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Research Article

Studies on Engineering Properties of Coconuts for Effective Dehusking

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ABSTRACT

Dehusking is a process of the removal of husk from the nut and one of the primary post-harvest operations in coconut processing. As a part of the development of coconut dehusker, the engineering properties such as size, weight, shell diameter, moisture content, husk thickness, husk penetrating force and husk separation force for both green and dry coconuts were studied. The physical properties of green coconuts were observed as average dimensions of 203 mm (X), 145 mm (Y) and 140 mm (Z), weight of 1kg, shell diameter of 89 mm and average moisture content of 45.2 % and husk thickness of 33 mm at pedicel, 22 mm at centre and 22 mm at apex. The maximum husk penetrating force for green coconuts of 196.2 N was observed at 47 mm thickness and a maximum husk separating force of 430 N was observed. The physical properties of dry coconuts were observed as the average dimensions of 182 mm (X), 123 mm (Y) and 120 mm (Z), weight of 0.71 kg, shell diameter of 88 mm and average moisture content of 23.5 % and husk thickness of 22 mm at pedicel, 12 mm at centre and 16 mm at apex. The maximum husk penetrating force for dry coconuts of 156 N was observed at a thickness of 35 mm and maximum husk penetrating force of 520 N was observed. The results showed the dependency of husk penetrating force on husk thickness. Maximum husk separating force was observed for dry coconuts than green coconuts. So it is easy to dehusk green coconuts than dry coconuts.

Key words: *Coconuts, Dehusking, Thickness, Moisture content, Force.*

INTRODUCTION

Coconut palm (*Cocos nucifera*) is one of the major cash crops belonging to the tropical and subtropical areas[5]. Coconut palm is a versatile plant popularly known as "kalpavriksha" – "tree of life", "tree of heaven" because it gives people diversified products from basic needs to luxury[4].

Coconut palm belongs to the family *Aracaceae* and the only accepted species in the genus *Cocos*. Based on usage the coconuts, they are harvested in two stages, immature and mature stage. In the immature stage, coconuts are harvested for coconut water and coconut kernel and in mature stage, coconuts are harvested for copra for oil production[3].

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India is the third largest producer of coconut in the world next to Indonesia and Philippines having area of about 2.09 million hectares with annual production of 23,904 million nuts with an average of 11481 nuts/ ha in the year 2015-16[2]. Coconuts are mainly grown for its nuts. Coconut is comprised of the outer exocarp of 1mm thick, fibrous mesocarp or coir of 1 to 5cm thick and the endocarp of 4 to 6 mm thick. The endocarp or shell becomes hard and dark on maturity.

Dehusking is a process of the removal of husk which occupies 35% of the total weight of the nut. The traditional method of dehusking is done by using traditional tools such as 'parang', hoe, blade or spear[8]. The manual dehusking process requires an operator to use his or her strength and skill to bring the coconut sharply down into the blade, twist the coconut to one side, loosen the husk and detach the fiber from the shell. This action is repeated several times until the entire fiber is detached from the shell. This process is not only difficult and dangerous but requires the necessary skill.

Attempts made so far in the development of dehusking tools have only been partially successful and not effective in replacing manual methods. Study of engineering properties of coconut is important in the development of coconut dehusking machine. Only a few researchers studied the engineering properties of coconut. This paper presents some of the engineering properties of coconut related to the dehusking process.

MATERIAL AND METHODS

2.1 Raw materials

Local varieties of coconuts from the farmers of Lalgudi, Tamil Nadu, were used for the determination of engineering properties. Randomly selected green (12 months maturity) and dry (13 months maturity) coconuts were used for the study. The following are the procedures to determine the engineering properties of coconut.

2.2 Size

Coconut size was determined by measuring their principal axes: major, minor and intermediate are shown in plate 2.1. Vernier caliper and measuring scale were used for measuring the dimensions of the coconut. Samples of 30 green and dry coconuts were randomly selected for determining the dimensions of the coconut.

