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Determination of the Energy for Breaking Palm Kernel Nuts by Single Impact

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Abstract
This research focuses on determining the energy required to break palm kernel nuts through a single impact. Palm kernel is a valuable byproduct of palm oil, with the nut's oil used in food and other products. The study aims to measure the work done and impact energy required to crack the kernel, considering force, time, and the kinetic phenomena involved. A specially designed machine was used to crack dried and moisture content palm kernel nuts, categorized by their diameter. The nuts were tested under two conditions: with and without moisture content (10%). The following visual criteria were used to evaluate the degree of cracking: shattered, entirely cracked, completely cracked with little damage, shattered without nut separation, difficult to crack, completely cracked. The nuts were cracked using the specially constructed apparatus. Data was collected on a number of variables, such as time, displacement height, kernel size, and shell thickness. The study measured force, work done, and impact energy under both moisture and moisture-free conditions. The integral form of the work or impact load is considered in the design of cracking machines. Results showed that the energy required to crack the kernel was lower in the moisture content condition compared to the moisture-free condition. The efficiency of cracking was also higher when there was no moisture in the kernels. During the experimentation certain kernels refused to crack until a certain height is reached resulting in the variations in height. The average value for force, work done and impact energy for breaking a palm kernel shell were calculated for moisture content and moisture free conditions employing those factors identified significant in the ANOVA tables and according to the models developed out of the actual factors coding in the analysis become: 3.16 Newton and 0.744Newton; 0.079Joule and 0.14Joule; and 0.02 Newton second and 0.03 Newton second respectively. The research suggests that using a double-impact approach may be more effective than the single-impact method. It also recommends further testing with more samples to assess the precision and resilience of the testing equipment.

Keywords: Determination, Energy, Cracking, Kernel Shell and Single Impact

1. Introduction

Palm kernel (*Elaeis guineensis* Jacq.) is the non-edible seed of the oil palm fruit. It is mainly generated as one of the by-products of oil palm fruit. According to Food and Agricultural bulletin, oil palm (Elaeis guineensis) originated from the tropical rain forest region of Africa. But due to its economic important as the world highest yielding source of edible and technical oils, it is now grown as a plantation crop in most countries with high rainfall in tropical climates within 23º N to 23º S of the equator and longitude 17º W to 102º E, (Food and Agricultural Organization 2012). Palm kernel is of great importance to the human race and highly sought for, because it contains oil which could be consumed directly or used as raw materials for other products. The palm kernel cake also serves as chief raw material for livestock's feed production. Cracking is an integral part of palm kernel processing which is influenced by some factors. The parametric factors that affect cracking and separation of kernel shell though hard but brittle from the kernel include: size, mass, shell thickness, work of impact.

Traditional techniques of breaking palm kernel nuts in rural areas where it is produced involved a lot of drudgery and hazard. To a large extent this has hindered the production of palm kernel nuts in large quantities to satisfy the yearnings of agro-allied processing and manufacturing industries. Through research, machines have to be developed to increase the efficiency of production but at the expense of mechanical energy. Palm kernels come in different diameters and strength and require certain amount of force or energy to be cracked. When this force is low, most of the palm kernels will not be cracked and when it is high some of the palm kernels will be crushed along with shells and become useless. Therefore, there is need to understand the required amount of energy for breaking the palm kernels of different diameters with little or no loss of kernel nuts. In addition, in mass production of breaking of kernel shells through machine designed process, certain amount of energy will be needed for a certain volume flow rate, which is the integral multiple of the threshold values determined from the average experimental values. This helps in the determination of cracker designed machine capacities. To achieve the success of this work, the following techniques are to be employed, which are: design and evaluate the performance of the designed machine (rig) for breaking palm kernel shell; analytically quantify the parameters of the designed system for determination of energy for breaking palm kernel shell; simulation of the system's operations and validation of the experimental results using the Taguchi orthogonal array; finally, the determination of the value of force/energy for breaking palm kernel shells and models development for the system behavior.

