Comparative Evaluation of Throughput Capacities and Whole Kernel Recovery for Cracking Operation of Dura, Tenera and Mixed Varieties of Palm Nut

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Abstract
This research focused on evaluating the comparison in throughput capacity and whole kernel recovery during cracking operation of Dura, Tenera and Mixed Varieties of Palm Nut. One thousand three hundred and fifty (1350) samples of 1000g each of fresh palm nuts were used for the experiment, 450 samples were dura, 450 samples tenera and 450 samples were mixed varieties. 150 samples were selected for each experimental run. Three (3) sets of runs were carried out for each variety at the same condition. The samples after drying to specified levels of moisture content, were cracked at 5 different speeds with 5 levels of feed rate. Mean values for each variety was computed and used for statistical analysis. Comparative analysis shows that mixed variety have significant variation of the percentage whole kernel recovery of 48.04 to 97.06%, while tenera variety have significant variation of the throughput capacity of 99.23 to 476.19kg/h. For dura variety, the highest whole kernel recovery of 90.35% was obtained at the cracking speed of 1600rpm, moisture content of 18.1% w.b and feed rate of 360kg/h, all at 0.05 level of significance. Analysis of variance (ANOVA) and result of the pairwise comparisons for variables in the three varieties of palm nut revealed that the effects of cracking speed, moisture content and feed rate on the performance parameters are statistically significant at 0.05 level of significance.

Keywords: *Comparative Evaluation; Throughput Capacities; Whole Kernel Recovery; Cracking Operation; Dura; Tenera; Mixed Varieties; Palm Nut*

1.0 INTRODUCTION

Oil palm is a unique crop with two distinct types of oil namely; palm oil and palm kernel oil. The palm oil is obtained from the mesocarp of the fruits while palm kernel oil is obtained from the kernels of the palm nuts (Sam *et al*., 2022b and Muthurajah, 2002). There are basically three distinct varieties of the oil palm fruit. These are the *Dura, Tenera* and *Pisifera*. *Dura* variety is made up of a thin mesocarp, thick endocarp (shell) and the kernel tends to be large, comprising 7 - 20% of the fruit weight. The *Tenera* variety has a large mesocarp, thin endocarp (shell) and large to medium kernel. The *Pisifera* variety possesses thick mesocarp, small or no endocarp (shell) with small kernel where applicable. The endocarp (shell) of palm nut generally contains one or more kernels (Okokon *et al*., 2007).

The 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 (Sam *et al.*, 2022a). The shell particles following nut cracking and kernel separation from cracked nut mixture are generally used as domestic fuel for cooking, decorating houses in many rural communities and a source of coarse aggregate in light concrete. Other usages are as a key biomass material, replacing fossil fuel for steam power plant (Sam *et al.*, 2022a; Oyejobi *et al.*, 2012; Sanni and Adegbenjo, 2002).

In the nut crackers, the nuts are either fed into a slot in a rotor and are thrown at high speed against a cracking drum, or fed into a cracking chamber where they are impacted upon by metal beaters (impeller) turning at high speed (Sam *et al*., 2024b; Obiakor and Babatunde, 1999). Palm kernel nut cracking occurs when nuts are loaded to rupture without crushing the embedded kernel. Palm nut cracker is one of the recent technologies capable of engendering economic growth in a Nation like Nigeria. Performance parameters of a palm nut cracking machine are: cracking efficiency, throughput capacity, power requirement, whole kernel recovery, percentage of broken nuts and cracking time. 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 (Sam *et al*., 2024b). This project is conceived as a practical contribution towards solving the problem. The drying time and rate of drying affects the loosening kernel from the shell which enhances the release of the kernel when the nuts are subjected to appropriate impact energy (Okoli, 2003; Gbadam *et al*., 2009).

Sorting out different varieties of palm nut also constitutes another major challenge in palm nut cracking. In most plantations, mixed varieties (Dura, Tenera and even Pisifera) of oil palm are planted, harvested and processed together in large quantities. To overcome the rigorous task of sorting and damages, the existing cracking machines needs to be improved for effective cracking of mixed varieties of palm nuts at the same time. The various factors affecting the performance of cracking machine as presented by Umoh *et al.*, 2024 and others such as Shahbazi (2012) includes: the nuts moisture content, bulk density, feed rate, throughput capacity, cracking time, cracking speed and power. These factors if not properly controlled could reduce the performance of the cracking machine.

2.0 MATERIALS AND METHODS

2.1 Sample Acquisition and Preparation: Fresh oil palm nuts of *Dura* variety, *Tenera* variety and mixed varieties were purchased from VIKA Farm, Uyo and NIFOR, Abak Station palm fruits processing mill. Cleaning of nuts was carried out manually to remove immature nuts and other unwanted materials from the bulk sample. The samples were preserved and taken to the laboratory in polythene bags to avoid excessive loss or gain of moisture.