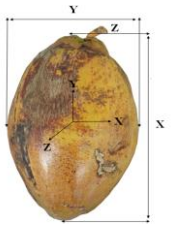

Plate 2.1 Principal axes: major (X), minor (Y), intermediate (Z)

2.3 Weight

The samples of 30 green and dry coconuts were randomly selected for determining the weight. The weight of the coconut was measured using an electronic weighing balance and the observations were averaged.

2.4 Shell diameter

Shell diameter of the coconuts was measured using a measuring tape. The circumference of the coconuts was measured initially the diameter was calculated using equation 2.1[9].

$$d = \left[\frac{C}{\pi}\right] \quad \ldots 2.1$$

Where,
d = diameter of the shell, mm
C = circumference of the nut, mm

2.5 Moisture content

The moisture content of the coconut husk was measured by the oven-drying method at 130 ± 1^{o} C for 6 h and expressed in wb%. The reduction in the weight of the sample was observed and recorded[7]. A samples of 20 green and dry coconuts were randomly selected for determining moisture content.

$$\text{Moisture content wb \%} = \left[\frac{Wi - Wf}{Wi}\right] \times 100\ \% \qquad \ldots 2.2$$

Where,
Wi = initial weight of the sample, g
Wf = final weight of the sample, g

2.6 Husk thickness

Husk thickness referred to the thickness of the husk (mesocarp) from the coconut shell (endocarp) to husk outer layer (epidermis)[9]. Husk thickness was measured using a graduated knife like structure fabricated in AEC&RI, Kumulur. Thickness was measured at various positions of coconut i.e. at the pedicel end, center, and apex end.

2.7 Husk penetrating force

The force required by the blades to penetrate the coconut husk was determined using the setup developed in AEC&RI, Kumulur shown in Plate 2.2. The setup consists of a base platform, vertical rods and weighing platform made up of mild steel angle (50×50×5mm). The base frame was fixed with two mild steel angles (50×50×5mm) in which one is fixed and the other one is made movable to fix variously sized coconuts. The vertical rods are welded to either side of the base platform and the weighing platform was made movable over the vertical rods. Two blades of the dehusking machine were welded to the bottom side of the weighing platform[7]. The coconut was placed on the base frame.

The blade penetrates the husk when the weights were added to them. The weight in the platform was increased from 5 to 25 kg at 2 kg interval until the blade reaches the shell. This was recorded as the husk penetrating force.

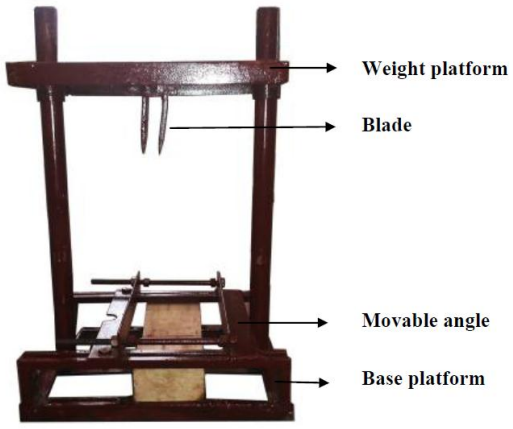

Plate 2.2 Measurement of husk penetrating force

2.8 Husk separating force

Husk separating force is the measure of the force required to detach or remove the husk from the nut. It was determined using the standard universal testing machine of 20 T capacities. Randomly selected 6 green and dry coconuts were used for determining the husk separating force.

RESULTS AND DISCUSSION

The results of engineering properties like size, weight, shell diameter, moisture content, husk

thickness, husk penetrating force and husk separating force are presented and summarized in this chapter.