Palm kernel nuts are an important crop in mainly tropical countries of the globe, providing a valuable source of oil and other products. However, the processing of palm kernel nuts requires the breaking of the hard shell to extract the kernel, which can be energy-intensive and costly. Currently, there is limited information on the energy required for breaking palm kernel nuts by single impact, and the effects of nut size, shape and moisture content on the energy required are not well understood. Therefore, there is the need to investigate the energy required for breaking palm kernel nuts by single impact and to examine the effects of nut size, shape, and moisture content on the energy required, in order to provide valuable insights into the optimization of kernel nut processing. The aim of this work is to determine the energy for breaking palm kernel nuts by single impact.

This research is restricted to previously completed or the energy requirement in breaking a palm kernel to the release of the nut, which is made to be done through the single impact method of kinetic action of the linear hammer on the kernel being placed on anvil-like plat form. The sample seeds were measured in different forms and were used to determine the factors significance for analysis. The study uses the design of experiment, factorial analysis, kinetic evaluations of the force, work done and impact energy. It involves the compilations of the researched results and other information and documentation. In the individual kernels breaking load, the values determined by the formula function matched the kernels flow rate of the hopper commonly used in machine design.

2.0 Materials and methods

The materials used included an H-beam, thick plate, weight block, nylon rope, 100 pieces of palm kernel, and pen and paper. The equipment comprised a mechanical rig, gauge, masking tape, steel meter rule, and ten containers. The tools involved were a digital weighing scale, digital Vernier caliper, oven, thermometer, and stopwatch. The methodology included five-gauge ranges to select sizes of kernels, development of rig to validate it, measurement of the group sizes of kernels with the rig, parametric measurements of the systems—kernel and rig—engineering evaluations of the kinetic loads, and factorial analysis of the determined data using Design Expert software.

2.1. Kinetics Relations in Energy Development of the Mechanical Rig.

Kinetics is characterized as the cause feature of motion. The why of motion is completely circumscribed by the Newton's second law and paraphrased as:

An unbalance mechanical action of any kind applied to a mass will result in a change in the momentum of that mass; and the rate at which this momentum changes with time is exactly equal to the magnitude of this applied mechanical action, and is in precisely the same direction as that applied action.

This statement, representing Newton's second law is the sole fundamental principle of Kinetics i.e. if the mechanical action is a net force, $\vec{F}$, Newton's second law may be written mathematically as

$$\vec{F} = \sum_{e=1}^{n} \vec{F}_e = \frac{d}{dt}(m\vec{v})$$

or

$$\vec{F} = \frac{d\vec{p}}{dt} = \dot{\vec{P}} \qquad (1)$$

Where $\vec{P} = m\vec{v}$, the angular momentum. Differentiating equation 1

$$\vec{F} = \frac{dm}{dt}\vec{v} + m\frac{d\vec{v}}{dt} = \dot{m}\vec{v} + m\dot{\vec{v}} \tag{1a}$$

Noting for an invariant mass that $\dot{m}$ = 0, and that $\dot{\vec{v}} = \vec{a}$

To this, write in the simpler term as

$$\vec{F} = m\vec{a} \tag{1b}$$

2.2. Work – Energy Equation

A scalar product of each member of equation (1) with an infinitesimal displacement d$\vec{r}$ is formed, simplified by using the velocity definition, and then the expression is integrated using the initial condition $\vec{v} = \vec{v_0}$ when $\vec{H} = \vec{H_0}$

