Research Article

Evaluation of Physicochemical and Mechanical Properties of *Lotan* Variety Whole Dry Coconut (*Cocos Nucifera* L.) and Dehusked Coconut Shell

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Abstract

A study was conducted to determine various physicochemical properties and mechanical properties of the *Lotan* variety of coconut which is locally grown in Saurashtra region of Gujarat, India. The physicochemical properties included in this study were size (length, breadth and thickness), thickness of husk and moisture content of dry coconut husk, size of dehusked coconut shell (length, breadth and thickness), shell thickness and moisture content of shell. The mechanical properties included husk removing force from coconut and shell breaking force of dry coconut. Upon concluding study, the average weight of mature dry coconut was 323.52 g. The average length, breadth and thickness were found to be 180.34, 134.07 and 126.44 mm respectively. The average thickness of husk was 23.33 mm. The average moisture content of mature dry coconut husk was evaluated at around 10.94% on wet basis. The average weight of dehusked coconut shell was found to be 138.96 g. The average length, breadth and thickness of dehusked coconut was found to be 92.03 mm, 77.41 mm and 77.04 mm respectively. Shell thickness of dehusked coconut was found to be 3.86 mm average. The moisture content of dehusked coconut shell was average 10.36% on wet basis. Husk separation force was ranged from average 0.76 kN at near the surface of coconut husk to average 1.86 kN at the shell and husk joint. The shell breaking force was average 3.29 kN.

Keywords: Dry Coconut, Coconut Size, Physico-chemical Properties, Mechanical properties

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Introduction

The coconut palm (*Cocos nucifera* L.) of family Arecaceae can be named as the most useful plant species to the humankind. Coconut is given some special names like *Kalpavriksha* ‘tree of life’, ‘nature’s supermarket’ and ‘tree of abundance’ etc. because, every part of coconut tree is useful. Coconut is native to coastal areas of Southeast Asia (Malaysia, Indonesia, Philippines) and Melanesia. Coconut is an important palm in the lives and livelihood of people in regions like Southeast Asia, Indian subcontinent, Africa, Central America/Caribbean, Melanesia, Polynesia and Micronesia [1, 2].

The coconut fruit is a fibrous drupe. From outside in, it consists of a thin hard skin known as exocarp, next to exocarp a thicker layer of fibrous mesocarp is present which is called husk. Further to the centre the hard endocarp known as shell covers the white albuminous endosperm called endosperm (kernel) and a large cavity filled with liquid (water). When immature, the exocarp is usually green and sometimes bronze. Wide variation in fruit shape and size exists within kinds and populations. coconut shapes vary from elongated to almost spherical and weigh between 850 and 3700 g when mature [3, 4]. Coconut fruit is useful source of edible oil, coconut water, coconut meat, coconut milk, coconut flour, dried copra, desiccated coconut, vinegar and jaggery [4, 5]. The coconut fruit is also source of fuel, fibre, ornamental purposes. There are some novel uses of coconut fruits which include use of coconut coir as an efficient and reusable heterogeneous catalyst for green synthesis of Imidazoles, β-Acetamidoketones and β-Hydroxyketones [6]. Also, coconut oil can be used as source to produce biodiesel [7].

Experimental

A study was conducted to determine various physicochemical properties and mechanical properties of *lotan* variety of coconut which is locally grown in Saurashtra region of Gujarat, India. The physicochemical and mechanical properties of mature dry coconuts are important in various post-harvest operations and design of tools and machinery

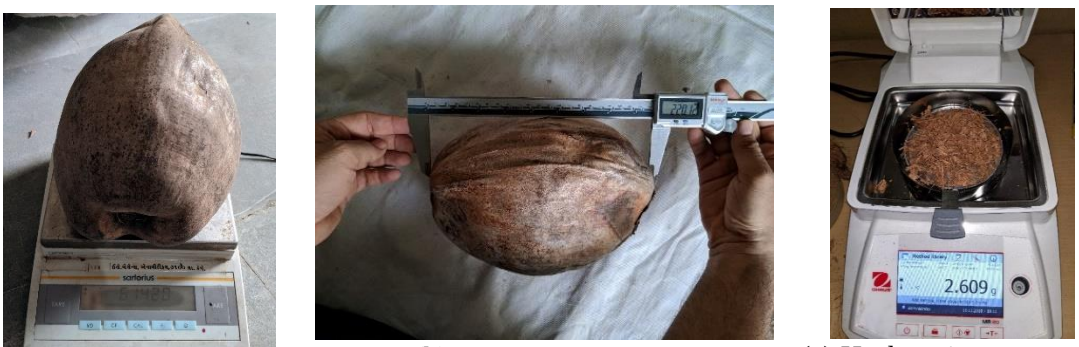
for dry coconut. Based on the physical properties' evaluation of peanut seed by Gojiya *et al*. and Varghese *et al*., the physical properties included weight of mature dry coconuts, size of whole dry coconut, thickness of mature dry coconut husk [8, 9]. The chemical property measured was moisture content of husk. Also, similar properties for dehusked coconut shell were measured viz., weight, size, and thickness of dehusked coconut shell. The chemical property for shell included moisture content of shell. All the properties were measured at the laboratory of Processing and Food Engineering Department, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat (India).