3.1 Size

The principle dimensions: Major, minor and intermediate axes were measured for 30 green and dry coconuts and the results obtained are given in the Appendix I and the maximum, minimum and average values are given in Table 3.1. For green coconuts, the values of the major axis (X) ranges from 180 mm to 240 mm with the mean value of 203 mm, the values for the minor axis (Y) ranges from 131 mm to 161 mm with the mean value of 145 mm and the values for the intermediate axis (Z) ranges from 121 to 160 mm with the mean value of 140 mm. For dry coconuts the value of the major axis (X) ranges from 162 mm to 220 mm with the mean value of 182 mm, the values for the minor axis (Y) ranges from 100 mm to 152 mm with the mean value of 123 mm and for intermediate axis (Z) the values ranges from 98 mm to 150 mm with the mean value of 120 mm. It was observed that the minor and intermediate axis have similar mean values and hence both are considered equal. Greater difference in the mean values of major and minor axis was observed. Alonge[1] and Patil[7] reported the similarities in the mean values of minor and intermediate axis and the values of the principle axis reported are found to be in accordance with the obtained results.

Table 3.1 Dimensions of green and dry coconut

	Green			Dry		
	Major (X) (mm)	**Minor (Y) (mm)**	**Intermediate (Z) (mm)**	**Major (X) (mm)**	**Minor (Y) (mm)**	**Intermediate (Z) (mm)**
Max.	240	161	160	220	152	150
Min.	180	131	121	162	100	98
Mean	203	145	140	182	123	120

3.2 Weight

Weight of the randomly selected 30 green and dry coconuts samples were observed and presented in the Appendix I. The mean values are given in Table 3.2. The average weight of the green coconuts was observed as 1 kg and the average weight of the dry coconuts were observed as 0.71 kg. Pandiselvam *et al.*[6] reported the average weight of 5 varieties of coconuts from the state of Kerala in which the Malayan Orange Dwarf and Chowghat Orange Dwarf varieties of green and dry coconuts found to have similar mean values.

Table 3.2 Weight of green and dry coconuts

	Green (kg)	**Dry (kg)**
Max.	1.47	1
Min.	0.75	0.48
Mean	1	0.71

3.3 Shell diameter

Shell diameter of 30 green and dry coconuts observed was presented in the Table 3.3. The observed values are given in Appendix I. The average shell diameters of green and dry coconuts are 89 mm and 88 mm respectively. Shell diameter was found to be same in green and dry coconuts; it indicates that the shell diameter remains the same after maturity.

Table 3.3 Shell diameter of green and dry coconuts

	Green Diameter (mm)	**Dry Diameter (mm)**
Max.	103	99
Min.	64	70
Mean	89.21	88.61

3.4 Moisture content

The moisture content of the green and dry coconuts were given in anpendix I and the mean values were given in and table 3.4.For green coconut the mean moisture content was found to be 45.2 % and the mean moisture content of dry coconut was found to be 23.25%. Moisture content for green coconut was found to be higher than the dry coconuts. The values observed in this study was found to be similar to the moisture content values reported by Pandiselvam *et al.*[6] and Patil[7] but was found to be higher than the values reported by Varghese and Jacob[8]. It was observed that dehusking of green coconuts was easier than dry coconuts. Force required to dehusk green coconuts was found to be lesser than dry coconuts. This is due the presence of more moisture content in green coconuts.

Table 3.4 Moisture content of green and dry coconut

	Green (wb%)	Dry (wb %)
Max.	60.82	30.86
Min.	25.50	13.46
Mean	45.2	23.25

3.5 Husk thickness

Husk thickness was measured at 3 points namely at apex, pedicel and center of green and dry coconuts were given in Appendix I and the mean values were given in Table 3.5. The mean husk thickness for green coconut at pedicel, center and apex was found to 32 mm, 22 mm and 22 mm. The mean husk thickness for dry coconut at pedicel, center, and apex were found to as 22 mm, 12 mm and 16 mm. Form the observed values, maximum amount of husk was found to be present in the pedicel portion and minimum amount of husk was found to be present in centre portion. The values found are in accordance with the findings of Varghese *et al.*[9] and Pandiselvam *et al.*[6]. The determination of husk thickness helps in the optimization of blade height in the dehusking roller.