$$\vec{F} \cdot d\vec{H} = \frac{d(mv)}{dt} \cdot d\vec{H}$$

$$= m\frac{d\vec{v}}{dt} \cdot d\vec{H}$$

$$\vec{F} \cdot d\vec{H} = m\,(d\vec{v}.\vec{v})$$

Thus, $\int \vec{F} \cdot d\vec{H} = m \int d\vec{v}.\vec{v}$

Where $m \int d\vec{v}.\vec{v} = m \int v_x\, i + v_y\, \mathbf{j} + v_z\, \mathbf{k}) \cdot (\mathbf{d}\, v_x\, I + d\, v_y\, j + d\, v_z\, k)$

$$= m\int v_x\, d\,v_x + m \int v_y\, dv_y + \int v_z\, dv_z$$

$$= \frac{1}{2} m\,(v_x^2 + v_y^2 + v_z^2 + C$$

Therefore,

$$\vec{F} \cdot d\vec{H} = \frac{1}{2}(m v^2 - m v_0^2) = T - T_0 \tag{2}$$

The quantity T = $\frac{1}{2}$ mv^2 represents the linear kinetic energy of the mass and

$\vec{F} \cdot d\vec{H}$ represents the work required to change that kinetic energy.

This work- energy integral form states that the total linear work done by the force action $\vec{F}$ *on the body mass is precisely the equivalent of the corresponding change in its linear kinetic energy.*

2.3. Conservation of Energy

The law of conservation of energy states that, Energy can neither be created nor destroyed, but can only be changed from one form to another (Fanger, 2005).

Knowing that any conservative force has an associated potential energy function given by

$$\vec{F_c} = -\vec{\nabla} V \qquad (3)$$

By the gradient of the body's potential energy, and that the work done by such a conservative force is always just equal to the decrease in the associated potential energy, this is linked to the relation with the second integral form of Newton's law of kinetics.

These respective relations are:

$$W_c = \int \vec{F} \, . \, d\overrightarrow{H} = V_1 - V_2$$

$$W = \int \vec{F} \, . \, d\overrightarrow{H} = T_2 - T_1 \qquad (3a)$$

Equating the change in the Kinetic energy to the change conservative work expressions to yield

$$W = W_c$$

$$T_2 - T_1 = V_1 - V_2$$

$$\text{i. e.} \quad T_1 + V_1 = T_2 + V_2 \qquad (3b)$$

This invariance is universally known as the law of conservation of mechanical energy. It states that,

'the sum of kinetic and potential energies is an invariant for conservative (non dissipative) systems'.

2.4 Determination of Velocity for Breaking Palm Kernel Nuts on Linear Impact Force

A mechanical rig apparatus was set up where individual kernel was placed on a hand steel plate holder. The kernel was gently loaded with weights. It was observed that over 200 N was not able to crack the nut. A different method was then adopted, basing it on the conservation of energy theory which states that energy is neither created nor destroyed but can be transformed from one form to another in this method, a small predetermined height was placed between the kernel and the weight. It was observed that as little as 10N was able to crack the kernel shell satisfactorily. Different weights were tried, but by the time the weights reached 20N they started smashing up the kernels which was unacceptable. The experiment employed analysis of potential and kinetic force models. The potential energy model postulates that the kernel absorbs the potential energy of a falling hammer or weight (M) due to the height (Y- y) through which it falls, making the nuts kinetic energy to be equal to the potential energy of the falling weight. While the centrifugal energy model postulates that, it is the force with which the kernel is thrown that will aid its cracking and also the distance between the throw force and cracking plate (R – P).

Figure 1: Moisture free content condition and moisture content condition of palm kernel nuts

Figure 2: Field Assessment of Single Breaking Impact Machine (Measuring Rig)