The mechanical properties of dry coconut were coconut husk separating force and dehusked coconut shell breaking force. Both the forces were measured at Farm Machinery and Power Department, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh and OM engineering college, Junagadh-Bhesan Road, Junagadh respectively. The standard procedures and techniques for measurement of various physicochemical and mechanical properties as described by Varghese *et al* [9] were used and explained in following sub sections.

Physical property of mature dry coconuts

Weight of mature dry coconut

Weighing analysis of dry coconuts was done using an electronic weight balance (Maker: Sartorius, Model: BP 3100 S) as shown in **Figure 1a**. According to provided manual, the weight balance was started and warmed and was prepared for weighing operation. Dry coconuts were placed on balance top in natural resting condition and stable weight reading was recorded in grams.



(a) Weight measurement (b) Size measurement (c) Husk moisture content measurement

Figure 1 Various physicochemical properties measurement of dry coconut

Size of mature dry coconut

The size was measured in terms of three perpendicular axis measurements of coconuts. These three measurements were noted as length, breadth and thickness. These three intersections of mature dry coconuts were measured using Mitutoyo Absolute digital calliper (Figure 1b).

Thickness of husk

Thickness of coconut husk was measured at middle-section of coconut. The husk thickness was measured as depth of coconut shell from exocarp layer of coconut. A cut was made on exocarp using sharp tool in a size which could accommodate a standard stainless-steel scale. The cut was made deep up to coconut shell. The steel scale was pushed in the cut till it reached to the shell surface. The division on scale which touches the exocarp was read and recorded in millimetre.

Moisture content of husk

Moisture content of husk was measured using Automatic Moisture Analyzer (Maker: Ohaus, Model: MB120). According to provided manual the moisture analyser was levelled with the help of bubble level provided on it. Moisture content measurement temperature was set at level of 105 °C while the time was set until the moisture content reached to constant level. The coconut husk was shredded into tiny pieces using pair of sharp scissors. The sample weight of husk was taken in range of 2 g. The shredded husk was placed in empty sample pan of moisture

analyser (Figure 1c). In the next step the cover of moisture analyzer was closed to run the test. Once the husk moisture content reached at constant level in around 45 minutes of time, the observations of moisture content of coconut husk was recorded in percentage wet basis.

Weight of dehusked coconuts

Weighing analysis of dehusked coconuts was done using an electronic weight balance (Maker: Sartorius, Model: BP 3100 S). Similar process was followed as it was done with whole dry coconut and described in subsection 1.1 of this section.

Size of dehusked coconuts

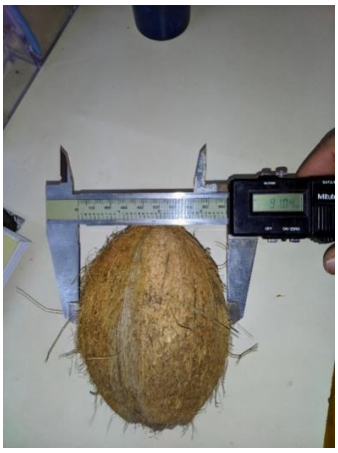
Similar approach was taken as it was done in whole dry coconut. The size was recorded in terms of length, breadth and thickness (**Figure 2a**).

