International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Optimization and Performance Evaluation of Palm Nut Cracking Machine

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Abstract: ***An electrically operated palm nuts cracking machine was optimized and its performance was evaluated. The machine was modified by introducing three pulleys with diameters as 82mm, 75mm and 69mm, which produced rotor speeds of 2200rpm, 2,400rpm and 2600rpm respectively. The rotor speeds were then used to test the designed machine and its efficiency were evaluated. Also a curve casing that leads the materials (palm kernels) to the cracking chamber was introduced. The curve casing was to prevent splashing or flying back of palm kernels during cracking. The machine has cracking chamber, which flap the palm kernel nuts on the stationary hard surface. The designed machine was operated by a 4hp electric motor. The performance test was carried out using two different varieties of palm nuts [Dura and Tenera palm nuts] at three different speeds which include 2200rpm, 2400rpm and 2600rpm, using 80kg, 120kg and 140kg weight of both varieties of palm nuts. Each one was replicated three times. The results show that cracking efficiency of the machine increase as the rotor speed increases. The statistical analysis [ANOVA] for the effect of moisture content, speed of the rotor, feed rate and the interactions on the capacity and performance of the evaluated machine for both varieties of palm nuts at 5% probability level was computed. The result of the analysis confirms that moisture content, speed of rotor and feed rate are significant processing parameters that affect machine efficiency on difference sizes of palm kernel cracking.***

Keywords: Optimization, Performance Evaluation, Palm nut, Cracking, Machine.

1. Introduction

Palm kernel oil, major viable oil in Nigeria is obtained from the kernel of the palm kernel tree after cracking the palm kernel nut. The kernels are not useful until the kernels are separated from the shell but usual way of cracking palm nut to get the kernel is a time consuming and labour intensive process,[Oke,2007]. This made to identified the essence of science and technology in national development; it is however worthy to note that no nation can said to be truly developed if her technologies are merely imported. This informs the clarion calls on our Engineers and technologists to develop indigenous technologies capable of engendering economic growth. One of such technologies is the Palm Nut cracker.

Processing unit operation

The processing of palm kernel and palm oil involves the reception of fresh fruit bunches from the plantations, sterilizing and threshing of the bunches to free the palm fruit, mashing the fruit and pressing out the crude palm oil, the crude oil is further treated to purify and dry it for storage and export, then the kernel will be subjected to further processing, (Jimoh and Olukunle, 2012).

Table 1: The unit operations in processing of palm oil and palm kernel

S/N	*Unit Operation*	*Purpose*
1	Fruit fermentation	To loosen fruit base from spike lets and allow ripening processes to abate.
2	Bunch chopping	To facilitate manual removal of fruit.
3	Fruit boiling	To sterilize and stop enzymatic spoilage congulate protein and expose microscopic oil cells.
4	Fruit Digestion	To rupture oil-bearing cells to allow oil flow during extraction while separating fibre from nuts.
5.	Mash pressing	To release fluid palm oil using applied pressure on ruptured cellular contents.
6	Oil purification	To boil mixture of oil and water to remove water soluble gums and resins in the oil, dry decanted oil by further heating.
7	Fibre-nut separation	To separate de-oiled fibre from palm nuts.
8	Second pressing	To recover residual oil for use as soap stock.
9	Nut Drying	To sun dry nuts for later cracking.

Source: (FAO 2005)

The product of palm nut cracking, palm kernel, is a very good source of foreign exchange. Palm kernel industry had remained very popular in third world because of the dependency of many companies on palm kernel oil as raw material, which is quite inadequate (Muthurajah, 2002).

Nigeria is one of the world largest exporters of palm kernel product in early sixties, providing about 400,000 metric tons amounting to 65 percent of the world trade. Nigeria palm kernel nut export reduced drastically within seventies, from 65 to 15 percent when there was an oil boom (Ndegwe, 1987). Based on high independent of many companies like soap, vegetable oil and body cream industries on within and outside this country, an efficient palm kernel-processing machine is therefore not only necessary but also important to revitalize the production of the palm kernel in other to meet up with increases industrial demand.

Several palm nut cracking machines designed and fabricated failed because they were not based on sound knowledge of the physical characteristics and properties of the palm nuts. This project has been conceived as a practical contribution towards solving the problem highlighted. According to the survey by Raw Material Research and Development Council [2004], "the local manufacture of palm processing equipment is concentrated in hands of technicians". This is

to bridge the gap between manual and mechanical ways of cracking palm kernel, for the efficient palm kernel processing. The objectives of this project is to modify an effective palm nut cracking machine that based on the sound knowledge of physical characteristics and mechanical properties of the palm nuts and also to carry out performance test of the modified palm nut cracker.