Vertical Breaking Impact Machine

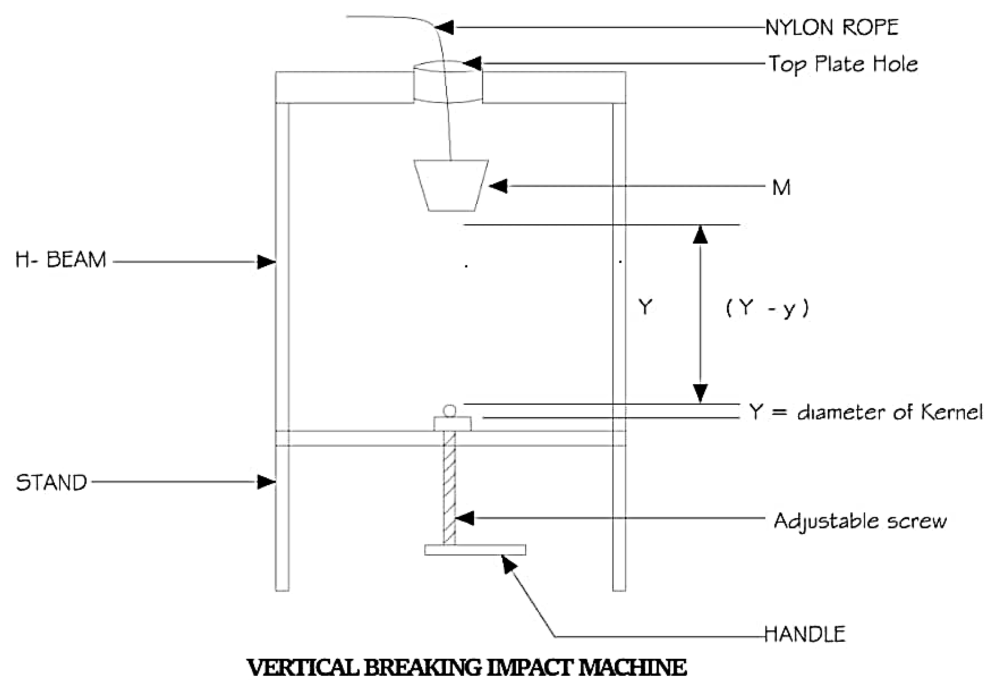

Figure 3: Determination of force to break kernel shell

The above diagram is the structure of the conceptual design of a vertical breaking by impact machine of palm kernel shells breaking energy determination. The machine has the following system components: top plate with a central hole through which the hammer is lifted up and falls down on velocity V, Nylon rope tied to the hammer, lower plate with a central hole through which height is adjusted with the help of the adjustable screw and handle. The H-Beams formed the height of the machine with the base attachments for balancing and rigidity. The region Y – y shows the effective height of velocity of impact while y is the diameter of the kernel to break. The center hole at the top is further connected with a pipe bent at angle 120 degrees as to prevent the sharp edge friction during the breaking hammer falling.

3.0 Result and Discussion

3.1Analysis of the Experimental Data

The practical implication is in the use for numerical analysis of work done or the impact loads determination. Impact load varies with kernel sizes relative to the impact surface or wall. Small size kernel requires closer impact wall relative to hopper chute and vise versa. Experimental data were analyzed in the content of the engineering evaluations of the kinetic parameters of the kernel shell and single impact designed rig parameters.

Table 1: Engineering Evaluations of Kinetic Parameters under Moisture Condition.

S/N	y(m)	M_k(kg)	M_t(Kg)	ST(m)	Y(m)	T(sec)	Force (N)	Work (J)	Impact (Ns)
1.	0.0200	0.005	4.00	0.0020	0.178	25	39.20	6.12	980
2.	0.0176	0.002	4.00	0.0018	0.178	25	39.20	6.27	980
3.	0.0149	0.001	4.00	0.0012	0.178	25	39.20	6.39	980
4.	0.0145	0.001	4.00	0.0015	0.178	25	39.20	6.43	980
5.	0.0128	0.001	4.00	0.0018	0.178	25	39.20	6.47	980

* **Measured values of the group 1 kernel size.**

Table 2: Engineering Evaluations of Kinetic Parameters under Moisture Free Condition