2.2 Description of the Experimental Machine: Palm nuts were cracked in a cracker developed by Etuk Tech. Engineering Company for NIFOR, based on the design consideration and analysis by Ismail *et al.* (2015) and Stephen and Lukeman (2015). It consists of five major units: the in-feed unit, the cracking unit, the discharge outlet, the driven unit and the dynamometer.

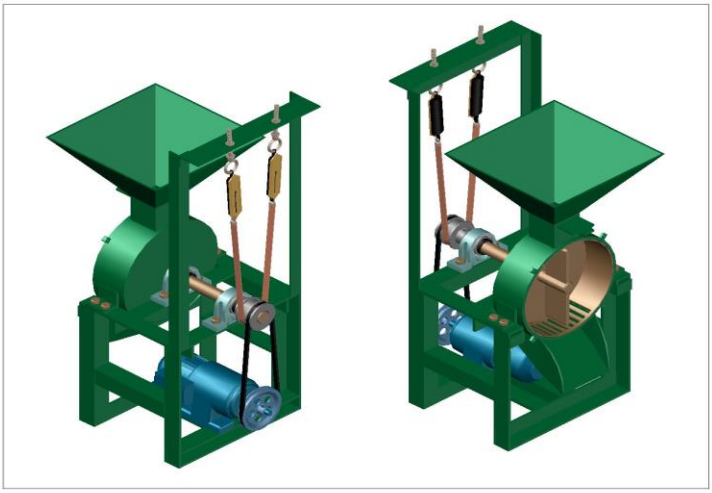


Figure 1: Isometric view of the palm nut cracker
Source: Sam *et al*., 2024a

2.3 Determination of Relevant Parameters

Relevant performance parameters for cracking process of oil palm nut cracking machine was formulated considering machine, crop and environmental factors. These factors were considered in other to identify variables required for model development, process optimization and also that affect the cracking efficiency and whole kernel recovery. However, there are many factors that determine the performance of palm nut cracking machine but only the relevant factors are considered in this study.

2.3.1 Moisture content: The nuts, usually at moisture content of about 27.7% (fresh nuts), are dried to recommended moisture content before cracking. Sam *et al*., (2024b) determined the optimum nut moisture content of 11.2 % on the average and the proportion of nuts that yielded whole kernel was 84.20 %. Gbadam *et al.* (2009) and Usoh *et al.* (2023) concluded that both moisture content and rotor speed have significant effects on the crackability of palm nut, then recommended moisture content of 16.01% and below. Judging from the reports of previous researchers and some preliminary experiment using different varieties of palm nuts, we observed that, moisture content of 10 - 19% wet basis yielded the best result. Drying beyond this limit increases the percentage of kernel breakage. For this study, five levels of moisture content (12.4, 14.0, 16.2, 18.1, 20.0% w.b) were selected. The moisture content of fresh nuts was also determined as 27.8% and this was used as control during the analysis of experiment.

Figure 2: Oven drying of the sample at 105°C

Oven dry method was used to determine the moisture content of the nuts (Figure 2). The nut moisture contents at wet basis MC (wb) and dry basis MC (db) were determined using the equation 1 and 2;

$$\text{MC (wb)} = \frac{W_i - W_f}{W_i} \times 100 \quad 1$$

$$\text{MC (db)} = \frac{MC(wb)}{1 - MC(wb)} \times 100 \quad 2$$

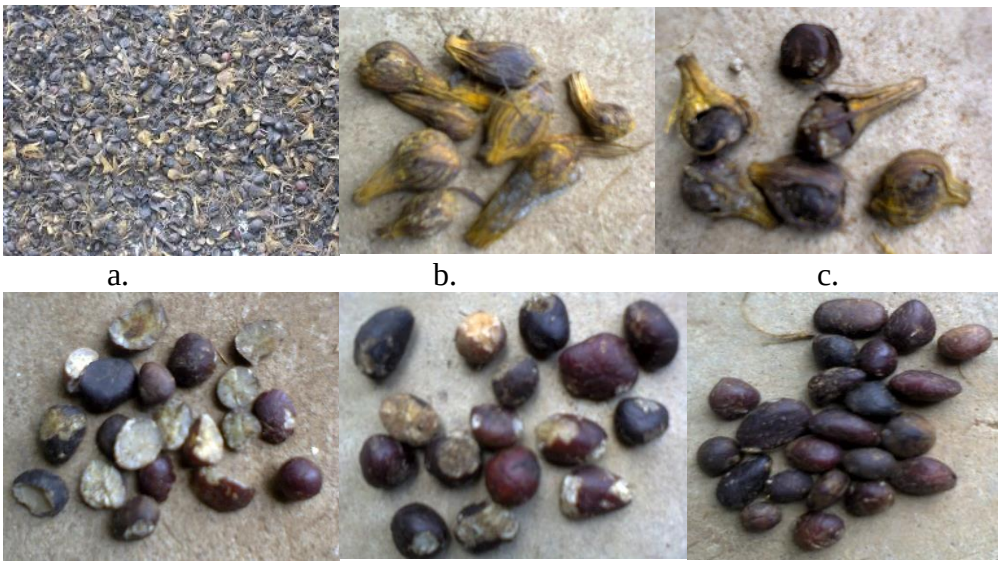
Where W_i = Average initial weight of sample (g)
W_f = Average final weight of sample (g)
MC (wb) = Moisture content (wet basis) of sample (%)
MC (db) = Moisture content (dry basis) of sample (%)