2. Materials and Methods

Force required to break one palm kernel is obtained from the experiment conducted in mechanical engineering laboratory of Enugu State University of Science and Technology Enugu, using tensile machine (compressive test). Five samples of palm nut were selected randomly and the experiment was performed on each sample and the force required to break each was recorded.

Physical properties of palm kernel used for the design are:
Mass of one palm nut = $3.4x10^{-3}$ kg
Major diameter of one palm nut = 16.70 mm
Intermediate diameter of one palm nut = 14.30 mm
Minor diameter of one palm nut = 9.20 mm
Density of one palm nut = 1.04 g/cm^3
Safe moisture content = 5.30 %
Volume of one palm nut = 2.80 cm^3

3. Determination of Power Required to Break Palm Kernel Nuts

The total force required in breaking palm kernel nuts by rotating disk is
$F_r = n_s\, n_r\, F$
F = force required to break one palm kernel (N).
F_r = Total force required in breaking palm kernel
n_s = no of seeds in the rotating disk = 80
n_r = no of rotating disk = 1
The power required to crack palm kernel is given as

$$P = T\omega = \frac{2\pi NT}{60}$$

Where
T = torque (Nm) = r Fr
r = radius of the disk = 0.105m
ω = Angular speed [rad/s] = 2πN/60
N = speed of rotation of disk (rpm) 2400rpm

Shaft design

The design of shaft is based on combined shock and fatigue, Bending and torsional moment. To determine the shaft diameter, we adopt the formula;

$$d^3 = \frac{16}{\pi\delta_{sy}}[(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}}$$

Where;
d = diameter of shaft (mm)
K_b = combined shock and fatigue factor for bending moment.
K_t = combined shock and fatigue factor for torsional moment.
M_b = Resultant bending moment (Nm)
M_t = Resultant torsional moment (Nm)
δ_{sy} = Allowable shear stress (MN/m^2)
π = constant, 3.142

Principle of operation of the machine

Palm nuts meant to be cracked are feed into the feed hopper with the discharge control plate closed; power is then supplied to the machine through a vee-belt drive arrangement between an electric motor and pulley keyed to the cracking disc shaft.

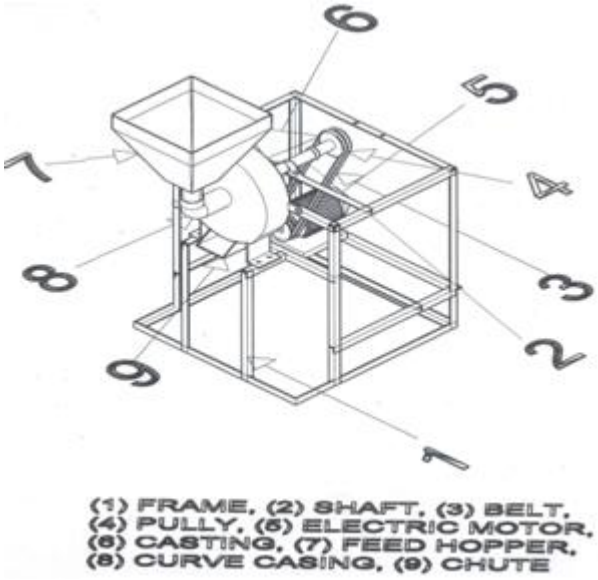

Figure 1:

Isometric View of palm Kernel Cracker

The machine is then allowed to attain a steady speed for about five (5) minutes, before the feed control plate is open to allow nuts to fall into the cracking chamber. As the palm nuts enter into chamber, they are then rotated by the disc and thrown away from it unto the rigid stationary casing. The impact force between the palm nut and the chamber casing causes it to crack, thus releasing the kernels and shell nuts that are then discharged through the outlet provided at the machine unto an optional collection tray.

Optimization of Palm Kernel Cracker

Three pulleys were introduced and the design and fabrication were extrapolated as follows: diameters are 82mm, 75mm and 69mm, which produced rotor speeds of 2200rpm, 2,400rpm and 2600rpm respectively. The rotor speeds were then used to test the designed machine and its efficiency were evaluated. The curve casing that leads the materials (palm kernels) to the cracking chamber was introduced. The curve casing was to prevent splashing or flying back of palm kernels during cracking. It also contributed to the high efficiency of the machine.