Table 3.5 Husk thickness of green and dry coconut

	Green (mm)			Dry (mm)		
	Pedicel	**Center**	**Apex**	**Pedicel**	**Center**	**Apex**
Max.	48	35	32	35	23	29
Min.	15	11	12	14	8	10
Mean	32	22	22	22	12	16

3.5 Husk penetrating force

Husk penetrating force was observed by the set up developed in AEC & RI, Kumulur. Randomly selected green and dry coconuts of 10 numbers were tested for husk penetration force. The force was found at the different points on the coconut. The force required for penetrating the respective thickness is given in the Appendix I. Maximum husk penetrating force for green coconuts of 196.2 N was observed at thickness of 47 mm and maximum husk penetrating force for dry coconuts of 156 N was observed at thickness of 35 mm. From the Figures 2.1 and 2.2, it is evident that the husk penetrating force dependent on husk thickness. Husk penetrating force increased with increase in husk thickness. Patil[7] reported that force required to penetrate the husk by the blades increases with increase in husk thickness.

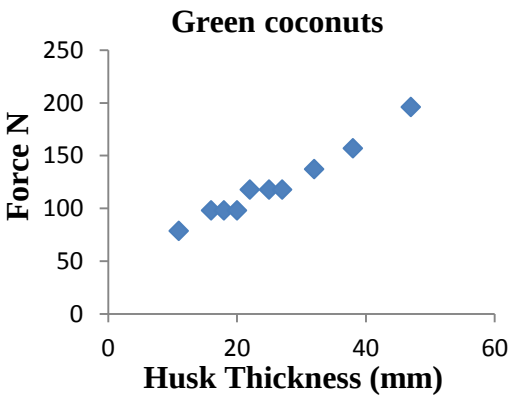

Fig. 3.1 Husk penetrating force for green coconuts

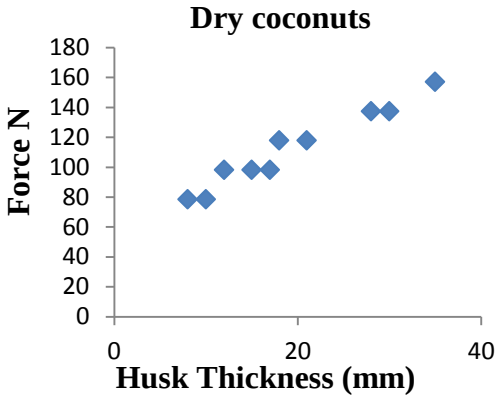

Fig. 3.2 Husk penetrating force for dry coconuts

3.6 Husk separating force

Maximum force required by the blades to remove the husk from the nut was found by Universal testing machine. Husk separating forces for green and dry coconuts was observed and are presented in Appendix I. Maximum husk separating force for green coconuts of 430 N and for dry coconuts of 520 N was observed. From the Figures 3.3 and 3.4 shows husk separating force increases with increase in size. Husk separating force for dry coconut was found to be more than green coconuts. It is evident that decrease in the husk moisture content increases the husk separating force. Varghese[9] reported the increase in the force with decrease in husk moisture content. The report shows that the dehusking of green coconuts was easier than dry coconuts.