2.3.2 Feed rate: Ndukwu and Asoegwu (2010) evaluated the functional performance of a vertical-shaft centrifugal palm nut cracker and found out that moisture content and feed rate affect the cracking speed. The result showed that for the lowest speed of 1,650 rpm, and the highest feed rate of 880 kg/h the cracking efficiency was not up to 65%. The kernel breakage ratio increased with much increase in feed rate. Taking several factors into considerations, which also includes the cracking time, varieties of palm nut, size of the hoper, moisture content, cracking speed and coefficient of friction during the experiment, five levels of feed rate (360, 400, 450, 514.29, 600kg/h) were also selected for the study.

2.4 Experimental Procedures

One thousand three hundred and fifty (1350) samples of 1000g each of fresh palm nuts were used for the experiment. Out of which, four hundred and fifty (450) samples were Dura variety, four hundred and fifty (450) samples Tenera variety and four hundred and fifty (450) samples were mixed varieties. Based on the experimental design, 150 samples were selected for each experimental run. Three sets of runs were carried out for each variety at the same condition. The samples were cracked at 5 different speeds of 1200rm, 1400rpm, 1600rpm, 1800rpm and 2000rpm using a prime mover with variable speed limits, with 5 levels of feed rate (360, 400, 450,

514.29, 600kg/h). Cracking time was recorded for each sample depending on the speed used. The cracked mixture was collected through the products exit beneath the cracking drum. The uncracked nuts (UN), whole kernels (WK), and broken kernels (BK) were sorted out, manually counted, and weighed (Figure 3). Nine (9) experimental runs of 150 samples each was carried out for this study, 3 replicates for each variety of Dura, Tenera and Mixed varieties. Mean values for each variety was computed and used for statistical analysis.



a. b. c.

d. e. f.

Figure 3: The test-run products

a. Un-separated cracked palm kernel shells and nuts,
b. Samples of un-cracked palm kernels nuts
c. Partially cracked palm kernel nuts
d. Samples of broken kernels
e. Samples of Defect kernel
f. Samples of un-broken kernels

2.5 Determination of throughput capacity and whole kernel recovery

From the experimental data, the performance parameters of the cracking process for palm nut cracking machine such as Throughput capacity and Whole kernel recovery were determined, based on equation 3 and 4 below as recommended by Edet *et al*. (2022), Antia *et al*. (2012), Udo *et al*. (2015) and others.

2.5.1 Determination of throughput capacity (T_P): This is the quantity of the nuts fed into the hopper divided by the time taken for the cracked mixture to completely leave the collecting chute. It is given by:

$$\text{Throughput} = \frac{T_w}{T} \qquad 3$$

Where: T_w = total weight of the palm nuts fed into the hopper (kg)
T = total time taken by the cracked mixture to leave the chute (h)

2.5.2 Determination of whole kernel recovery (WKR)

The performance efficiency (WKR) also known as Whole Kernel recovery is given by:

$$\text{WKR}\ (\%) = \frac{\text{Total weight of un-broken}}{\text{Total weight of expected kernels}}$$

$$\text{WKR}\ (\%) = \frac{W_{UN}}{W_{UB}+W_{BN}+W_{PK}+W_{UC}} \times 100 \qquad 4$$

3.0 RESULT AND DISCUSSION

3.1 Results of moisture content of the three varieties of palm nut

The average moisture contents for dura, tenera and mixed varieties of palm nuts varying with drying time is given in Table 1 below.