Evaluation of the Machine

The machine was tested with different varieties of palm nut at difference machine speed. The effect of these different varieties on machine parameters such as mass flow rate, percentage losses, cracking efficiency, recovering rate and mechanical damage were determined. During cracking, weight of nuts introduced, weight of kernels cracked, weight

of shell cracked, weight of shell cracked, weight of palm nuts not cracked, weight of nuts damage and time of cracking were taken. The performance test was conducted for each variety of palm nuts using those parameters. The results obtained were analyzed using analysis of variance (ANOVA).

4. Results and Discussion

The performance test carried out was to determine the cracking efficiency, percentage losses, mass flow rate, recovery rate, and palm nut damage of the machine using two varieties of palm nuts which include Dura and Tenera. The cracking performance of the machine using Dura palm nuts at three different moisture content was lower than using Tenera palm nuts at different speed. The averages weight of palm nuts not cracked were higher using Dura palm nut to Tenera palm nut at each moisture content. The results shows that the weight of kernel cracked increases as the speed of the rotor increases which recorded that the machine performed highest at 2,600rpm as compared to, 2,400rpm and 2,200rpm. It also showed that the average weight of shell, cracked with the machine increase as the speed of rotor increases and palm nuts damage from the machine decrease as the speed of the rotor increases.
Tables 2 to 7 give the average results obtained for testing the machine using Dura and Tenera palm nuts. The average weight of kernel cracked, and shells cracked using 80kg, 120kg and 140kg at moisture content of 9 %(db), 11%db and 13%db were lowest at 2,200 rpm and highest at 2,600 rpm. The shells cracked were highest at 2,600 rpm and lowest at 2,200 rpm. The average weights of palm nuts not cracked and palm nut damaged using 80kg of palm nut shows highest at 2,200 rpm and lowest at 2,600 rpm respectively. The average time used for cracking decrease as the speed of rotor increases. The time used for cracking 80kg of palm nuts was highest at 2,200 rpm and lowest at 2,600 rpm for 9%, 11% and 13% (db) moisture content respectively.

Tables 8 to 13 show the summary of the result of the machine performance at 2600rpm for Dura and Tenera palm nuts. They present that the cracking efficiency was highest using moisture\ content of 9% (db) of the palm nuts and lowest using moisture content of 13% (db) of the palm nuts. This reveals that the best performance of the machine at 2600rpm was 9% (db) moisture content and lowest was 13% (db) moisture content. It also indicates that the cracking efficiency was highest using 80kg palm nut and lowest using 140kg of palm nuts. This means that the more weight of palm nuts introduce into the machine the lower the cracking efficiency. The percentage losses of the machine shows highest using moisture content of 13% (db) and lowest at moisture content of 11% (db). The recovery rate was highest at 11% (db) and lowest at moisture content of 13% (db) of palm nuts. The mechanical damage was highest at moisture content of 13% (db) and lowest at moisture content of 9% (db). Also mass flow rate was highest at moisture content of 9% (db) and lowest at moisture content of 13% (db) of palm nuts.

Figures 2 and 3 are the graph of cracking efficiency of the machine at different moisture contents and speeds. The graphs show that the cracking efficiency of the machine was highest at moisture content1 (9.0%) and speed3 (2600rpm).

Generally, It was seen that the cracking efficiency of the machine increase as the speed of the rotor increases, that means the cracking efficiency was highest at 2600 rpm and lowest at 2,200 rpm for both varieties. The increase in speed of rotor also increase the percent losses, mass flow rate and decrease the recovery rate and the mechanical damage for Dura variety. In Tenera variety, the increase in speed of the rotor vary the percentage losses and recovery rate and increase the mass flow rate and decrease the mechanical damage.

However, the cracking efficiency was higher using 9.0% moisture content and lower using 13% moisture content in both varieties. This is because as the moisture content reduces, kernel loosed from shell, this create sufficient clearance between kernel and shell to absorb impact during cracking. Even as the kernel shrinks, cracks initiated in the shell. The net recovery rate was high showing that high percentage of palm nut was recovered and the mass flow rate obtained shows that the machine saves time.

The cracking efficiency of the machine was higher using Tenera as compared to Dura, which has more compressive strength and shearing force due to its shell thickness. It was also showed that the cracking efficiency of the machine was increase as the feed rate of Dura palm nuts increases, means that cracking efficiency was highest at 140kg. On the other hand, the cracking efficiency of the machine increase as the feed rate of Tenera Palm nuts decreases, means the cracking efficiency of the machine was higher at 80kg. This is because as too much palm nuts entering the cracking chamber at a time decreasing the impinging velocity of the palm nuts due to collision with one another and cracking efficiency decreases with increased feed rate. The analysis of results (ANOVA) confirmed that moisture content, speed of rotor and feed rate are significant processing parameters that affect machine performance [efficiency] on difference sizes of palm kernel cracking on both varieties