Thickness of shell

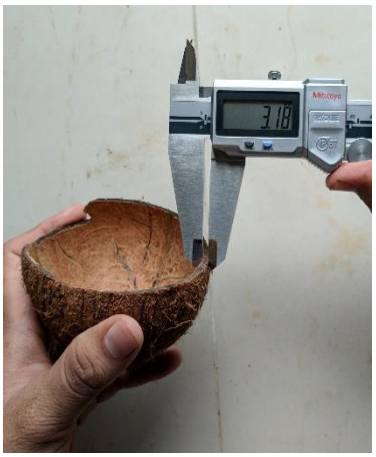
Thickness of coconut shell was measured using digital Vernier callipers (Mitutoyo Absolute digital calliper). Coconut shells were broken manually carefully. The coconut meat inside the shell was completely scrapped and removed if it was attached with the shell. The calliper was opened approximately just wider than the shell thickness. After that, the shell was kept between the callipers jaws and jaws were pressed slightly till they touch the shell surface. That reading was recorded in millimetre as shown in (Figure 2b). The measurement was taken at four different equatorial locations of shell.

Moisture content of coconut shell

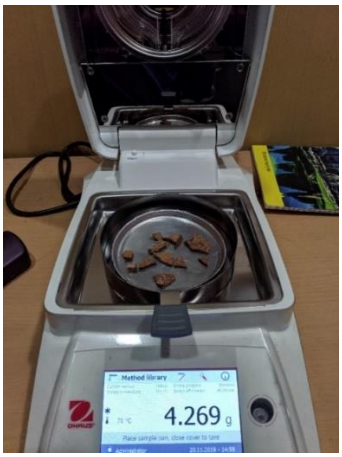
Moisture content of coconut shell was determined using Automatic Moisture Analyzer (Maker: Ohaus, Model: MB120). The moisture analyser was levelled and properly calibrated as described in manual. Moisture determination temperature was set to 105 °C. Mortar and pestle were used to break the shell in small pieces. Coconut shell sample weighing around 4 - 5 g was taken for moisture content evaluation. The shell pieces were kept in sample pan of moisture analyser and cover was closed to run the test (Figure 2c). The drying progress was closely followed on display of instrument. The test run was allowed to run till moisture was found to be reaching at constant level. The observations on moisture content were recorded in percent wet basis.



(a) Size measurement of dehusked coconut



(b) Shell thickness measurement using vernier calipers



(c) Shell moisture content measurement

Figure 2 Physicochemical property evaluation of dehusked coconuts.

Mechanical properties of dry coconut

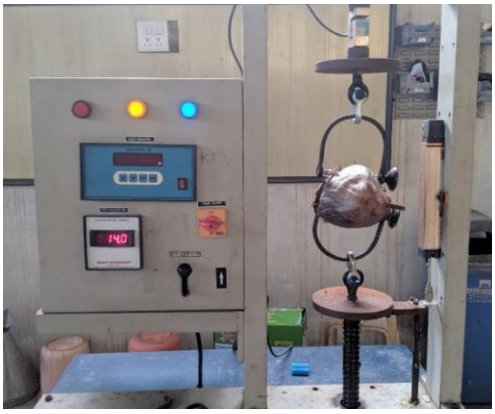
Husk separating force

Husk separating force was measured using cultivator spring testing rig made by ATS test systems. The testing machine contained two hooks to attach test specimen, a transducer, a distance measuring apparatus, force display and

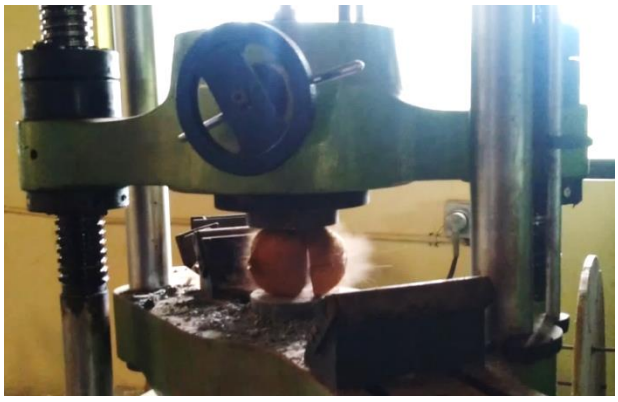
control panel. Two U shaped TMT steel rebar, two high strength steel rods and D shackles were used to create a special fixture to attach coconut sample with hooks of machine. Coconut was attached in horizontal position on the testing rig as it can be seen from **Figure 3a**. The lower part of the developed fixture was used to hold the coconut rigidly during peeling away of coconut and the upper part of fixture was attached through the husk where husk was separated from the shell. For lower attachment of fixture to coconut, a hole was made throughout the middle portion of coconut and shell, this hole was bored to hold the coconut on test hook. Another hole was made through husk at three levels on husk for different coconuts on husk, these holes were made for the fixture that would separate the husk. The holes were created at around 30% distance from shell to husk outer level (at the shell level, 30% distance from shell, 60% distance from shell. During testing, the coconut holding part of fixture was attached to bottom hook of test rig, where it would pull the coconut downwards with power of electric motor and screw mechanism. The other part attached to husk was joined at force sensing transducer end. After proper adjustments, the test was run, during testing the motor would pull down the coconut at steady and slow pace. Because that end was held through the coconut shell it would hold the coconut without any deformation. This arrangement was done to provide force only to husk removal portion as it was assumed that the husk removal force was lower than the shell breaking force. The force required to remove husk was sensed at transducer end and the magnitude of force was shown on display panel. Maximum force required to completely removal of husk was recorded in kN.

