight of material/Volume of material …….. (6)

Results and Discussion

The various physical and engineering properties of Nutmeg were determined by following standard procedure and presented as follows.

Physical properties of Nutmeg fruit

The physical and engineering properties of matured Nutmeg fruit (Cv Konkan Sugandha, Shrimanti and Vishwashri) required for designing the fruit harvesting, handling and storage equipment were determined and presented in Table 1 (Cv Konkan Sugandha), Table 2 (Cv Konkan Shrimanti) and Table 3 (Cv Konkan Vishwashri) respectively.

Fruit length

The length of matured Nutmeg fruit was determined by taking each 50 numbers of Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The length of matured Nutmeg fruits varied in the range from 52.62 to 79.01 mm, 43.56 to 74.73 mm and 43.73 to 78.11 mm for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. An average fruit length of single fruits was obtained 65.94 (±7.28), 57.21 (±7.92) and 60.31 (±8.99) mm respectively. It is observed that, length of Konkan Sugandha fruit was higher as compared to other variety of Nutmeg fruits and lower in Konkan Shrimanti as compared to other variety.

Fruit breadth

The breadth of matured Nutmeg fruit was determined by taking each 50 numbers of Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The breadth of matured Nutmeg fruits varied in the range from 44.34 to 65.2 mm, 38.71 to 63.28 mm, and 34.26 to 60.18 mm for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. An average fruit breadth of single fruits was obtained 54.41 (±4.74), 50.14 (±6.18) and 45.11 (±6.15) mm respectively. It is observed that, breadth of Konkan Sugandha fruit was higher as compared to other variety of Nutmeg fruits and lower in Konkan Vishwashri as compared to other variety.

Fruit thickness

The thickness of matured Nutmeg fruit was determined by taking each 50 numbers of matured Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The thickness of matured Nutmeg fruits varied in the range from 39.11 to 54.32 mm, 33.8 to 68.69 mm and 29.95 to 71.4 mm for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. An average fruit thickness of single fruits was obtained 46.07 (±3.71), 43.43 (±6.83) and 38.61 (±6.90) mm respectively. It is observed that, thickness of Konkan Sugandha fruit was higher as compared to other variety of Nutmeg fruits and lower in Konkan Vishwashri as compared to other variety.

Weight of fruit

The weight of matured fruit was weighed by taking each 50 numbers of Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The weight of matured Nutmeg fruits varied in the range from 46.01 to 106.6, 30.2 to 102.9 and 27.1 to 86.2 g for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively at moisture content 39.53 %. An average fresh fruit weight of single fruits was observed 74.83 (±15.03), 57.9 (±21.09) and 43.72 (±16.01) g respectively. It is observed that, weight of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Weight of nut

The weight of Nut was weighed by taking each 50 numbers of Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The weight of Nut varied in the range from 5.6 to 15, 2.1 to 21.4 and 2.7 to 11.2 g for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively at 33.33 % moisture content. An average Nut weight of single Nut was observed 10.16 (±2.34), 8.36 (±3.80) and 5.95 (±0.95) g respectively. It is observed that, Nut weight of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Weight of mace

The weight of Mace was weighed by taking each 50 numbers of Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The weight of Mace varied in the range from 1.4 to 6.2, 0.7 to 5.8 and 0.8 to 4.6 g for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively at 43.33 % moisture content. An average Mace weight of single Mace was observed 3.35 (±0.99), 2.9 (±1.23) and 2.39 (±2.29) g respectively. It is observed that, Mace weight of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Weight of pericarp

The weight of pericarp was determined by taking each 50 numbers of Nutmeg fruits of three different varieties of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri. The weight of fresh pericarp varied in the range from 34.38 to 88.8, 26.3 to 86.5 and 16.3 to 70.9 g for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively at 44.11 % moisture content. An average pericarp weight of single pericarp was observed 61.31 (±12.90), 46.6 (±17.44) and 37.08 (±15.52) g respectively. It was observed that, pericarp weight of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Engineering properties of Nutmeg fruit

The mean value of length, breadth and thickness of Nutmeg (Cv Konkan Vishwashri) fruit were considered while determining the engineering properties. The measured of engineering properties of size or equivalent diameter, sphericity, unit volume, projected area, surface area of matured Nutmeg fruits are presented in Table 1 (Cv Konkan Sugandha), Table 2 (Cv Konkan Shrimanti) and Table 3 (Cv Konkan Vishwashri) respectively. The engineering properties of Nutmeg fruit was considered for designing the fruit harvesting, handling and storing equipment as presented below.