Table 2: Results of Cracking Performance Test at Moisture Content of 9.00%db for Dura

Rotor speed (rpm)	Weight of palm nuts introduced (kg)	Weight of kernels cracked (kg)	Average weight of kernel cracked (kg)	Wight of shells (kg)	Average weight of shell (kg)	Weight of palm nuts not cracked (kg)	Average palm nuts not cracked (kg)	Mechanical damage of palm nuts (kg)	Average mechanical damage (kg)	Time of cracking (sec)	Average of time cracking (sec)
	80.00	23.70	23.75	52.90	52.88	2.05	2.00	1.30	1.25	260	262
	80.00	23.80		52.90		1.95		1.25		262	
2,200	80.00	23.75		52.85		2.00		1.29		265	
	120.00	34.00	34.05	78.00	78.00	3.40	3.37	2.00	1.98	361	363
	120.00	34.10		78.00		3.35		2.00		366	

	120.00	34.05		78.00		3.35		1.95		363	
	140.00	40.40	40.47	89.80	89.82	4.00	4.07	2.85	2.82	373	373
	140.00	40.55		89.80		4.10		2.80		368	
	140.00	40.45		89.85		4.10		2.80		369	
	80.00	24.35	24.33	53.10	53.10	1.40	1.42	0.55	0.55	244	248
	80.00	24.35		53.15		1.45		0.60		247	
2,400	80.00	24.30		53.05		1.40		0.50		252	
	120.00	35.00	35.02	78.30	78.30	2.10	2.08	1.70	1.68	340	343
	120.00	35.00		78.25		2.10		1.65		345	
	120.00	35.05		78.35		2.05		1.70		343	
	140.00	41.20	41.20	90.80	90.75	2.40	2.40	1.90	1.87	361	364
	140.00	41.10		90.75		2.40		1.85		364	
	140.00	41.25		90.70		2.40		1.85		366	
	80.00	24.85	24.85	53.40	53.40	0.75	0.72	0.20	0.22	235	234
	80.00	24.75		53.35		0.70		0.25		230	
2,600	80.00	24.95		53.45		0.70		0.29		236	
	120.00	36.00	36.05	78.60	78.63	1.30	1.33	0.90	0.90	321	323
	120.00	36.05		78.65		1.35		0.85		326	
	120.00	36.10		78.65		1.35		0.95		322	
	140.00	42.15	42.5	91.85	91.78	2.20	2.20	1.20	1.22	342	342
	140.00	42.10		91.80		2.15		1.25		340	
	140.00	41.90		91.70		2.25		1.29		345	

Table 3: Results of Cracking Performance Test at Moisture Content of 11.00% (db) for Dura

Rotor speed (rpm)	Weight of palm nuts introduced (kg)	Weight of kernels cracked (kg)	Average weight of kernel cracked (kg)	Wight of shells (kg)	Average weight of shell (kg)	Weight of palm nuts not cracked (kg)	Average palm nuts not cracked (kg)	Mechanical damage of palm nuts (kg)	Average mechanical damage (kg)	Time of cracking (sec)	Average of time cracking (sec)
	80.00	22.65	22.75	51.40	51.45	30.00	3.02	2.55	2.52	270	273
	80.00	22.85		51.55		3.95		2.50		273	
2,200	80.00	22.75		51.40		3.90		2.50		275	
	120.00	33.75	33.75	77.25	77.20	4.75	4.78	3.10	3.08	380	378
	120.00	33.80		77.10		4.80		3.05		378	
	120.00	33.70		77.15		4.80		3.10		375	
	140.00	39.50	39.55	90.10	89.97	5.20	5.22	3.45	3.43	432	432
	140.00	39.55		89.90		5.20		3.45		435	
	140.00	39.60		89.90		5.25		3.40		428	
	80.00	23.30	23.37	51.85	51.80	2.15	2.12	1.45	1.43	259	257
	80.00	23.45		51.70		2.10		1.45		257	
2,400	80.00	23.35		51.85		2.10		1.40		255	
	120.00	34.45	34.40	77.60	77.65	3.15	3.10	1.95	1.92	354	357
	120.00	34.40		77.70		3.05		1.90		358	
	120.00	34.35		77.65		3.10		1.90		360	
	140.00	40.25	40.30	90.80	90.75	4.55	4.53	2.25	2.28	386	388
	140.00	40.30		90.70		4.55		2.30		390	
	140.00	40.35		90.75		4.50		2.30		399	
	80.00	23.85	23.85	52.45	52.47	1.35	1.37	0.90	0.90	244	241
	80.00	23.80		52.55		1.40		0.95		240	
2,600	80.00	23.90		52.40		1.35		0.85		238	
	120.00	35.40	35.35	78.05	78.02	2.05	2.03	1.15	1.12	330	330
	120.00	35.30		78.00		2.00		1.10		327	
	120.00	35.35		78.00		2.05		1.10		334	
	140.00	41.80	41.83	91.55	91.53	3.25	3.25	1.00	1.02	376	375
	140.00	41.85		91.50		3.25		1.00		375	
	140.00	41.85		91.55		3.35		1.05		374	

