



Design, Construction and Evaluation of A Multiple Impact Oil Palm Nuts Cracker

K.O. Chilakpu and G. I. Nwandikom

Department of Agricultural Engineering, Federal University of Technology, Owerri.

(Submitted: March 10, 2007; Accepted: August 9, 2008)

Abstract

A multiple stage impact Palm nut cracker was designed and constructed to handle mixed nuts of Dura and Tenra species without initial sorting and grading. The test results show an effective cracking of the nuts with minimal un-cracked nuts and minimal broken kernel. The Nuts samples were pre dried to a moisture content of 12% wet basis before cracking. The chamber shafts operate at a speed of 144 l rpm for the first chamber (A) and 1660 rpm for the second chamber (B). The final result reveals cracking efficiency of 95% at a throughput of 170kg/hr.

Keywords: Multiple stage, cracker, chamber, throughput.

1.0 Introduction

The oil palm (*Ealers Guineensis*) is a monocotyledonous plant predominant in the West African sub-region. Their different varieties and type could be noticed from the quantity of extractable oil derived from them, size of the fruit and nut thickness of the shells. A simple classification based on its internal structures present the fruit under three broad heading-Viz:

- i. Dura – Thick nuts with less mesocarp thickness
- ii. Tenera – thin nuts with thicker mesocarp.
- iii. Pisifera _ Small nut and thick mesocarp.(Kaya *et al.* 2004).

The fruit of the oil palm is a drupe, the outer layer provides the palm oil. Within the pulp or mesocarp lies a hard shelled nut containing the palm kernel which is the endocarp of the fruit. The major products of oil palm processing are- the palm oil, the palm kernel oil (PKO), the shells and the palm kernel cake (PKC). (Onwualu *et al.* 2006). These products have wide ranges of nutritional, medicinal and industrial uses. These include their rich contents of vitamin B carotene, carbohydrate and fibre. It could be further processed for the production of soaps, candles, cosmetics epoxy resins, grease, e.t.c. Palm kernel oil called "Eluaki" in Igbo is used among other things to control convulsion in children, is a popular body cream extracted from the kernel. Researchers have shown that the rich saturated fatty acids of palm kernel oil helps in the prevention of heart diseases through its enhancement of the body to synthesize cholesterol, (Jacquamord, 1998).

Despite the huge nutritional, medicinal and industrial values of palm kernel and its by- products, the significant role it is playing in the global trade and its abundance in the tropical rainforest region, its production has remained relatively low even in this region. This has been largely blamed on the drudgery and time wasted in sorting the nuts and less efficient cracking devices available.

In the past researchers have done some work in the area of palm nuts cracking. Makanjuola (1978), designed and constructed palm nuts cracker which makes use of the impeller system. The nuts are cracked as a result of impact force generated by the impeller. Apratum (1982), in his work, evaluated a pioneer oil mill which described a hammer type palm nuts cracker. PRODA (1985), worked on an impact palm nut cracker which consists of a shaft mounted horizontally on two bearings which allows the shaft to rotate axially inside a cylindrical container.

A common feature of the single stage palm nuts cracking machines is that, there must be sorting and grading of the nuts before cracking to achieve meaningful cracking efficiency by the machines. The cost and time spent on this sorting operation is a huge problem to the farmers and bottleneck to the processing operations.

The major objective of this work, therefore, is to design and construct a machine that can achieve

high cracking efficiency without prior sorting or grading of the nuts.

2.0 Design Consideration and Material Selection

2.1 Assumptions

This machine is designed to be powered by an electric motor. When operational, a level of vibration is expected from the driving motor. The random impacts of the nuts on the walls of the chambers will generate some levels of shock on the component parts. To avoid excessive vibration and slip on the driving belts, the chamber shafts are operated at safe speeds.

So, prior to the material selection and fabrication of the machine, the following assumptions were made.