Size or equivalent diameter

The size or equivalent diameter is the geometric mean of the three dimensions viz., length, breadth, thickness. The size of a fruit of irregular shape can be determined by equivalent diameter (ED). A sample of 50 numbers of fruits was taken to calculate equivalent diameter (ED) of three different variety of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. An average equivalent diameter of matured Nutmeg fruit was found as 54.88, 49.94 and 47.18 mm for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri varieties of Nutmeg fruit respectively. It was observed that, equivalent diameter of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Sphericity

The sphericity was determined to define the shape of matured Nutmeg fruits. A sample of 50 fruits was taken to calculate the sphericity of the matured fruit of three different variety of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. The average sphericity was found as 0.83, 0.87 and 0.78 for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri varieties of Nutmeg fruit respectively. It was observed that, sphericity of Konkan Shrimanti fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Unit volume

A sample of 50 fruits was taken to calculate the unit volume of the matured fruit of three different variety of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. The average unit volume was found as 86.57, 65.25 and 55.01 cc for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri varieties of Nutmeg fruit respectively. It was observed that, unit volume of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Table 1: Physical and engineering properties of Nutmeg fruits (Cv Konkan Sugandha)

Sr. No.	Particular	Observation					
		Max.	Min.	Range	Mean	SD	CV %
1.	Length, mm	79.01	52.62	26.39	65.94	7.28	11.05
2.	Width, mm	65.2	44.34	20.86	54.41	4.79	8.71
3.	Thickness, mm	54.32	39.11	15.21	46.07	3.71	8.05
4.	Weight of fruit, g	106.6	46.1	60.5	74.83	15.03	20.08
5.	Weight of Mace, g	15	5.6	9.4	10.16	2.34	23.08

6.	Weight of Nut, g	6.2	1.4	4.8	3.75	0.99	29.73
7.	Weight of pericarp, g	88.8	34.38	54.42	61.31	12.90	21.03
8.	Equivalent Diameter, mm	54.88					
9.	Sphericity	0.83					
10.	Unit volume, cc	86.57					
11.	Surface area, cm^2	23.67					
12.	Projected area, cm^2	94.63					
13.	Shape	Elleptical					
14.	Colour	Yellow-Red					

Table 2: Physical and engineering properties of Nutmeg fruits (Cv Konkan Shrimanti)

Sr. No.	Particular	Observation					
		Max.	Min.	Range	Mean	SD	CV %
1.	Length, mm	74.73	43.56	31.17	57.21	7.92	13.85
2.	Width, mm	63.28	38.71	24.57	50.19	6.18	12.33
3.	Thickness, mm	68.69	33.8	34.89	43.43	6.83	15.73
4.	Weight of fruit, g	102.9	30.2	72.7	57.9	21.09	36.43
5.	Weight of Nut, g	21.4	2.1	19.3	8.36	3.80	45.47
6.	Weight of Mace, g	5.8	0.7	5.1	2.9	1.23	42.66
7.	Weight of pericarp, g	86.5	26.3	60.2	46.65	17.44	37.38
8.	Equivalent Diameter, mm	49.94					
9.	Sphericity	0.87					
10.	Unit volume, cc	65.25					
11.	Surface area, cm^2	19.61					
12.	Projected area, cm^2	78.37					
13.	Shape	Elleptical					
14.	Colour	Yellow-Red					