Table 4: Results of Cracking Performance Test at Moisture Content of 13.00% (db) for Dura

Rotor speed (rpm)	*Weight of palm nuts introduced (kg)*	*Weight of kernels cracked (kg)*	*Average weight of kernel cracked (kg)*	*Wight of shells (kg)*	*Average weight of shell (kg)*	*Weight of palm nuts not cracked (kg)*	*Average palm nuts not cracked (kg)*	*Mechanical damage of palm nuts (kg)*	*Average mechanical damage (kg)*	*Time of cracking (sec)*	*Average of time cracking (sec)*
	80.00	22.10	22.15	51.20	51.15	3.70	3.70	2.90	2.88	287	289
	80.00	22.20		51.10		3.65		2.90		289	
2,200	80.00	22.15		51.15		3.75		2.85		292	
	120.00	33.10	33.12	76.75	76.73	5.45	5.47	3.50	3.47	400	405
	120.00	33.20		76.75		5.50		3.45		410	
	120.00	33.05		76.70		5.45		3.45		405	

	140.00	38.75	38.77	90.45	90.40	5.70	5.80	3.60	3.63	470	472
	140.00	38.75		90.35		5.85		3.65		474	
	140.00	38.80		90.40		5.80		3.65		472	
	80.00	22.70	22.65	51.50	51.52	3.10	3.08	2.50	2.52	270	275
	80.00	22.60		51.55		3.05		2.55		279	
2,400	80.00	22.65		51.50		3.10		2.50		275	
	120.00	33.60	33.56	77.10	77.15	4.70	4.73	3.10	3.10	387	388
	120.00	33.55		77.20		4.75		3.10		387	
	120.00	33.55		77.15		4.75		3.10		389	
	140.00	39.40	39.45	90.90	90.85	5.05	5.07	2.70	2.72	452	454
	140.00	39.50		90.80		5.10		2.75		454	
	140.00	39.45		90.85		5.05		2.70		455	
	80.00	22.85	22.85	52.10	52.15	2.80	2.82	1.90	1.87	260	261
	80.00	22.90		52.20		2.85		1.85		264	
2,600	80.00	22.85		52.15		2.80		1.85		260	
	120.00	33.95	33.95	77.60	77.55	4.15	4.13	2.20	2.22	370	368
	120.00	33.90		77.55		4.10		2.20		368	
	120.00	34.00		77.50		4.15		2.25		365	
	140.00	40.55	40.50	91.45	91.47	4.25	4.28	1.70	1.72	430	435
	140.00	40.45		91.45		4.30		1.70		440	
	140.00	40.50		91.50		4.30		1.75		435	

Table 5: Results of Cracking Performance Test at Moisture Content of 9.00% (db) for Tenera