Table 1: Average moisture contents for Dura, Tenera and Mixed varieties of palm nuts

Drying Time (Hours)	Average Moisture Content (%)(w.b) Dura Variety	Tenera Variety	Mixed Variety	Average Moisture Content (%)
0	28.0	27.5	27.9	**27.8**
2	20.4	19.5	20.1	**20.0**
4	18.6	17.4	18.2	**18.1**
6	16.7	15.7	16.2	**16.2**
8	14.3	13.7	13.9	**14.0**
10	13.1	11.9	12.3	**12.4**

The average moisture contents for dura, tenera and mixed varieties of the palm nuts at 2 hour intervals is hereby presented in Table 1. The initial weight for each sample was 1000g. After 14 hours of drying, the constant average weight of 723g was obtained.

3.2 Experimental Results of the Cracking Process of Three Varieties of Palm Nut Using Impeller-Type Cracker

The average summary of the experimental results for throughput capacity (T_P) and whole kernel recovery (WKR) under various cracking process conditions of cracking speed, moisture content and feed rate for cracking process of dura, tenera and mixed varieties of palm nut are presented in Tables 2, 3 and 4 respectively.

Table 2: Average experimental result for T_P and WKR under different cracking process conditions of Dura variety of palm nut

Runs Order	Cracking Speed (S_c) (rpm)	Moisture Content (α_{mc}) (%)	Feed Rate (F_r) (kg/h)	Throughput Capacity (T_P) (kg/h)	Whole Kernel Recovery (%)
1	1200	12.4	360	270.27	22.30
2	1400	12.4	360	285.71	24.22
3	1600	12.4	360	322.58	28.64
4	1800	12.4	360	333.33	25.72
5	2000	12.4	360	416.67	20.80
6	1200	14.0	360	205.00	59.52
7	1400	14.0	360	237.37	61.44
8	1600	14.0	360	250.56	65.86
9	1800	14.0	360	273.33	62.94
10	2000	14.0	360	334.07	58.02
11	1200	16.2	360	174.28	62.22
12	1400	16.2	360	198.05	64.14
13	1600	16.2	360	229.32	68.56
14	1800	16.2	360	256.29	65.64
15	2000	16.2	360	300.48	60.72
16	1200	18.1	360	156.63	82.01
17	1400	18.1	360	172.61	85.93
18	1600	18.1	360	211.45	90.35
19	1800	18.1	360	222.58	87.43
20	2000	18.1	360	272.84	82.51
21	1200	20.0	360	148.93	74.47
22	1400	20.0	360	163.53	78.39
23	1600	20.0	360	170.20	82.81
24	1800	20.0	360	193.95	79.89
25	2000	20.0	360	238.29	74.97
26	1200	27.8	360	124.79	69.76
27	1400	27.8	360	142.00	73.68
28	1600	27.8	360	164.72	78.10
29	1800	27.8	360	171.58	75.18
30	2000	27.8	360	196.10	70.26
136	1200	18.1	600	100.69	75.46
137	1400	18.1	600	109.84	79.60
138	1600	18.1	600	130.12	83.92
139	1800	18.1	600	128.15	81.15
140	2000	18.1	600	140.97	75.88
141	1200	20.0	600	99.29	67.92
142	1400	20.0	600	106.92	72.06

143	1600	20.0	600	112.70	76.38
144	1800	20.0	600	119.14	73.61
145	2000	20.0	600	139.00	68.34
146	1200	27.8	600	85.79	63.21
147	1400	27.8	600	96.89	67.35
148	1600	27.8	600	106.96	71.67
149	1800	27.8	600	109.81	68.90
150	2000	27.8	600	117.66	63.63

The machine performance parameters: throughput capacity and whole kernel recovery during the cracking process of dura variety of palm nut at different level combinations of cracking speed, moisture content and feed rate ranged from 85.79 to 416.67kg/h and 14.17 to 90.35% (Table 2), respectively. The maximum throughput capacity (T_P) of 416.67kg/h was obtained at cracking speed, moisture content and feed rate of 2000rpm, 12.4% w.b and 360kg/h respectively. The highest whole kernel recovery of 90.35% was obtained when the dura palm nut was cracked at cracking speed of 1600rpm, moisture content of 18.1% w.b and feed rate of 360kg/h.

Table 3: Average experimental result for T_P and WKR under different cracking process conditions of Tenera variety of palm nut

Runs Order	Cracking Speed (S_c) (rpm)	Moisture Content (α_{mc}) (%)	Feed Rate (F_r) (kg/h)	Throughput Capacity (T_P) (kg/h)	Whole Kernel Recovery (%)
1	1200	12.4	360	312.50	40.41
2	1400	12.4	360	357.14	44.23
3	1600	12.4	360	400.00	48.65
4	1800	12.4	360	454.55	45.73
5	2000	12.4	360	476.19	40.81
6	1200	14.0	360	231.28	53.82
7	1400	14.0	360	265.29	57.64
8	1600	14.0	360	300.67	62.06
9	1800	14.0	360	290.97	59.14
10	2000	14.0	360	360.80	54.22
11	1200	16.2	360	202.65	87.67
12	1400	16.2	360	223.44	89.49
13	1600	16.2	360	256.29	93.91
14	1800	16.2	360	300.48	89.99
15	2000	16.2	360	348.56	85.07
16	1200	18.1	360	169.16	74.44
17	1400	18.1	360	183.87	76.26
18	1600	18.1	360	222.58	80.68
19	1800	18.1	360	248.76	76.76
20	2000	18.1	360	302.07	71.84