Shell breaking force

Shell breaking force of dehusked coconut shell was measured using Universal Testing Machine (UTM) (Model: UTN 40, maker: Fuel instruments and engineering PVT. LTD., Vadrav, Maharashtra (India)) having maximum capacity of 400 KN. The UTM consisted of several sub units viz., loading unit, control unit and display unit. In the display unit the force was shown on an analogue dial gauge which could be adjusted according to required range of force. The control unit had hydraulic valve controls which were used for movement of crosshead up and down according to required specimen. For the experiment the force range was set up to maximum limit of 40 kN. The completely dehusked coconut was placed between fixed table and movable crosshead at natural resting position. The movable crosshead was lowered up to the position where it can barely touch the coconut sample. The test was run and the the hydraulic pressure lowering the crosshead was gradually increased just till the shell was broken (**Figure 3b**). The pointer on analogue display indicated the amount of force required to break the shell and that reading was recorded in kN.



(a) Husk separation force measurement



(b) Shell breaking force measurement using Universal Testing Machine

Figure 3 Mechanical property evaluation of mature dry coconut and dehusked coconut shell

Results and Discussions

Physicochemical properties evaluation of mature dry coconuts

Physicochemical properties such as weight, size of whole dry coconut, thickness of husk, moisture content of husk, weight, size of dehusked coconut, thickness and moisture content of shell were determined as per the procedure described in sections 1.1 – 2.2 and are presented in following subsections.

Weight of mature dry coconuts

The weight of mature dry coconuts was measured using electronic weight balance as described in section no. 1.1. Dry coconut in 100 numbers, of normal average size were selected randomly and weighed on the scale. The minimum,

maximum and average weight of coconuts was measured and the results are shown in **Table 1**(a).

Size of mature dry coconut

The size was determined by measuring three intersecting perpendicular sections of dry coconut as length, breadth and thickness as described in section 1.2 using vernier callipers. A sample size of 100 mature dry nuts was selected randomly for size measurements. The minimum, maximum and average values of length, breadth and thickness are shown in Table 1(b). The size values are described in millimetre.

Table 1 Weight and size of mature dry coconuts

(a) Weight of mature dry coconuts			**(b) Size of mature dry coconuts**			
S. no.	**Parameter**	**Weight (g)**	**Parameter**	**Length (mm)**	**Breadth (mm)**	**Thickness (mm)**
1	Minimum	193.00	Minimum	113.89	75.03	80.27
2	Maximum	614.00	Maximum	244.17	179.19	174.88
3	Average	323.52	Average	180.34	134.07	126.44
4	SD	82.02	SD	20.44	15.65	14.74

Thickness of mature dry coconut husk

Thickness of husk is important parameter in design of machines which are employed for dehusking of coconuts. The husk thickness was measured by method described in section 1.3. The sample size was of randomly selected 20 mature dry coconuts. The minimum, maximum and average values are described in **Table 2**. The husk thickness was measured in millimetres.

Moisture content of husk

Moisture content of mature dry coconut was measured by method described in section 1.4. A sample size of 10 coconut was taken randomly and the values of moisture content in wet basis are shown in **Table 3**.

