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Determination of Engineering Properties and Fruit Detachment Force (FDF) of Nutmeg (*Myristica fragrans* Houtt.) Fruit for Harvesting Purpose

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A B S T R A C T

The physical and engineering properties of Nutmeg (*Myristica fragrans* Houtt.) are important for developing manual Nutmeg harvesting system and different process equipment machineries, for its mass handling and storage. Keeping this in view, a study was undertaken to determine these properties and fruit detachment force (FDF) of Nutmeg Cv Konkan Vishwashri. The average length, breadth and thickness of Nutmeg were found to be 60.30, 45.11 and 38.61 mm respectively. Whereas, the average sphericity and size or equivalent diameterwere0.78 and 47.18 mm respectively. The unit volume, surface area and projected area of the Nutmeg were found to be 55.00 cm3, 69.94and 17.50 cm2respectively. The bulk density of matured fruit was found to be 0.58 g/cm3. The average weight of matured whole fruit, nut, mace and pericarp were found to be 43.71, 5.95, 2.39, and 37.08g respectively. The average fruit detachment force FDF for matured fruit was found to be 1.39kg. Similarly FDF/W ratio of matured and un-matured fruits were found to be0.019kg/g and 0.029 kg/g respectively.

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). The female Nutmeg tree starts fruiting from sixth years, till the peak period is reached after 20 years. The fruits are ready for harvest in about 9 months after flowering. The peak harvesting season is during June to August. The fruits are considered as matured and ready for harvesting when the pericarp splits open. If

the matured fruits are left on tree, then there are chances of birds getting attracted towards the mace and Nutmeg fruit gets carried by birds and rodents. After harvest, the outer fleshy portion is removed and the mace is manually separated from the nut and then dried separately in the sun (Anandaraj *et al.,* 2005).

Presently, the manual harvesting method is adopted for Nutmeg in Konkan region of Maharashtra state (India) i.e. by hand and another method of harvesting is to hit the fruits by stick. Hand picking is very troublesome and time consuming while the hitting the fruits with stick cause mechanical damage to the fruit that makes the fruit unfit for further processes. While manually harvesting any fruits, often the worker has to reach above shoulder height or below knee height and has to twist to the back. Neck and shoulder discomfort can also be caused by the repetitive moments of the arms when picking fruit and placing it in the container (Anonymous, 2017).

Hence, a study was undertaken to determine some physical properties, engineering properties and fruit detachment force (FDF) of fully matured Nutmeg fruit required for development of manual Nutmeg harvesting system and/or device. The experiment of measurement of physical properties and FDF of fully matured fruits was carried out at Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dr. BSSKKV, Dapoli, Dist. Ratnagiri (Maharashtra), India.

Materials and Methods

Determination of physical properties of Nutmeg fruit (Cv Konkan Vishwashri)

The Nutmeg Cv Konkan Vishwashriwas used for the experiment. The Nutmeg has three different parts viz., nut, mace (aril), pericarp (rind). The physical properties of Nutmeg fruits were measured in the laboratory of All India Co-ordinated Research Project (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) Plate 1.

The length (L) of the sampled fruits from stalk base is to the apex of fruit. The maximum linear distance between two sides of the fruits was considered on the breadth (B) and the third longest dimension perpendicular to both is called thickness (T) of the fruit. The respective weights of the individual Nutmeg fruit, nut, mace and pericarp were measured on the digital balance (Range 0 to 2 kg and least count 0.1 g).

Measurement of fruit detachment force (FDF)

To know the detachment force required for detaching the matured (i.e. pericarp split opened) and unmatured (i.e. pericarp not spilt opened) Nutmeg fruit with respective to weight for the purpose of development of manual Nutmeg harvesting system. Fruit Detachment Force (FDF) per unit weight (W) of the Nutmeg was measured at the time of maturity level of Nutmeg between the last week of August and first week of September 2017.