21	1200	20.0	360	160.38	92.66
22	1400	20.0	360	166.80	94.48
23	1600	20.0	360	203.41	96.90
24	1800	20.0	360	231.67	92.98
25	2000	20.0	360	260.63	88.06
26	1200	27.8	360	137.27	73.22
27	1400	27.8	360	164.72	75.17
28	1600	27.8	360	171.58	77.59
29	1800	27.8	360	196.10	73.67
30	2000	27.8	360	242.24	69.95
136	1200	18.1	600	109.84	67.89
137	1400	18.1	600	115.86	69.73
138	1600	18.1	600	132.16	74.25
139	1800	18.1	600	138.66	70.48
140	2000	18.1	600	148.39	65.41
141	1200	20.0	600	111.20	86.11
142	1400	20.0	600	109.74	87.95
143	1600	20.0	600	126.36	90.47
144	1800	20.0	600	132.38	86.70
145	2000	20.0	600	148.93	81.63
146	1200	27.8	600	99.23	65.61
147	1400	27.8	600	106.96	68.64
148	1600	27.8	600	109.81	71.03
149	1800	27.8	600	119.36	67.27
150	2000	27.8	600	135.02	63.72

The throughput capacity and whole kernel recovery, broken kernel, cracking efficiency and power requirement during the cracking process of tenera variety of palm nut (Table 3) at various combinations of cracking speed, moisture content and feed rate ranged from 99.23 to 476.19kg/h and 33.86 to 96.90% respectively. The maximum throughput capacity (T_P) of 476.19kg/h was obtained at cracking speed, moisture content and feed rate of 2000rpm, 12.4%w.b and 360kg/h respectively. The highest whole kernel recovery of 96.90% was obtained when the tenera palm nut was cracked at cracking speed of 1600rpm, moisture content of 20.0%w.b and feed rate of 360kg/h.

Table 4: Average experimental result for T_P and WKR under different cracking process conditions of Mixed variety of palm nut

Runs Order	Cracking Speed (S_c) (rpm)	Moisture Content (α_{mc}) (% w.b)	Feed Rate (F_r) (kg/h)	Throughput Capacity (T_P) (kg/h)	Whole Kernel Recovery (%)
1	1200	12.4	360	277.78	58.37
2	1400	12.4	360	294.12	60.19
3	1600	12.4	360	344.83	62.51
4	1800	12.4	360	357.14	58.59
5	2000	12.4	360	384.62	54.67
6	1200	14.0	360	205.00	62.00
7	1400	14.0	360	231.28	63.82
8	1600	14.0	360	257.71	66.14
9	1800	14.0	360	281.88	62.22
10	2000	14.0	360	322.14	58.30
11	1200	16.2	360	185.40	85.20
12	1400	16.2	360	223.44	87.02
13	1600	16.2	360	235.51	89.34
14	1800	16.2	360	290.47	85.42
15	2000	16.2	360	300.48	81.50
16	1200	18.1	360	159.58	92.92
17	1400	18.1	360	176.21	94.74
18	1600	18.1	360	216.87	97.06
19	1800	18.1	360	241.66	93.14
20	2000	18.1	360	256.30	89.22
21	1200	20.0	360	148.93	80.94
22	1400	20.0	360	166.80	82.76
23	1600	20.0	360	185.33	85.08
24	1800	20.0	360	203.41	81.16
25	2000	20.0	360	245.29	77.24
26	1200	27.8	360	128.69	61.48
27	1400	27.8	360	147.07	63.40
28	1600	27.8	360	164.72	65.60
29	1800	27.8	360	183.02	61.88
30	2000	27.8	360	211.18	57.96
121	1200	12.4	600	161.29	52.72
122	1400	12.4	600	185.19	53.66
123	1600	12.4	600	200.00	56.08
124	1800	12.4	600	208.33	52.31
125	2000	12.4	600	222.22	48.04
126	1200	14.0	600	127.04	56.35
127	1400	14.0	600	134.63	57.29