- * The machine will operate under vibration and shock conditions.
- * The machine will not operate under an extreme high velocity (i.e. beyond 4000rpm)

2.2 Design Considerations

Some basic factors considered in designing the machine include;

- * The nuts size distribution in a mixed sample of oil palm nuts. This was achieved by randomly selecting 300 mixed nuts as the sample size. The sample size was divided into six equal groups of 50 mixed nuts. The numbers of nuts sizes below 1.69cm mean diameter falls into the Tenera group and the nuts sizes above 1.7cm mean diameter (Dura) were handpicked and noted Chilakpu 2007).

$$X = \frac{100n}{N}$$

where X is the percentage of nuts size on each sample size, n is number of nuts size and N is the total number of sample group

- * The cracking force requirement of the Dura and Tenera species.

The mathematical relationships between the required force ,the mass of the striking object, acceleration due to gravity and height of fall of striking object was used thus;

$$\text{P.E.} = mgh$$

where P.E. is the Potential Energy in *Newton-meter*, m is the mass in *kilogram*, g is the acceleration due to gravity in *meter per second squared* and h is the height of fall in *meter*

- * The average size of a kernel in relation to the size of its nut. Physical measurements of mean diameter of different nut samples were taken before the nuts were manually cracked .The mean diameters of the kernels were also taken with a venire caliper.
- * The size and speed of the prime mover to generate the required cracking force. The required prime mover speed was calculated using;

$$mgh = \frac{1}{2} mv^2$$

where m is the mass of object (kg), g is the acceleration due to gravity, h is the height of throw (m) and v is the speed of shaft (rpm)

2.3 Material Selection

Mild steel was chosen for the shafts, chamber drums, mainframe, hoppers and outlets to withstand shock and vibration and also to avoid brittle failures of the shafts (Shigley and Mishke 1990).

Flexible V- belts connectors were chosen due to their ability to absorb shocks while in operation (Hall 1995).

3.0 Machine Description

The fabricated machine is made up of two interconnected cracking chambers (See Figure 1 and Plate 1). The first chamber (A) which handles mostly the Tenera species consists of a 460mm diameter cylinder of 630mm long. The hopper is fixed at the left end of the cylinder while the main chute is at the lower right end of the cylinder. At the floor of the cylinder, a screen is placed midway to serve as kernel and shell outlet. Thick metal bars of 16mm length are fixed spirally on a shaft mounted on two ball bearings length wise across the cylinder. The bars while rotating are to generate the impact force required for nuts cracking and also provide the forward movement of the materials within the chamber. The free kernel and the shell will escape through the screen outlet to avoid multiple hit. The uncracked larger nuts move on to the next cracking

stage via the main chute.