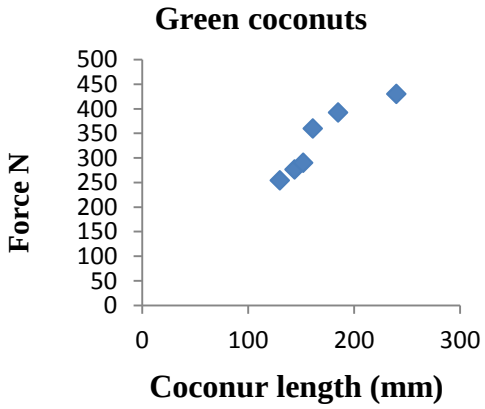

Fig. 3.3 Husk separating force for green coconuts

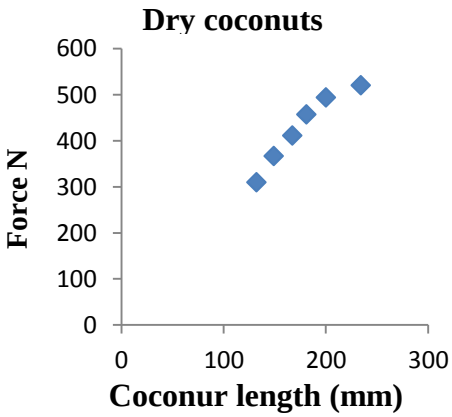

Fig. 3.4 Husk separating force for dry coconuts

APPENDIX I

a. Dimensions of the green and dry coconut

Sl. No.	Green			Dry		
	Major (X) (mm)	Minor (Y) (mm)	Intermediate (Z) (mm)	Major (X) (mm)	Minor (Y) (mm)	Intermediate (Z) (mm)
1	215	150	140	162	104	103
2	195	153	149	170	102	98
3	215	143	136	220	125	121
4	205	140	135	162	103	100
5	195	150	142	186	105	101
6	205	150	145	170	100	98
7	190	133	130	168	101	98
8	215	161	160	190	102	99
9	240	143	140	195	140	138
10	198	147	135	178	126	125
11	215	138	130	198	135	130
12	216	143	140	182	152	150
13	196	141	136	170	130	127
14	219	153	149	192	131	129
15	184	142	140	182	130	127
16	183	131	129	172	128	125
17	214	140	135	214	139	134
18	182	142	140	200	125	121
19	205	160	156	178	118	114
20	180	154	150	192	131	128
21	193	156	149	191	125	121
22	223	149	139	171	120	117
23	199	159	150	165	128	124
24	220	137	130	170	150	145
25	200	131	121	190	145	139
26	202	140	134	185	125	122
27	217	143	139	200	110	108
28	198	134	133	170	135	131
29	180	145	140	185	120	118
30	197	158	150	165	115	110

b. Weight of the green and dry coconut

Sl. No.	Green coconut weight (kg)	Dry coconut weight (kg)
1	1.31	1
2	1.23	0.65
3	1.47	0.86
4	1.46	0.78
5	1.1	1
6	1.2	0.9
7	0.75	0.76
8	1.1	0.92
9	1.1	0.81
10	1.1	0.74
11	0.84	0.85
12	0.96	0.71
13	1.04	0.69
14	1.06	0.78
15	1.08	0.48
16	0.78	0.54
17	0.92	0.99
18	1.1	0.51
19	1	0.89
20	1.16	0.55
21	1.32	0.84
22	1.23	0.65
23	1.11	0.67
24	0.98	0.78
25	0.77	0.63
26	0.87	0.65
27	0.99	0.66
28	0.98	0.71
29	0.98	0.8
30	1.16	0.85

c. Shell diameter of green and dry coconuts

Sl. No.	Green		Dry	
	Circumference (mm)	Diameter (mm)	Circumference (mm)	Diameter (mm)
1	201	64	246	78.3
2	250	79.6	284	90.4
3	279	88.8	298	94.9
4	245	78	247	78.6
5	320	102	280	89
6	298	94.9	311	99
7	311	99	220	70
8	245	78	289	92
9	278	88.5	278	88.5
10	267	85	260	82.8
11	248	78.9	285	90.7
12	254	80.8	267	85
13	267	85	298	94.9
14	298	94.9	283	90
15	241	76.7	287	91.4
16	211	67.1	298	94.9
17	324	103	267	85
18	297	94.5	277	88.2
19	298	94.9	284	90.4
20	304	96.8	276	87.8
21	310	98.7	269	85.6
22	302	96.1	289	92
23	298	94.9	271	86.3
24	267	85	260	82.8
25	278	88.5	311	99
26	314	100	279	88.8
27	306	97.4	285	90.7
28	311	99	281	89.5
29	298	94.9	274	87.3
30	287	91.4	297	94.5