128	1600	14.0	600	155.52	59.71
129	1800	14.0	600	170.19	55.94
130	2000	14.0	600	173.46	51.67
131	1200	16.2	600	114.66	79.55
132	1400	16.2	600	130.06	80.49
133	1600	16.2	600	138.32	82.91
134	1800	16.2	600	155.61	79.14
135	2000	16.2	600	152.88	74.87
136	1200	18.1	600	105.73	87.27
137	1400	18.1	600	111.29	88.21
138	1600	18.1	600	130.12	90.63
139	1800	18.1	600	136.42	86.86
140	2000	18.1	600	136.42	82.59
141	1200	20.0	600	105.57	75.41
142	1400	20.0	600	108.31	76.23
143	1600	20.0	600	117.46	78.65
144	1800	20.0	600	122.65	74.88
145	2000	20.0	600	141.36	70.61
146	1200	27.8	600	89.52	55.85
147	1400	27.8	600	99.23	56.87
148	1600	27.8	600	108.37	59.17
149	1800	27.8	600	114.39	55.50
150	2000	27.8	600	122.93	51.32

The results obtained for the machine performance based on throughput capacity and whole kernel recovery (Table 4) during the cracking of mixed variety of palm nut at different level combinations of the cracking speed, moisture content and feed rate ranged from 89.52 to 384.62kg/h and 48.04 to 97.06% respectively. The maximum throughput capacity (T_P) of 384.62kg/h was obtained at cracking speed, moisture content and feed rate of 2000rpm, 12.4%w.b and 360kg/h respectively. The highest whole kernel recovery of 97.06% was obtained when the mixed variety of palm nut was cracked at cracking speed of 1600rpm, moisture content of 18.1% w.b and feed rate of 360kg/h.

4.0 COMPARISON IN THROUGHPUT CAPACITY AND WHOLE KERNEL RECOVERY FOR CRACKING OPERATION OF DURA, TENERA AND MIXED VARIETIES OF PALM NUT

Figures 4 and 5 show experimental data for throughput capacity (T_P) and whole kernel recovery (WKR) during cracking of dura, tenera and mixed varieties of palm nuts in an impeller-type palm nut cracker. For all the crop condition and machine parameters used, most significant changes occur at the higher levels of the independent variables during the cracking process. Values of throughput capacity (Figure 4) and whole kernel recovery (Figure 5) vary during the cracking process depending on cracking speed of the machine, moisture level of the nut, feed rate during cracking as well as the nut variety.

4.1 Comparison of Throughput Capacity for Dura, Tenera and Mixed Varieties of Palm Nut

The variation of throughput capacity (T_P) for cracking speed of the machine, nut moisture content and feed rate during the cracking of dura, tenera and mixed varieties of palm nut is shown in Figure 4. It is observed that a significant variation occurred between throughput capacity using tenera variety of palm nut at different levels of the cracking process conditions having higher machine throughput capacity as compared to throughput capacity using dura and mixed varieties of palm nut. The results also show that throughput capacity obtained for dura, tenera and mixed varieties ranged between 85.79 to 416.67kg/h, 99.23 to 476.19kg/h and 89.52 to 384.62kg/h, respectively with the tenera variety having the highest ranged of the machine throughput capacity. The higher values of throughput capacity using the tenera variety as compared to dura and mixed could be due to the fact that, varieties have different properties and characteristics which meets the cracking process conditions, the cracking process is enhanced for evenly distribution of the variation in the combination of levels of the crop and machine condition irrespective of the variety.

The result of the pairwise comparisons for the throughput capacity in the three varieties of palm nut is presented in Table V2 of Appendix V. From the comparison test analysis, it is revealed that there is statistically significant difference at 0.05 level of significance with *p*-values of 0.002.