To measure the fruit detachment force, the load cell (Range 0 to 40 kg and least count 0.1 g) was attached to the fruit harvester. The arrangement of load cell measuring FDF is shown in Plate 2. The respective weights of the Nutmeg fruit harvested were measured on the electronic balance.

Physical/engineering properties

Size or equivalent diameter or geometric or meandiameter

Size or equivalent diameter is the geometric meanof the three dimensions viz., length, breadth and thickness (Mohsenin, 1950).The size was calculated by using following relationship

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

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). The degree of sphericity was determined with the help of following formula.

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

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.

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

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). This was investigated by using unit volume above as,

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

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).

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

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),

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 Vishwashri) required for designing the fruit harvester, capacity of fruit collection net as well as capacity of fruit collecting basket were determined and presented in Table 1. The moisture content of whole Nutmeg fruit, nut, mace and pericarp was measured separately on wet basis and it was found to be 39.53, 33.33, 43.33, 44.11 per cent respectively.

The length, breadth and thickness of matured Nutmeg fruit were determined by taking 50 numbers of Nutmeg (Cv Konkan Vishwashri) fruits. The length, breadth and thickness of matured Nutmeg fruits varied in the range from 43.73to 78.11mm, 34.26 to 60.18mm and 29.95 to 71.4mm respectively. An average fruit length, breadth and thickness of single fruit was found to be 60.30 (±8.99), 45.11 (±6.15), and 38.61 (±6.90) mm respectively. These values could be used for the designing the V shaped picker hook of fruit harvester.

The weight of matured fruit, nut, mace and pericarp were determined by taking 50 numbers of Nutmeg fruits. The weight of matured Nutmeg fruit, nut, mace and pericarp varied in the range from 27.1 to 86.2 g, 2.7to 11.2 g, 0.8 to 0.6 g and 16.3 to 70.9 g respectively. An average weight of fruit, Nut, mace and pericarp of single fruits were observed 43.72 (±16.01), 5.95 (±2.29), 2.39 (±0.95) and 37.08 (±15.52) g respectively. The values of the weight could be used for designing the fruit harvester and capacity of fruit collection net.

Engineering properties of nutmeg fruit

The average values of the engineering properties of matured nutmeg fruits are shown in Table 1. The mean value of length, breadth and thickness of Nutmeg (Cv Konkan Vishwashri) fruit were considered while determining the engineering properties. The size or equivalent diameter is the geometric mean of the three dimensions viz., length, breadth, thickness. The size of a fruit of elliptical shape can be determined by equivalent diameter (ED). A sample of 50 numbers of fruits was taken to calculate equivalent diameter (ED) of Konkan Vishwashri variety of Nutmeg fruit. An average equivalent diameter of matured Nutmeg fruit was found to be 47.18 mm and the average sphericity was found to be 0.78.

The average unit volume and projected area of Nutmeg fruit were found to be 55.01 cc and 17.50 cm^2 respectively. Similarly the average surface area was found to be 69.94 cm^2. To find out the bulk density of matured Nutmeg fruit Cv Konkan Vishwashri three replication were taken. The average bulk density was found 0.58 gm/cc.

Fruit detachment force required for Nutmeg fruit

To know force required for detachment of fruit from the panicle, it was necessary to find out the fruit detachment force (FDF).The fruit maturity has an important effect on the force required for detachment of fruit. During the experimental test FDF, was recorded in kg with the help of load cell (0 to 40 kg). Initially the load cell was calibrated with the standard weights. After the satisfactory results of calibration test, load cell was attached with the fruit harvester, and further observations were recorded. The FDF/W ratio as a function of maturity time is presented in Table 2 and 3. It was observed that, the ratio was higher for the

unmatured fruits and lower for the matured fruits. Higher detachment force required in unmatured fruit as compare to matured fruit because of its maturity time and stronger bond. Fully matured fruit get easily detached from tree and partially matured fruit require some more detachment force as compared to fully matured fruits. Similarly for unmatured fruit require higher detachment force as compared to fully or partially matured fruit. Weight of the fruit also effect on the detachment force, if weight of fruit is more, then the required fruit detachment force will be more as compared to light weight of fruit. It was found that average FDF/W ratio for matured and unmatured Nutmeg fruit 0.019 (±0.0059) kg/g and 0.029 (±0.007) kg/g respectively. The harvester need to be designed for matured fruit and detachment force was used for designing fruit harvesting device.