d. Moisture content of green and dry coconuts

Sl. No.	Green wb (%)	Dry wb (%)
1	45.8993	25.8407
2	44.7674	24.5283
3	53.3333	19.9029
4	37.931	22.3022
5	49.5283	19.1621
6	40.2597	24.4444
7	60.8247	20.8253
8	56.7251	20
9	46.8172	30.7832
10	35.1852	26.4605
11	33.3333	22.0779
12	46.3415	19.7368
13	25.5014	15.0943
14	49.4118	16.9231
15	53.2609	29.1339
16	46.1957	28.2051
17	44.1955	30.8673
18	51.86	25
19	36.7454	13.4615
20	45.8993	30.2703

d. Husk thickness for green and dry coconuts

Sl.No.	Green			Dry		
	Pedicle (mm)	Centre (mm)	Apex (mm)	Pedicle (mm)	Centre (mm)	Apex (mm)
1	40	20	24	16	9	12
2	35	30	29	17	9	15
3	27	25	20	20	13	13
4	28	21	20	22	15	16
5	40	35	23	23	14	12
6	40	13	25	23	14	15
7	27	24	15	28	18	22
8	40	27	21	22	9	14
9	26	23	24	26	10	14
10	20	19	16	30	14	20
11	15	19	12	15	9	10
12	40	15	25	27	14	17
13	33	31	25	15	11	13
14	34	22	27	19	10	15
15	35	20	23	31	20	25
16	48	30	23	25	20	18
17	42	22	25	18	14	13
18	28	30	19	35	23	29
19	36	27	15	31	12	19
20	30	27	25	29	11	24
21	19	11	16	14	12	11
22	23	20	17	27	12	16
23	45	12	18	19	12	15
24	40	29	24	21	14	18
25	29	22	30	23	12	17
26	30	18	26	16	10	12
27	40	20	32	14	8	10
28	25	15	18	24	12	19
29	29	25	22	19	9	15
30	35	23	22	23	13	16

e. Husk penetrating force

Sl.No	Green			Dry		
	Thickness (mm)	Weight (kg)	Force (N)	Thickness (mm)	Weight (kg)	Force (N)
1	11	8	78.48	8	8	78.48
2	16	10	98.1	10	8	78.48
3	18	10	98.1	12	8	98.1
4	20	10	98.1	15	10	98.1
5	22	12	117.72	17	10	98.1
6	25	12	117.72	18	10	117.72
7	27	12	117.72	21	12	117.72
8.	32	14	137.34	28	14	137.34
9.	38	16	156.96	30	14	137.34
10	47	20	196.2	35	16	156.96

f. Husk separating force

Sl. No	Green		Dry	
	Size (mm)	Force (N)	Size (mm)	Force (N)
1.	130	254	132	310
2.	144	276	149	367
3.	152	290	167	411
4.	161	360	181	457
5.	185	392	200	494
6.	240	430	234	520

CONCLUSIONS

It is important to study the engineering properties of coconut for the design and development of coconut dehusker. Difference in the engineering properties of green and dry coconut was observed. The physical properties of green coconuts were observed as average dimensions of 203 mm (X), 145 mm (Y) and 140 mm (Z), weight of 1kg, shell diameter of 89.61mm and average moisture content of 45.2 % and husk thickness of 33 mm at pedicel, 22 mm at centre and 22 mm at apex. The maximum husk penetrating force for green coconuts of 196.2 N was observed at 47 mm thickness and a maximum husk separating force of 430 N were observed. The physical properties of dry coconuts were observed as the average dimensions of 182 mm (X), 123 mm (Y) and 120 mm (Z), weight of 0.71 kg, shell diameter of 88.6 mm and average moisture content of 23.5 % and husk thickness of 22 mm at pedicel, 12 mm at centre and 16 mm at apex. The maximum husk penetrating force for dry coconuts of 156.96 N was observed at a thickness of 35 mm and maximum husk penetrating force of 520 N was observed. The results showed the dependency of husk penetrating force on husk thickness. Maximum husk separating force was observed for dry coconuts than green coconuts. So it is easy to dehusk green coconuts than dry coconuts.

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