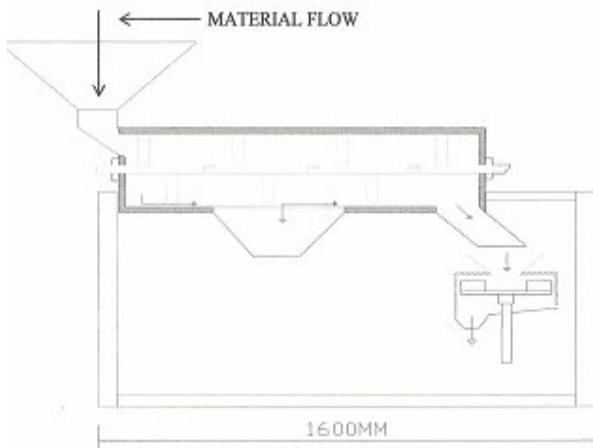


Figure 1: Cross section view of Cracking Chambers

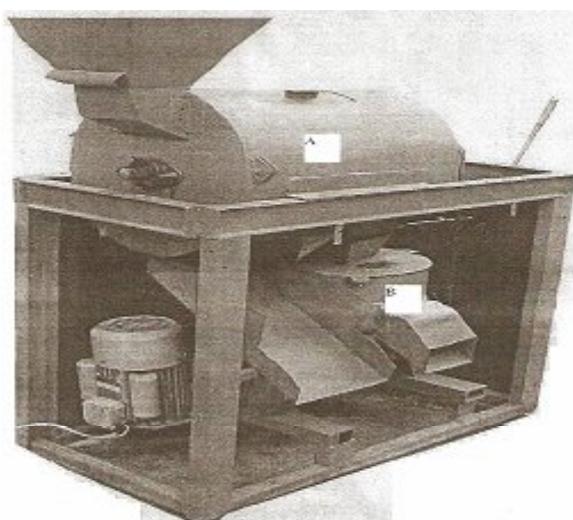


Plate 1: Fabricated Machine

The second cracking chamber (B) consists of a 400mm diameter ring of 15mm thickness. The product is introduced directly at the centre of the ring from the top onto a circular disc carrying metal bars (vanes) mounted on a vertical shaft. The spinning of the shaft generates a centrifugal force which throws the nuts against the ring to effect the required

cracking. Given the higher force generated within the second chamber, mostly the dura which are of thicker shells are cracked here.

4.0 Performance Evaluation

We present the performance evaluation data of the fabricated machine in Table 1. Various quantities of nuts samples were weighed and introduced independently into the hopper.

The cracking discharge time from the machine was noted. The whole kernel, un-cracked nuts and broken kernels were hand picked for each sample and weighed. The performance evaluation parameters were calculated thus:

- **The through put capacity of the machine - Q**

The determination of the allowable material flow into the machine during operation is necessary to ensure an optimal utilization of the machine at a high efficiency.

$$Q = \frac{W_I}{t_c} \quad \dots 1$$

where W_I is the total weight of nuts introduced (kg) and t_c is the cracking time (hr).

- **Percentage of nuts cracked**

After the cracking process, the free kernels were hand picked and weighed.

$$\% \text{ cracked} = \frac{100W_C}{W_I} \quad \dots 2$$

W_C is the weight of cracked nuts.

- **Percentage of nuts uncracked**

The nuts that passed through the machine un-cracked were hand picked and weighed.

$$\% \text{ uncracked} = \frac{100W_{UC}}{W_I} \quad \dots 3$$

W_{UC} is the weight of uncracked nuts

Table 1: Performance Evaluation Data

Total Weight of Nut (kg)	Cracking Time (min)	Weight of Whole Kernel (kg)	Weight of Broken Kernel (kg)	Weight of Cracked Nut (WT) (kg)	Weight of Uncracked Nuts (Wn) (kg)	Weight of Impurities (kg)	Qty of Sample Per Hour (kg/hr) Q	Machine Efficiency (A) (%) EFF	Cracked Nuts (%)	Uncracked Nuts (%)	Breakage Factor KBF.
2.00	1.50	0.31	0.06	1.67	0.28	0.05	66.67	86	83.5	14	0.19
3.00	1.53	0.53	0.09	2.52	0.40	0.08	100.00	87	84.0	13	0.75
5.00	1.80	1.19	1.00	4.39	0.50	0.11	167.00	90	88.0	10	0.42
6.50	2.32	2.18	1.08	5.88	0.52	0.10	168.00	92	90.0	8	0.23
8.50	2.85	2.50	1.84	7.94	0.42	0.14	170.00	95	93.0	5	0.17
10.50	3.60	3.20	2.51	9.69	0.63	0.18	175.00	94	92.0	6	0.20
12.00	4.00	3.44	3.25	10.87	0.92	0.21	179.00	92	90.0	8	0.27
15.00	4.90	4.10	3.86	12.91	1.80	0.29	184.00	88	86.0	12	0.44

- **Kernel breakage factor (KBF)**

From the free kernel population, the broken kernels were handpicked and weighed. The unbroken kernels were also weighed.

$$KBF = \frac{W_B}{W_{UB}} \quad ...4$$

W_B is the weight of broken kernel and W_{UB} is the weight of un-broken kernel

- **Efficiency of the machine (EFF)**

The weight of the total nuts introduced into the machine was noted .After the cracking process, the efficiency is calculated thus;

$$EFF = \frac{(W_I - W_{UC})}{W_I} \quad ...5$$

5.0 Results and Conclusion

The evaluation result shows a 95% cracking efficiency of the machine at 170kg/hr throughput. That also has the least (KBF) and least un-cracked nuts. The moisture content of the samples was pre dried to 12% wet bases. The first and second cracking chamber shafts operate at a speed of 1441rpm and 1660rpm respectively. The impurity level of the sample was found to be 1.65% of the sample introduced.