S/N	y(m)	M_k(kg)	M_t(Kg)	ST(m)	Y(m)	T(sec)	Force (N)	Work (J)	Impact (Ns)
1.	0.0240	0.006	4.00	0.0025	0.255	35	39.20	9,06	1372
2.	0.0230	0.006	4.00	0.0030	0.255	35	39.20	9.09	1372
3.	0.0229	0.006	4.00	0.0022	0.255	35	39.20	9.09	1372
4.	0.0227	0.005	4.00	0.0028	0.305	35	39.20	9.09	1372
5.	0.0222	0.005	4.00	0.0022	0.255	35	39.20	9.13	1372

* **Measured values of the group 2 kernel size.**

Table 3: Experimental Measurements and Evaluations for Moist Kernels

S/N	M_k(kg)	Y(m)	y(m)	Y-y(m)	T(sec)	Velocity	Broken	Unbroken	Energy(J)
1.	0.007	0.255	0.0292	0.2258	35	0.0065	Yes	No	$8x10^{-5}$
2.	0.007	0.305	0.0273	0.2777	36	0.0077	Yes (0.305	No (0.255)	$1x10^{-4}$
3.	0.006	0.255	0.0248	0.2302	35	0.0066	Yes	No	$8x10^{-5}$
4.	0.006	0.255	0.0245	0.2305	35	0.0066	Yes	No	$8x10^{-5}$
5.	0.006	0.255	0.0242	0.2308	35	0.0066	Yes	No	$8x10^{-5}$

3.2 Data Analysis of Breaking Force, Work Done, and Impact Energy for Palm Kernel Under Moisture Condition.

From design of experiments for the analysis of the experimental data in table of engineering evaluations of kinetic parameters under moisture condition, the following results were obtained in the responses ($R_{1,}$ R_2, R_3): force, work done and impact energy respectively as shown in the design of Experimental data results under moisture content and moisture free conditions. These were used to determine various statistical results. The models are shown as 1, 2, 3 and 4, 5, 6 respectively of the moisture conditions as shown in equation numbers.

Table 4: ANOVA Force Analysis for the Selected Factors Models

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	6.51E-12	5	1.30E-12	14.96	< 0.0001	significant
A-Kd	8.08E-28	1	8.08E-28	9.29E-15	1	
B-Mk	2.12E-12	1	2.12E-12	24.33	< 0.0001	
C-St	0	1	0	0	1	
D-Hf	1.01E-12	1	1.01E-12	11.64	0.0021	
E-Tsec	3.38E-12	1	3.38E-12	38.84	< 0.0001	
Residual	2.26E-12	26	8.70E-14			
Cor Total	8.77E-12	31				

Final Equation In Term of Actual Coded Factors

Force = 1.50E-06 + 1.75E-20 Kd + 0.000171 Mk + 7.74E-20 St + 2.99E-06 Hf - 6.50E-06 (4)

Table 5: ANOVA for Selected Factorial Model

Response: Work 3

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4.22E-12	11	3.84E-13	21.68	< 0.0001	significant
A-Kd	0	1	0	0	1	
B-Mk	1.10E-12	1	1.10E-12	62.01	< 0.0001	
C-St	8.08E-28	1	8.08E-28	4.56E-14	1	
D-Hf	1.23E-13	1	1.23E-13	6.97	0.0157	
E-Tsec	1.34E-12	1	1.34E-12	75.78	< 0.0001	
BC	8.08E-28	1	8.08E-28	4.56E-14	1	
BD	4.19E-13	1	4.19E-13	23.68	< 0.0001	
BE	9.90E-13	1	9.90E-13	55.96	< 0.0001	
CD	0	1	0	0	1	
DE	2.49E-13	1	2.49E-13	14.09	0.0013	
BCD	0	1	0	0	1	
Residual	3.54E-13	20	1.77E-14			
Cor Total	4.58E-12	31				