Projected area

A sample of 50 fruits was taken to calculate the unit volume of the matured fruit of three different variety of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri respectively. The average projected area were found as 23.67, 19.61 and 17.50 cm^2 for Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri varieties of Nutmeg fruit respectively. It was observed that, projected area of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Surface area

A sample of 50 fruits were taken to calculate the surface area of the matured fruit of three different variety of Nutmeg fruit viz., Konkan Sugandha, Konkan Shrimanti and Konkan Vishwashri which had average surface area as 94.63, 78.37 and 69.94 cm^2 respectively. It was observed that, surface area of Konkan Sugandha fruit was maximum as compared to other variety of Nutmeg fruits and minimum in Konkan Vishwashri as compared to other variety.

Table 3: Physical and engineering properties of Nutmeg fruit (Cv Konkan Vishwashri)

Sr. No.	Particular	Observation					
		Max.	Min.	Range	Mean	SD	CV %
1.	Length, mm	78.11	43.73	34.38	60.30	8.99	14.90
2.	Width, mm	60.18	34.26	25.92	45.11	6.15	13.63
3.	Thickness, mm	71.4	29.95	41.45	38.61	6.90	17.87
4.	Weight of fruit, g	86.2	27.1	59.1	43.71	16.01	36.72
5.	Weight of Nut, g	11.2	2.7	8.5	5.95	2.29	38.55
6.	Weight of Mace, g	4.6	0.8	3.8	2.39	0.95	39.89
7.	Weight of pericarp, g	70.9	16.3	54.6	37.08	15.52	0.41
8.	Equivalent Diameter, mm	47.18					
9.	Sphericity	0.78					
10.	Unit volume, cc	55.00					
11.	Surface area, cm^2	17.50					
12.	Projected area, cm^2	69.94					
13.	Bulk density, g/cc	0.58					
14.	Shape	Elleptical					
15.	Colour	Yellow-Red					

Bulk density

A sample was taken to calculate the bulk density of matured Nutmeg fruit of Konkan Vishwashri variety. The average bulk density was found 0.58 g/cc. The above mentioned bulk density of matured fruit was used to design of capacity of storage house.

Conclusion

1. The mean value of length, breadth and thickness of matured Nutmeg fruit (Cv Konkan Sugandha) was found to be 65.99 (±7.28), 54.41 (±4.79) and 46.07 (±3.71) mm respectively. Similarly weight of fruit, nut, mace and pericarp was found to be 74.83 (±15.03), 3.35 (±0.99), 10.16 (±2.34) and 61.31 (±12.90) g respectively. The mean value of equivalent diameter, sphericity, unit

volume, surface area and projected area was found to be 54.88 mm, 0.83, 86.57 cc, 23.67 cm^2 and 94.63 cm^2 respectively.

2. The mean value of length, breadth and thickness of matured Nutmeg fruit (Cv Konkan Shrimanti) was found to be 57.21 (±7.92), 50.14 (±6.18) and 43.43 (±6.83) mm respectively. Similarly weight of fruit, nut, mace and pericarp was found to be 57.9 (±21.09), 2.9 (±1.23), 8.36 (±3.80) and 46.65 (±17.44) g respectively. The mean value of equivalent diameter, sphericity, unit volume, surface area and projected area was found to be 49.94 mm, 0.87, 65.25 cc, 19.61 cm^2 and 78.37 cm^2 respectively.
3. The mean value of length, breadth and thickness of matured Nutmeg fruit (Cv Konkan Vishwashri) was found to be 60.30 (±8.99), 45.11 (±6.15) and 38.61 (±6.90) mm respectively. Similarly weight of fruit, nut, mace and pericarp was found to be 43.71 (±16.01), 5.95 (±38.55), 2.39 (±0.95) and 37.08 (±0.41) g respectively. The mean value of equivalent diameter, sphericity, unit volume, surface area and projected area was found to be 47.18 mm, 0.78, 55.00 cc, 17.50 cm^2 and 69.94 cm^2 respectively.
4. The bulk density of matured Nutmeg fruit was found to be 0.58 g/cc.

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