Rotor speed (rpm)	*Weight of palm nuts introduced (kg)*	*Weight of kernels cracked (kg)*	*Average weight of kernel cracked (kg)*	*Wight of shells (kg)*	*Average weight of shell (kg)*	*Weight of palm nuts not cracked (kg)*	*Average palm nuts not cracked (kg)*	*Mechanical damage of palm nuts (kg)*	*Average mechanical damage (kg)*	*Time of cracking (sec)*	*Average of time cracking (sec)*
	80.00	30.95	30.90	46.45	46.48	1.20	1.22	0.50	0.48	251	249
	80.00	30.85		46.50		1.20		0.50		249	
2,200	80.00	30.90		46.50		1.25		0.45		247	
	120.00	46.10	46.13	69.20	69.22	2.50	2.52	1.50	1.53	345	346
	120.00	46.15		69.25		2.50		1.55		347	
	120.00	46.15		69.20		2.55		1.55		345	
	140.00	53.80	53.85	80.70		3.00	3.05	1.85	1.83	362	360
	140.00	53.90		80.75	80.72	3.05		1.80		359	
	140.00	53.85		80.70		3.10		1.85		360	
	80.00	31.15	31.17	46.75	46.73	1.00	1.02	0.20	0.22	234	234
	80.00	31.20		46.70		1.00		0.25		236	
2,400	80.00	31.15		46.75		1.05		0.29		233	
	120.00	46.40	46.43	69.60	69.63	2.10	2.12	1.10	1.13	320	325
	120.00	46.45		69.65		2.15		1.15		335	
	120.00	46.45		69.65		2.10		1.15		332	
	140.00	54.05	54.02	81.10	81.10	2.60	2.58	1.50	1.48	334	347
	140.00	54.00		81.10		2.55		1.45		339	
	140.00	54.00		81.10		2.60		1.50		337	
	80.00	31.35	31.37	47.05	47.10	0.80		0.10	0.12	212	213
	80.00	31.40		47.15		0.80	0.82	0.15		216	
2,600	80.00	31.35		47.10		0.85		0.10		210	
	120.00	46.75	46.77	69.85	69.90	1.65	1.70	0.75	0.72	305	302
	120.00	46.80		69.90		1.75		0.70		300	
	120.00	46.75		69.95		1.70		0.70		302	
	140.00	54.30	54.32	81.45	81.47	2.15	2.18	1.15	1.13	331	333
	140.00	54.35		81.45		2.20		1.10		335	
	140.00	54.30		81.50		2.20		1.15		333	

Table 6: Results of Cracking Performance Test at Moisture Content of 11.00% (db) for Tenera

Rotor speed (rpm)	Weight of palm nuts introduced (kg)	Weight of kernels cracked (kg)	Average weight of kernel cracked (kg)	Weight of shells (kg)	Average weight of shell (kg)	Weight of palm nuts not cracked (kg)	Average palm nuts not cracked (kg)	Mechanical damage of palm nuts (kg)	Average mechanical damage (kg)	Time of cracking (sec)	Average of time cracking (sec)
	80.00	30.65	30.67	46.05	46.08	1.45	1.50	0.65	0.67	259	256
	80.00	30.70		46.10		1.50		0.70		256	
2,200	80.00	30.65		46.10		1.55		0.65		254	
	120.00	45.85	45.90	68.85	68.87	2.70	2.73	1.85	1.87	368	368
	120.00	45.95		68.90		2.80		1.85		371	
	120.00	45.90		68.85		2.70		1.90		364	
	140.00	53.70	53.68	80.50	80.50	3.35	3.33	2.10	2.10	421	418

	140.00	53.65		80.50		3.35		2.10		417	
	140.00	53.70		80.50		3.30		2.10		415	
	80.00	31.00	30.95	46.35	47.37	1.35	1.33	0.55	0.53	249	249
	80.00	30.95		46.40		1.30		0.55		246	
2,400	80.00	30.90		46.35		1.35		0.50		252	
	120.00	46.20	46.17	69.30	69.28	2.35	2.37	1.50	1.53	337	340
	120.00	46.15		69.25		2.35		1.55		340	
	120.00	46.15		69.30		2.40		1.55		342	
	140.00	53.95	53.92	80.70	80.75	2.95	2.95	1.75	1.73	389	387
	140.00	53.90		80.80		2.95		1.70		387	
	140.00	53.90		80.75		2.95		1.70		384	
	80.00	31.20	31.22	46.70	46.73	1.10	1.12	0.35	0.37	218	221
	80.00	31.25		46.75		1.10		0.35		224	
2,600	80.00	31.20		46.75		1.15		0.40		220	
	120.00	46.45		69.55		1.90	1.95	1.25	1.23	317	319
	120.00	46.40	46.43	69.50	69.53	1.95		1.20		320	
	120.00	46.45		69.55		2.00		1.25		321	
	140.00	54.20		81.25	81.22	2.50	2.48	1.60	1.58	359	359
	140.00	54.15	54.18	81.20		2.45		1.55		362	
	140.00	54.20		81.20		2.50		1.60		357	

Table7: Results of Cracking Performance Test at Moisture Content of 13.00% (db) for Tenera