Figure 2.0 shows the graphs of cracking efficiency and uncracked nuts against the nuts input of the machine. The maximum cracking efficiency of the machine occurred at the least value of uncracked nuts at 170kg / hr.

The multiple stage impact palm nut cracker was designed, constructed and tested. The test result shows a 95% cracking efficiency of the machine at a gradual feedrate of 170kg/hr of the mixed sample. The best result was obtained at a sample moisture content of 12% wet basis with 1441rpm and 1660rpm as the speed of the first cracking chamber and second cracking chamber respectively. The machine performed well in a dusty and shock conditions and required no nuts size grading to achieve its recorded efficiency.

References

- Apratum, D.B. 1982, "Evaluation of processing performance of pioneer oil mill", in the proceedings of Nigeria Society of Agricultural Engineers, **6**, 76.
 Chilakpu, K.O. 2007, "Development and Evaluation of Multiple Impact Oil Palm Nuts Cracker", M.Sc. Thesis Federal Uni. of Tech., Owerri, Nigeria.

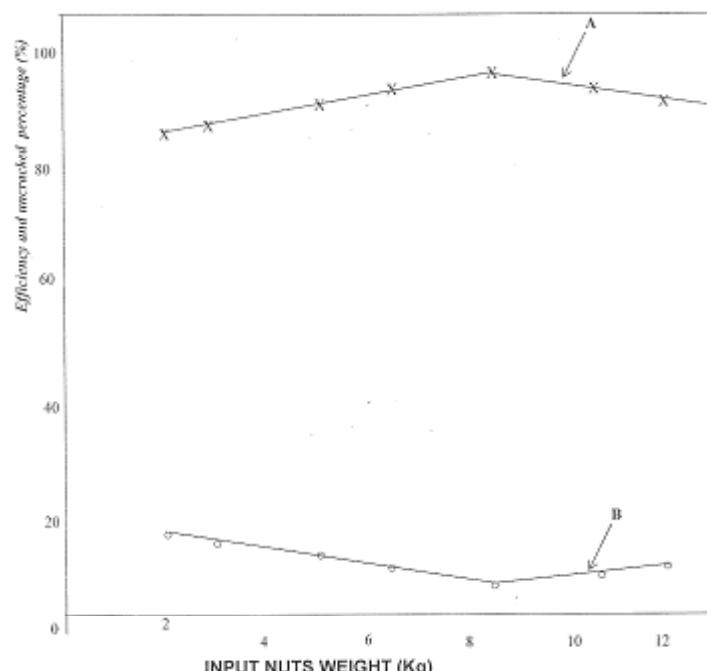


Figure 2: Graph of machine efficiency and uncracked nuts vs weight of sample introduced.
 Curve A is the machine efficiency curve while curve B is the percentage of nuts uncracked.

- Hall, 1995, Theory and problems of machine design, Schaum outline series; Megraw - Hill Book company.
- Jacqumond, J.C. 1998, Oil Palm, The Tropical Agriculturist; Macmillan, Hong Kong.
- Kaya, O.A., Idowu, A. and Faborode, M.O. 2004, "Some Properties of Palm Kernel and Shell relevant in Nuts Cracking and Products Separation", J. of Agricultural Engineering and Technology, **12**, 33.
- Makanjuola 1978, "Design of Conophor Nut Cracker", Appropriate technology, **5**(1)
- Onwualu, A.P., Akubuo, C.O. and Ahaneku, I.E. 2006, Fundamentals of Engineering Agriculture, Immaculate Publication LTD. Enugu Nigeria
- Proda 1985, Science and Technology Exhibition pp 25.
- Shigley, J.E. and Mishke C.R. 1990, Power transmission Elements. Mechanical designers work book, Megraw- Hill International, Auckland.