Final Equation In Terms of Actual Factors

Work = -3.97E-07 + 7.59 E-21 Kd + 0.001061 Mk - 9.13 E-21 St - 5.46 E-06 Hf - 1.30 E-08 Tsec. + 6.74 E-17 Mk*St - 0.00128 Mk*Hf - 2.3 E-05 Mk*Tsec + 9.67 E-19 St*Hf + 2.97 E-07 Hf*Tsec (5)

Table 6: ANOVA for Selected Factorial Model
Response 3:

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	2.80E-09	5	5.61E-10	5.53	0.0013	significant
A-Kd	4.14E-25	1	4.14E-25	4.08E-15	1	
B-Mk	3.16E-10	1	3.16E-10	3.12	0.0892	
C-St	0	1	0	0	1	
D-Hf	9.05E-10	1	9.05E-10	8.94	0.006	
E-Tsec	1.58E-09	1	1.58E-09	15.62	0.0005	
Residual	2.63E-09	26	1.01E-10			
Cor Total	5.44E-09	31				

Final Equation In Terms of Actual Factors
Impact Force = 0.000049 + 3.07E-19 Kd - 0.00209 Mk + 1.61 E-18 St + 0.000049 Hf - 1.41E-06 Tsec (6)

Final Equation in Terms of Actual Factors
Force = 6.18E-07 - 2.09E-22Kd + 2.05 E-04 Mk - 4.87E-20 St + 4.14E-06Hf - 4.58 E-08 Tsec (7)

Final Equation in Terms of Actual Factors
Work done = - 4.86 E-07 + 8.82 E-23Kd + 4.70E-05Mk -7.30 E-21 St + 2.80E-06Hf + 1.59E-08 T sec + 4.09 E-04 Mk*Hf - 2.56 E-06 Mk*Tsec - 9.18E-08 Hf*Tsec (8)

Final Equation in Terms of Actual Factors
Impact Force = 4.9 E-05 + 3.07 E-19 Kd - 2.09E-03Mk + 1.61E-18 St + 8.9 E-05 Hf - 1.41 E-06 T sec (9)