Rotor speed (rpm)	Weight of palm nuts introduced (kg)	Weight of kernels cracked (kg)	Average weight of kernel cracked (kg)	Weight of shells (kg)	Average weight of shell (kg)	Weight of palm nuts not cracked (kg)	Average palm nuts not cracked (kg)	Mechanical damage of palm nuts (kg)	Average mechanical damage (kg)	Time of cracking (sec)	Average of time cracking (sec)
	80.00	30.20	30.22	45.35	45.37	2.30	2.30	1.10	1.13	270	270
	80.00	30.25		45.40		2.35		1.15		267	
2,200	80.00	30.20		45.35		2.25		1.15		274	
	120.00	45.45	45.48	68.15	68.17	3.00	3.03	2.30	2.27	389	389
	120.00	45.50		68.20		3.05		2.25		386	
	120.00	45.50		68.15		3.05		2.25		392	
	140.00	53.15	53.17	79.75	79.78	3.70	3.73	2.40	2.38	458	459
	140.00	53.15		79.80		3.75		2.35		462	
	140.00	53.20		79.80		3.75		2.40		456	
	80.00	30.45	30.48	45.65	45.67	1.70	1.73	1.00	0.98	257	259
	80.00	30.50		45.65		1.75		1.00		260	
2,400	80.00	30.50		45.70		1.75		0.95		259	
	120.00	45.75	45.73	68.50	68.53	2.75		2.00	2.00	370	350
	120.00	45.70		68.55		2.70	2.72	2.00		368	
	120.00	45.75		68.55		2.70		2.00		373	
	140.00	53.35	53.35	80.10	80.12	3.25		2.10	2.15	429	430
	140.00	53.35		80.15		3.30	3.27	2.15		427	
	140.00	53.35		80.10		3.25		2.20		433	
	80.00	30.65	30.68	46.00	46.03	1.50	1.55	0.80	0.82	251	247
	80.00	30.70		46.05		1.60		0.85		244	
2,600	80.00	30.70		46.05		1.55		0.80		247	
	120.00	45.90	45.93	68.80	68.82	2.30	2.35	1.70	1.75	351	232
	120.00	45.95		68.85		2.35		1.75		348	
	120.00	45.95		80.80		2.40		1.80		356	
	140.00	53.65	53.67	80.45	80.48	2.80	2.83	1.80	1.80	389	390
	140.00	53.70		80.50		2.80		1.70		393	
	140.00	53.65		80.50		2.90		1.85		387	

Table 8: Summary of Machine Performance of the three feed rate at 2,200rpm for Dura

Moisture content (%)	*Cracking Efficiency (%)*	*Percentage losses (%)*	*Recovery Rate (%)*	*Mass flow rate (Kg/Min)*	*Mechanical Damage (%)*
9.0	95.52	1.44	98.56	20.28	1.74
11	93.45	1.11	99.12	18.69	2.72
13	92.53	0.72	99.28	17.40	3.09
Average	**93.83**	**1.09**	**98.98**	**18.79**	**2.52**

Table 9: Summary of Machine Performance of the three feed rate at 2,400rpm for Dura

Moisture content (%)	*Cracking Efficiency (%)*	*Percentage losses (%)*	*Recovery Rate (%)*	*Mass flow rate (Kg/Min)*	*Mechanical Damage (%)*
9.0	97.12	1.96	98.04	21.14	1.14
11	95.51	1.86	98.14	20.17	1.67
13	93.64	0.91	99.09	18.17	2.56
Average	**95.42**	**1.58**	**98.42**	**19.83**	**1.79**

Table 10: Summary of Machine Performance of the three feed rate at 2,600rpm for Dura

Moisture content (%)	*Cracking Efficiency (%)*	*Percentage losses (%)*	*Recovery Rate (%)*	*Mass flow rate (Kg/Min)*	*Mechanical Damage (%)*
9.0	98.18	1.85	98.15	22.45	0.63
11	97.16	2.12	97.88	21.38	0.93
13	94.85	1.21	98.79	19.09	1.81
Average	**96.73**	**1.72**	**98.25**	**20.98**	**1.32**

Table 11: Summary of Machine Performance of the three feed rate at 2,200rpm for Tenera

Moisture content (%)	*Cracking Efficiency (%)*	*Percentage losses (%)*	*Recovery Rate (%)*	*Mass flow rate (Kg/Min)*	*Mechanical Damage (%)*
9.0	96.53	0.68	99.32	21.14	1.06
11	96.53	0.72	99.28	19.47	1.30
13	95.64	0.93	99.08	18.20	1.67
Average	**96.39**	**0.78**	**99.23**	**19.60**	**1.34**

Table 12: Summary of Machine Performance of the three feed rate at 2,400rpm for Tenera

Moisture content (%)	*Cracking Efficiency (%)*	*Percentage losses (%)*	*Recovery Rate (%)*	*Mass flow rate (Kg/Min)*	*Mechanical Damage (%)*
9.0	97.61	0.75	99.25	22.29	0.76
11	97.03	0.67	99.33	20.72	1.06
13	96.27	1.02	98.97	19.54	1.48
Average	**96.97**	**0.81**	**99.18**	**20.85**	**1.10**

Table 13: Summary of Machine Performance of the three feed rate at 2,600rpm for Tenera