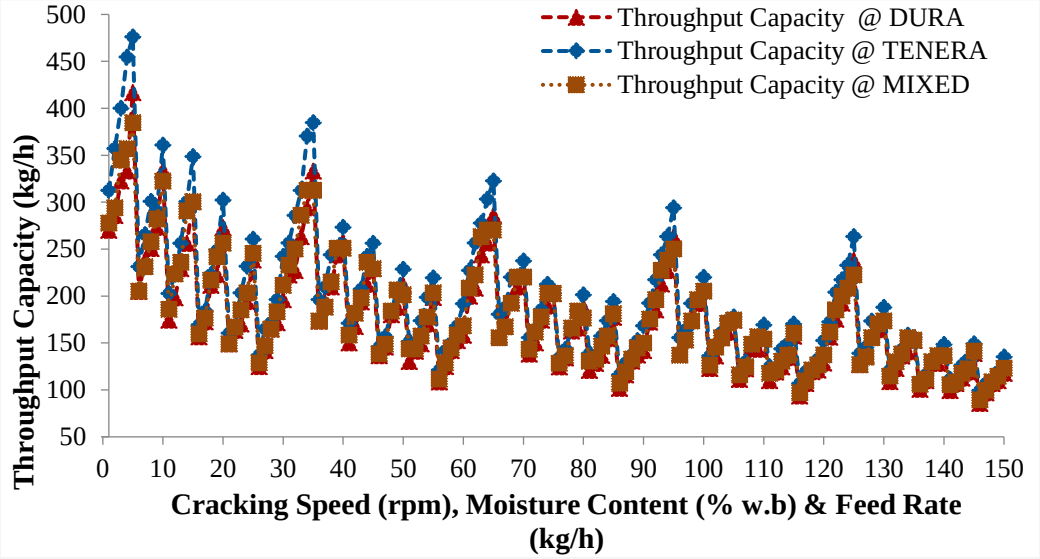


Figure 4: Comparative evaluation of throughput capacity for Dura, Tenera and Mixed varieties of palm nut during cracking in impeller-type cracker

4.2 Comparison of Whole Kernel Recovery for Dura, Tenera and Mixed Varieties of Palm Nut

The variation of whole kernel recovery (WKR) for cracking speed of the machine, nut moisture content and feed rate during the cracking of dura, tenera and mixed varieties of palm nut is shown in Figure 5. It is observed that a significant variation occurred between whole kernel recovery using mixed variety of palm nut at different levels of the cracking process conditions having higher percentage whole kernel recovery as compared to percentage whole kernel recovery

using dura and tenera varieties of palm nut. The results also show that whole kernel recovery obtained for dura, tenera and mixed varieties ranged between 14.17 to 90.35%, 33.86 to 96.90 % and 48.04 to 97.06 %, respectively with the mixed variety having the highest ranged of percentage whole kernel recovery. The higher values of whole kernel recovery using the mixed variety as compared to dura and tenera could be due to the fact that the varieties have different properties and characteristics which meets the cracking process conditions, the cracking process is enhanced for evenly distribution of the variation in the combination of levels of the crop and machine condition irrespective of the variety.

The result of the pairwise comparisons for the percentage whole kernel recovery in the three varieties of palm nut is presented in Table V3 of Appendix V. From the comparison test analysis, it is revealed that there is statistically significant difference at 0.05 level of significance with p-values of 0.002

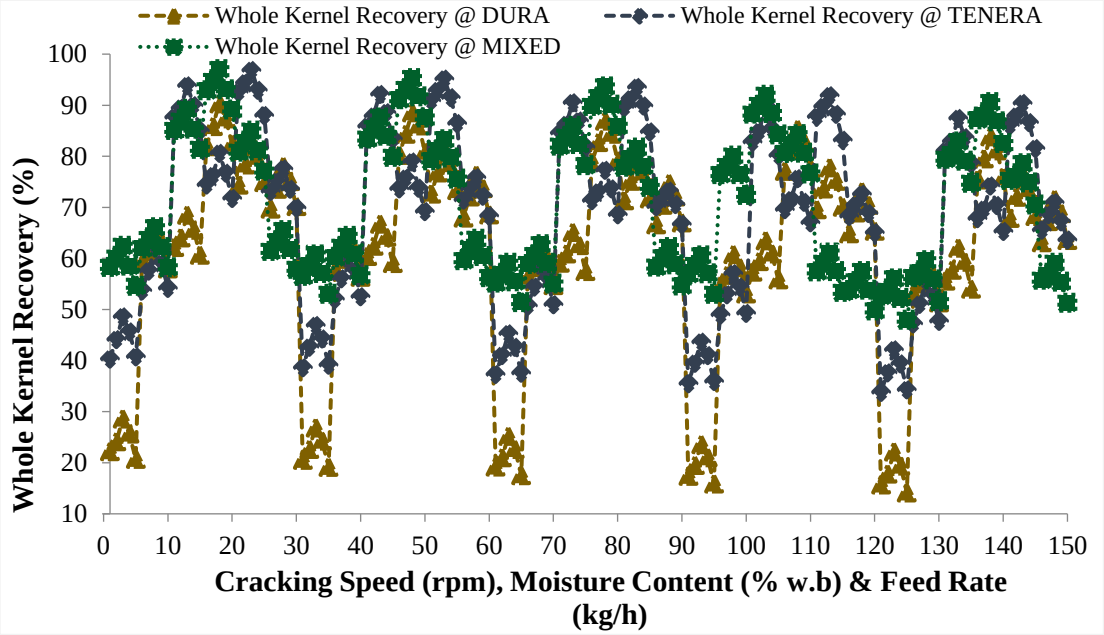


Figure 5: Comparative evaluation of whole kernel recovery for Dura, Tenera and Mixed varieties of palm nut during cracking in impeller type cracker