Force Analysis Under Moisture Content Free Condition

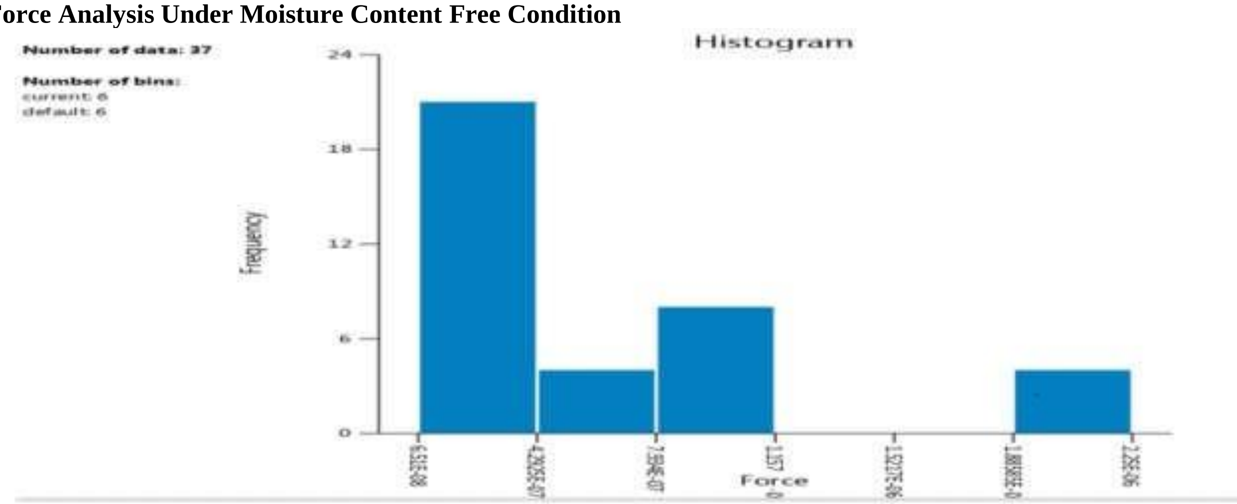

Figure 4: Graph of Histogram of Force Data

In the event of finding solutions to the problem of determining the energy required to break an average palm kernel, after some parameters of importance were measured using the fabricated rig and other measuring instruments as seen in section 4. The data collected were put in orthogonal arrays amenable for computer analyses in the categories of moisture content and moisture free conditions. Design expert software was used to formulate the factors missing for the analytical calculations. Different tables were developed by computer through the use of the design expert software as the tables of kinetic experimental values and analytical values. Factorial analysis of the factors to discover the effects of the independent variables (size, mass, shell thickness, displacement height and time) to the dependent variables (force, work done and impact energy) were carried out. Six models were developed in the actual factors and six for coded factors model in terms of the three dependent variables. ANOVA was used to determine the significance of the models and the independent variable factors and other parameters of importance in the analyses as could be shown tables above. Evaluation of the dependent variables through substitutions of the relevant factors resulting to the force, work done and / or impact energy of breaking palm kernel or certain quantity of kernels.

In this section different tables and figures will be discussed to show their relevance to the expected results, having had the problems investigating for as the effects of these independent factors (size, mass, thickness, height of fall and time) have on the dependent variables of (force, work-done and Impact energy). In the tables generated in the course of analysis as depicted as followed showed the effects of independent factors on the force, work done and impact energy under moisture content condition of palm kernels, where the percentage contribution of each independent factors on force as: B-Mk = 24.13, D -Hf = 11.55, E- Tsec = 38.53, BD =0.43, BE = 12.08, DE = 8.90, and BDE = 4.39; on Work done: B-Mk = 24.00, D -Hf = 2.7, E- Tsec = 29.32, BD =9.16, BE = 21.65, DE = 5.45, and BDE = 7.74; and on Impact energy : B-Mk = 5.81, D -Hf = 11.65, E- Tsec = 29.10, BD = 18.52, BE = 2.`17, DE = 8.30, and BDE = 27.45.

From the ANOVA in tables it was shown in general that both the Model, and B-Mk, D-Hf, and E-T sec among the actual factors are significant, hence, these factors can correctly predict models as depicted by the equations 4, 5, 6, 7, 8, & 9. From the tables of fit statistics in appendices, it was observed that the predicted R^2 is in agreement with the adjusted R^2 since the difference between them is less than 0.2. The adequate precision measures the signal to noise ratio and a ratio greater than 4 is desirable. Their ratios of 11.90, 14.55, 7.11, 16.34, 13.56 and 40.32 respectively indicated adequate signal. This model can be used to navigate the design space. Also, their respective R^2 indication of 74, 92, 52, 84, 56, and 52 is able to predict the dependent variables in the studies. The model F-values of 14.96, 21.68, 5.53, 30.47, 6.62, and 5.53 respectively are significant implying that the coefficients in the models did not occur by chance. It is worthy to note that in general the effect of size and shell thickness are not significant in the analysis. From the results, the effect of diameter (mm) of palm kernel, D_k and shell thickness on the force for breaking of palm kernels are generally insignificant and so are disregarded in the model expression.

The effect of mass of kernel M_k of palm kernel, on the force for breaking of palm kernels is generally significant and is regarded in the model expression. It is also observed that from the table height and force affect the magnitude of the breaking energy of palm kernels. The effect of moisture content on the energy for breaking palm kernel is empirically given as

$$WD_{mcf} = 0.577\ WD_{mcc}$$

Where, WD_{mcf} is the work done under moisture free and WD_{mcc} is the work done in moisture content condition.