Moisture content (%)	*Cracking Efficiency (%)*	*Percentage losses (%)*	*Recovery Rate (%)*	*Mass flow rate (Kg/Min)*	*Mechanical Damage (%)*
9.0	98.15	0.71	99.29	23.87	0.52
11	97.53	0.60	99.40	22.56	0.87
13	96.77	0.99	99.01	20.88	1.26
Average	97.48	0.77	99.23	22.44	0.88

Table 14: Analysis of variance (ANOVA) for the effect of moisture content, rotor speed and feed rate on cracking efficiency of Dura Palm Kernel

Source of Variation	*Sum of squares*	*Degree of freedom*	*Mean squares*	*Computed F.*
A (Moisture content)	249.11	2	124.56	0.3201
B (Rotor speed)	247.99	2	124.00	0.3186
C (Feed rate)	248.55	2	124.28	0.3193
Treatments	17.64	2	8.82	0.0227
Combination	2307.47	8	288.43	0.7411
Error	3891.72	10	389.17	-
Total	**6962.48**	**26**	-	-

Table 15: Analysis of variance (ANOVA) for the effect of moisture content, rotor speed and feed rate on cracking efficiency of Tenera Palm Kernel

Source of Variations	*Sum of squares*	*Degree of freedom*	*Mean squares*	*Computed F.*
A (Moisture content)	201.14	2	100.57	0.3275
B (Rotor speed)	201.09	2	100.55	0.3274
C (Feed rate)	201.06	2	100.53	0.3274
Treatments	6.82	2	3.41	0.0111
Combination	1837.06	8	229.63	0.7478
Error	3070.82	10	307.08	-
Total	5517.99	26	-	-

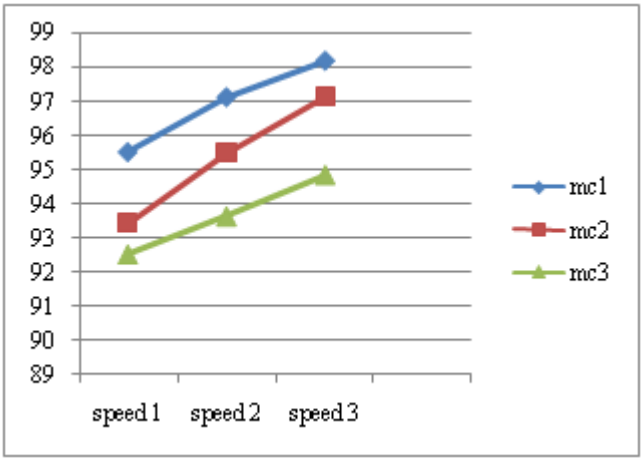

Figure 2: Cracking efficiency at different moisture content and speed for Dura

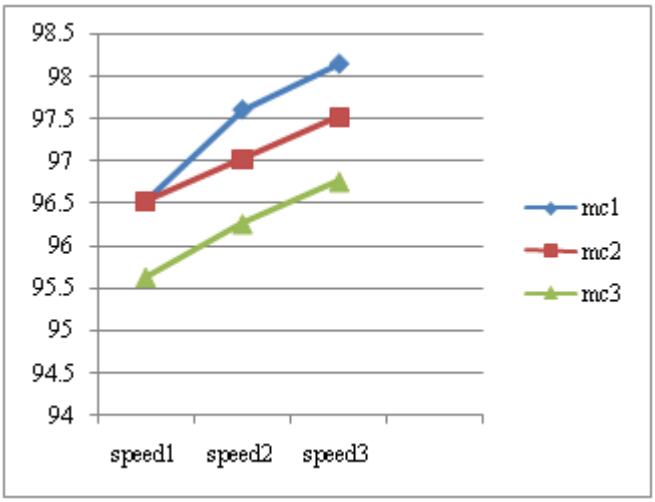

Figure 3: Cracking efficiency at different moisture content and speed for Tenera

5. Conclusion

The results showed that there was tremendous improvement over the machine that has no curve casing. Compressive strength of palm nuts was significantly affected by moisture content and shell thickness. Strength decreased with decrease in moisture content but increased with increase in shell thickness. Drying the palm nut on the sun to reduce its moisture content pave the way for appropriate performance of palm nut cracker and with minimum mechanical damage.

The cracking efficiency of the machine increase as the speed of the rotor increases. That means the cracking efficiency was highest at 2600rpm and 9.0% moisture content for both varieties. But the feed rate of the machine vary which shows that cracking efficiency was highest at 80kg and 140kg for Tenera and Dura palm nuts respectively.

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