4.3 Effects of Cracking Speed, Moisture Content and Feed Rate on Throughput Capacity and Whole Kernel Recovery

For effects of cracking speed, moisture content and feed rate on performance parameters, increase in the cracking speeds, increased the throughput capacity of the palm nut cracker, increase in the moisture content and feed rate of the nut results in decrease in the throughput capacity. For whole kernel recovery of nut cracker, increase in the cracking speed from 1200 – 2000rpm, increased the percentage whole kernel recovery of the palm nut up to the cracking speed of 1600rpm, and then declined with further increase in the cracking speed. Increase in the moisture content of the nut from 12.4 – 27.8 % w.b, resulted in increase in percentage whole kernel recovery from the palm nut up to moisture content of 18.1 % w.b, then decreases with further increase in the moisture content and increase in feed rate of the product from 360 – 600 kg/h results in decrease

in the percentage whole kernel recovery; This trend is also seen across all the levels of moisture content, cracking speed and feed rate for the three varieties of dura, tenera and mixed.

4.4 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) for the effects of cracking speed, moisture content and feed rate on throughput capacity and whole kernel recovery of the dura, tenera and mixed varieties of palm nut as presented in Table 5 - Table 10 revealed that the effects of cracking speed, moisture content and feed rate with *p*-values of 0.0001, 0.0001 and 0.0001 respectively are statistically significant at 0.05 level of significance.

Table 5: ANOVA for throughput capacity using dura variety at 5% significance level

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Cracking Speed (rpm)	4	95002	95002	23750.6	104.11	0.0001
Moisture Content (% w.b)	5	229908	229908	45981.6	201.56	0.0001
Feed Rate (kg/h)	4	150487	150487	37621.8	164.92	0.0001
Error	136	31025	31025	228.1		
Total	149	506423				

Table 6: ANOVA for throughput capacity using tenera variety at 5% significance level

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Cracking Speed (rpm)	4	113081	113081	28270.2	69.01	0.0001
Moisture Content (% w.b)	5	355078	355078	71015.7	173.35	0.0001
Feed Rate (kg/h)	4	232862	232862	58215.5	142.11	0.0001
Error	136	55713	55713	409.7		
Total	149	756734				

Table 7: ANOVA for throughput capacity using mixed variety at 5% significance level

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Cracking Speed (rpm)	4	83883	83883	20970.9	101.88	0.0001
Moisture Content (% w.b)	5	229666	229666	45933.2	223.15	0.0001
Feed Rate (kg/h)	4	163725	163725	40931.2	198.85	0.0001
Error	136	27994	27994	205.8		
Total	149	505268				

Table 8: ANOVA for whole kernel recovery using dura variety at 5% significance level

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Cracking Speed (rpm)	4	1264.2	1264.2	316.0	1729.20	0.0001
Moisture Content (% w.b)	5	58331.9	58331.9	11666.4	63830.43	0.0001
Feed Rate (kg/h)	4	775.7	775.7	193.9	1060.99	0.0001
Error	136	24.9	24.9	0.2		
Total	149	60396.6				

Table 9: ANOVA for whole kernel recovery using tenera variety at 5% significance level

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Cracking Speed (rpm)	4	1166.7	1166.7	291.69	390.26	0.0001
Moisture Content (% w.b)	5	43953.7	43953.7	8790.74	11761.43	0.0001
Feed Rate (kg/h)	4	782.1	782.1	195.53	261.60	0.0001
Error	136	101.6	101.6	0.75		
Total	149	46004.2				

Table 10: ANOVA for whole kernel recovery using mixed variety at 5% significance level

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Cracking Speed (rpm)	4	970.2	970.2	242.56	9.59	0.0001
Moisture Content (% w.b)	5	23396.4	23396.4	4679.28	185.09	0.0001
Feed Rate (kg/h)	4	743.2	743.2	185.80	7.35	0.0001
Error	136	3438.3	3438.3	25.28		
Total	149	28548.1				

5.0 CONCLUSION

For comparative analysis, the results shows that throughput capacity (Figure 4) obtained for dura, tenera and mixed varieties ranged between 85.79 to 416.67kg/h, 99.23 to 476.19kg/h and 89.52 to 384.62kg/h, respectively with the tenera variety having the significant variation (highest ranged) of the machine throughput capacity; whole kernel recovery (Figure 5) obtained for dura, tenera and mixed varieties ranged between 14.17 to 90.35%, 33.86 to 96.90% and 48.04 to 97.06%, respectively with the mixed variety having the significant variation (highest ranged) of percentage whole kernel recovery. From the comparison test analysis, it is revealed that there is statistically significant difference at 0.05 level of significance.

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