Moisture content decreases the energy requirement of palm kernel breaking as shown in equation above. Variable shell thickness, kernel mass and measurement accuracies are its limitations. Effect of shell thickness on broken efficiency of palm kernel is seen to be the thicker the shell wall thicknesses the lower the breaking efficiency i.e. breaking efficiency is inversely proportional to shell thickness. The average value of the magnitude of force for breaking a palm kernel shell varies due to mass, height and time rate of fall was calculated for moisture content and moisture free conditions employing those factors identified significant in the ANOVA tables 5 and (absent) according to equations 4 and 7 of the actual factors coding in the analysis to be 3.16 Newton and 0.744 Newtons respectively. It was observed that the force required for breaking palm kernel shell under moisture content condition is greater than that of moisture free condition. It was also observed that the efficiency of breaking is high in the moisture free condition than that of moisture content condition

The average value for work done or energy for breaking a palm kernel shell was calculated for moisture content and moisture free conditions employing those factors identified significant in the ANOVA tables 6 and (absent) according to equations 5 and 8 of the actual factors coding in the analysis to be 0.08 Joules and 0.14 Joules respectively. It was observed that the energy required for breaking palm kernel shell under moisture content condition is lower than that of moisture free condition. It was also observed that the efficiency of breaking is high in the moisture free condition than that of moisture content condition. The average value for impact energy for breaking a palm kernel shell was calculated for moisture content and moisture free conditions employing those factors identified significant in the ANOVA tables 6 and (absent) according to equations 6 and 9 of the actual factors coding in the analysis to be 0.02 Newton second and 0.03 Newton second respectively. It was observed that the impact force required for breaking palm kernel shell under moisture content condition is lower than that of moisture free condition. It was also observed that the efficiency of breaking is high in the moisture free condition than that of moisture content condition. The numerical values of all these kinetic system elements: force, work done and impact energy magnitudes per unit seed will be helpful in designing a machine of throughput capacities and efficiencies in performance of palm kernel cracking machines. The integral multiple in the developed models can approximate the values of the kinetic system under consideration.

4.0. Conclusion

In conclusion, the problem desiring to address, was addressed using the stated objectives in which after the instrument was validated to have giving standard measurement values were used to generate standard data to be used in all the analyses. Design of experiment software was used to develop the factorial table of orthogonal array design out of the engineering kinetic measurements and evaluations values obtained. Statistical analyses of parameters of importance were carried out such as: effect of the independent factors, percentage contribution on the dependent factors, ANOVA, fit statistics, Model comparison statistics, coefficient estimate and other graphical illustrations of the relational representation of the factors. The average values of force, work done and impact energy for breaking a palm kernel shell was calculated for moisture content and moisture free conditions employing those factors identified significant in the ANOVA tables 5 and 6 according to equations 4, 5, 6, 7, 9 and 6 of the actual factors coding in the analysis to be 3.16 Newton and 0.744Newton; 0.079 Joule and 0.14 Joule; and 0.02 Newton second and 0.03 Newton second respectively. It was observed that the kinetic system elements required for breaking palm kernel shell under moisture content condition is lower than that of moisture free condition. It was also observed that the efficiency of breaking is high in the moisture free condition than that of moisture content condition. The numerical values of all these kinetic system elements: force, work done and impact energy magnitudes per unit seed obtained will be helpful in designing a machine of throughput capacities and efficiencies in performance of palm kernel cracking machines. The integral function in the developed models can be used to approximate the average values of the kinetic system parameter under consideration in the design.

5.0 Recommendation

1. It was recommended that instead of the single impact method, a double impact method be used to verify the result obtained in this research.
2. The practical recommendations for industrial applications will be considering kernel size, chute diameter and impact wall gap distances.
3. There is need to increase the number of samples size of both moisture conditions in the subsequent experimentation in order to determine the robustness of the developed measuring instrument to determine accuracy or precision of measurement.
4. in the study is in using an organized system with established parameters to be manipulated in measurable quantities that gives the standard engineering kinetic quantity.

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