Table.1 Average values for 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					

Table.2 Fruit Detachment Force (FDF) and FDF/Weight ratio of matured fruit Cv Konkan Vishwashri (Average of 20 fruits)

Parameters	FDF of matured fruit, kg	Weight of matured fruit, g	matured FDF/W ratio, kg/g
Max.	2.35	109.92	0.032
Min.	0.65	42.81	0.011
Range	1.7	67.11	0.021
Mean	1.39	71.82	0.019
SD	0.404	20.24	0.006
CV, %	29.06	28.18	31.05

Table.3 Fruit Detachment Force (FDF) and FDF/weight ratio of unmatured fruit Cv Konkan Vishwashri (Average of 20 fruits)

Parameters	FDF of unmatured fruit, kg	Weight of unmatured fruit, g	Un-matured FDF/W ratio, kg/g
Max.	1.92	67	0.048
Min.	0.97	30	0.020
Range	0.95	37	0.028
Mean	1.39	47.45	0.029
SD	0.27	8.51	0.007
CV, %	19.42	17.93	24.78

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

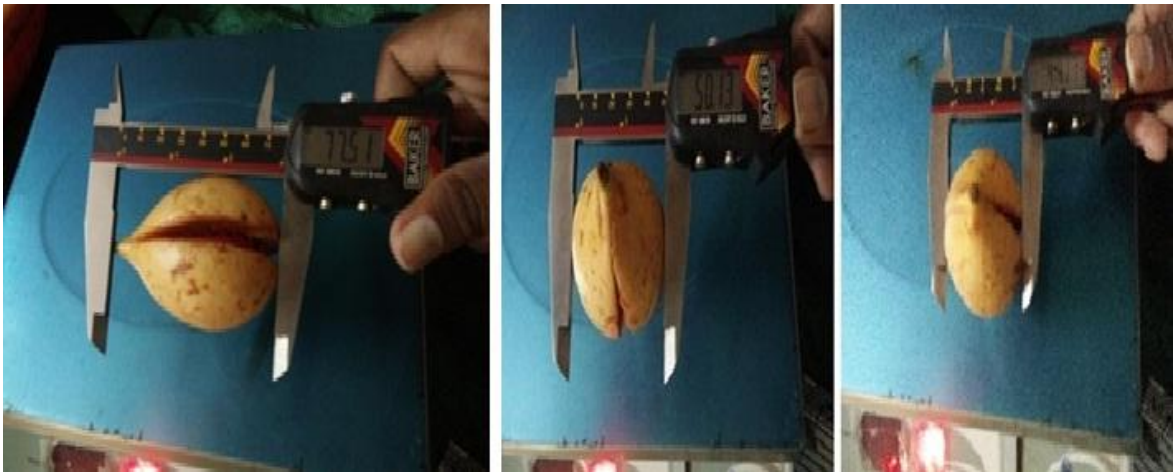

Plate.2 Load cell arrangement and measurement of fruit detachment force

In conclusion

The mean value of length, breadth and thickness of matured Nutmeg fruit 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.

The bulk density of matured Nutmeg fruit was found to be 0.58 g/cc.

The mean fruit detachment force (FDF) for matured and unmatured Nutmeg fruit was found to be 1.39 (±0.404) kg and 1.39 (±0.27) kg respectively.

The fruit detachment force/weight (FDF/W) ratio for matured Nutmeg fruit was found to be lower as compared to unmatured fruit depends on maturity level of the fruit.

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