Table 2 Thickness of husk

S. no.	**Parameter**	**Husk thickness (mm)**
1	Minimum	12.00
2	Maximum	50.00
3	Average	23.33
4	SD	9.16

Table 3 Moisture content of husk

S. no.	**Moisture content (%)**
1	10.40
2	9.69
3	8.12
4	10.43
5	11.38
6	12.27
7	10.40
8	12.78
9	13.11
10	10.80
Average	10.94
SD	1.50

Weight of dehusked coconuts

Weight of dehusked coconuts was measured as described in section 1.5. A sample size of 100 nuts was taken randomly for weight determination. Minimum, maximum and average values of weight of dry coconuts are given in **Table 4**.

Table 4 Weight and size of dehusked coconuts

Weight of dehusked coconut shell			Size of dehusked coconut shell			
S. no.	**Parameter**	**Weight (g)**	**Parameter**	**Length (mm)**	**Breadth (mm)**	**Thickness (mm)**
1	Minimum	49.00	Minimum	73.44	57.91	61.47
2	Maximum	235.00	Maximum	107.22	98.89	100.67
3	Average	138.96	Average	92.03	77.41	77.04
4	SD	40.37	SD	8.47	7.92	7.58

Size of dehusked coconuts

A sample size of 40 completely dehusked coconuts was randomly taken to determine the size parameters of dehusked coconut. Length, breadth and thickness of completely dehusked coconuts were measured and their minimum, maximum and average values are reported in Table 4.

Thickness of shell

Shell thickness was measured using method discussed in section 1.7. A sample size of 10 completed dehusked coconuts was taken to determine shell thickness. The thickness is measured in mm. the minimum, maximum and average values of shell thickness are given in **Table 5**. The minimum and maximum values are highlighted in bold fonts.

Moisture content of shell

Moisture content of shell was determined as per the process given in section 1.8. Five completely dehusked coconuts were used to determine moisture content of the shell. The resulting moisture content values of coconut shell on wet basis are shown in **Table 6**. The minimum moisture content was found to be 9.77 % and maximum moisture content value was 10.69 % with average of 10.36.

Table 5 Shell thickness

S. no.	Shell thickness (mm)
1	2.77
2	3.83
3	4.30
4	3.31
5	4.37
6	4.69
7	3.02
8	3.64
9	4.87
10	3.81
Average	3.86
SD	0.70

Table 6 Coconut shell moisture content

S. no.	Shell moisture content (%)
1	10.69
2	9.77
3	10.40
4	10.44
5	10.49
Average	10.36
SD	0.34

Mechanical properties of dry coconut

Mechanical properties of dry coconut evaluation included determination of husk separation force and shell breaking

force. The mechanical properties were determined by process described in section 2.1 and 2.2 and results of those procedures are described in following subsections.

Husk separating force

Husk separation force was measured according to process described in section 2.1 The husk separation force was measured at three incremental levels from shell, 1) at shell, 2) at middle of exocarp and shell (around 30% distance from shell) and 3) near the surface of exocarp (around 60% distance from shell). The highest values of force were observed at shell, average force of 1.86 kN, minimum and maximum values are displayed in **Table 7**. The minimum values of force were observed at near the husk with average force value 0.76 kN. As seen from data it could be said that as husk thickness increases, husk separation force increases. Similar findings were also reported by Varghese *et al*. for husk separating force [8]. They had also reported husk removing force value for dry coconut ranging from 0.63 kN to 0.96 kN with average force of 0.85 kN [8].

Shell breaking force

The shell breaking force was determined using UTM. A sample size of 10 completely dehusked coconuts was taken to evaluate the shell breaking force. The results are displayed in **Table 8**. As it can be seen from table the force was recorded in kilo newtons, the minimum value was found to be 2 kN and maximum value was 4.5 kN with average value 3.29 kN. For breaking of shell with highest strength 4.5 kN of force should be required. Similar findings were also reported by Varghese *et al*., for coconut shell breaking force [8]. Their reported shell breaking force value ranged from 2.92 kN to 6.78 kN with average shell breaking force 4.43 kN.

Table 7 Dry coconut husk separation force

S. no.	Parameter	Force (kN)		Average (kN)
		1	2	
1	Force at shell and husk joint	1.87	1.85	1.86
2	Force at middle of shell and husk surface (approx. 30% from shell)	1.01	0.99	1.00
3	Force near husk surface (approx. 60% from shell)	0.75	0.78	0.76

Table 8 Coconut shell breaking force

S. no.	Force (kN)
1	4.0
2	2.0
3	2.0
4	4.0
5	4.2
6	4.5
7	2.2
8	3.5
9	3.8
10	2.7
Average	3.29
SD	0.97

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