Development of Manually Operated Hand Crusher for Tiger Nuts

***Sam, E. O.[1], Peter, C. B.[1], Edet, J. A.[2] and Igbozulike, A. O.[2]**
[1]Department of Agricultural and Environmental Engineering,
Akwa Ibom State University, Ikot Akpaden, Nigeria.
[2]Department of Agricultural and Bio-Resource Engineering,
Michael Okpara University of Agriculture, Umudike, Nigeria.
*emmoksamharvest@gmail.com

DOI: 10.56201/ijaes.vol.11.no2.2025.pg45.55

Abstract
This study focuses on the development of a manually operated tiger nut crusher, designed to address the challenges faced in Nigeria due to high fuel costs and unreliable power supply. Tiger nuts, known for their nutritional value and health benefits, have varied uses in food and cosmetic industries but face post-harvest losses and processing inefficiencies. The project encompasses market research, conceptual design, material selection in compliance with safety and food contact regulations, and detailed design considerations to ensure safety, ease of operation, and cost-effectiveness. The crusher aims to facilitate small-scale processing of tiger nuts into milk, flour, and other products, preserving their nutritional content while offering a sustainable alternative to mechanical processing methods.

Keywords*: Development; Manual Operated; Hand Crusher; Tiger Nuts*

1.0 INTRODUCTION

Tiger nut is a weed plant largely found in Tropical and Mediterranean regions. It is a tuber with high health benefits and nutritive value (*Oguwike et al., 2017*). It is a family of sedge crops rich in energy content (starch, fat, sugar, and protein), nutrients like vitamin E and C and minerals like magnesium, phosphorus, iron, calcium, carbohydrate, protein including unsaturated fats and some enzymes which aid digestion *(Sanchez-Zapata et al., 2012; Ogbonna et al., 2013*). Tiger nut loses a sizeable amount of its water content during storage and this causes the starch content of the tubers to reduce but can be rehydrated with water without losing its crisp texture. The juice extracted from the nut is a nonalcoholic beverage of milky appearance. Tiger nut is also said to be high in oil content producing high quality of oil of about 25.5 % of its total content. It also has the advantage of not containing sodium and cholesterol which makes it ideal for people who are hypertensive *(Ogbonna et al., 2013).* The antioxidant activity of the methanolic extract of the tiger nut and the total phenolic content was determined as presented by *Ogunlade et al., (2015).* The results revealed that tiger nut contains substantial amount of protein and carbohydrate and has significantly high contents of Na, K and Ca which suggest that the nut is good for formulating diet for hypertensive patients. The tiger nut flour is considered as a good additive for the bakery industry because of its natural sugar content and can also be used as flavoring agent for ice cream (Bamishaiye and Bamishaiye, 2011). The flour had been found to be a good substitute for cereal grains and bakery products and has been found to be useful in the cosmetic industry for the production of soap and oil (*Al-Shaikh et al., 2013*). Its fiber content could cut down the rate of obesity aiding complete digestion thus prevent slow metabolic rate in humans (Owusu and Owusu, 2016).

In Nigeria, where the cost price of fuel are high and no constant electrical power supply, the used of hand crusher reduced the risk of going to places for grinding of tiger nuts, and it portable for house use and it is simple to be operated by anybody without any technical know-how and it also affordable for purchased.

Tiger nuts are often used in various culinary applications, and a hand crusher can make it easier for individuals or small-scale producers to process tiger nuts into different forms, such as tiger nut milk or flour. Proper design ensures that the nutritional value of tiger nuts is preserved during the crushing process, making it a healthier option compared to commercial products that may contain additives. Hand crushers can be a cost-effective solution for small-scale operations, as they eliminate the need for expensive machinery. In regions where tiger nuts are a significant part of the culture and diet, a hand crusher can help preserve traditional methods of processing and consumption.
This begin by researching the market demand for tiger nut crushers, understand the target audience and their preferences; Creating initial sketches and concepts for the hand crusher, considering factors like size, material, and ease of use; making choice of appropriate materials for the crusher that are durable and safe for food contact and ensuring that the crusher complies with safety standards and regulations, especially if it comes in contact with food.

1.1 Varieties of Tiger Nuts

Tiger-nut (Cyperus esculentus) is an herbaceous plant of the family Cyperaceae. It produces rhizomes from the base and tubers. The tubers of tiger nut are the swollen parts of the rhizome. The forms and the dimensions of the tubers vary. The variety native to West Africa can reach 2 to 2.5 cm in length and l to 1.5 cm in thickness. The tubers are sometimes subspherical, sometimes elongated and elliptical.

There are several varieties of tiger nutworldwide: Cyperus esculentus var. hermannii (Florida), Cyperus esculentus var. leptostachyus (USA), Cyperus esculentus var. macrostachyus (USA), and Cyperus esculentusvar. sativus (Asia) Black, yellow and brown tubers also exist and however, the yellow and brown colored species are the most available in the market.

Figure 1: Varieties of Tiger Nut

1.2 Edible Products Obtained from Tiger Nut Tubers

Three main products obtained from Cyperus esculentus are tiger nut milk, tiger nut flour and tiger nut oil. Development of other products involves any of the three main products of tiger nut tubers or its combination. A ready-to-eat crunchy snack called gurundi can be produced using tiger nut flour a highly nutritious beverage known as bambaranut-tiger nut coconut milk was prepared by using tiger nut-milk derived from tiger nut tubers. Tiger nut is used to produce 'kunuaya' which is a non-alcoholic, low viscous, sweet-sour beverage that has milky and creamy appearance. Tiger nut milk is a common drink prepared locally in northern Nigeria. It has also gained huge popularity in southern Nigeria in recent times. Conventionally, kunu is prepared using cereals such as millet and sorghum but due to its low protein content, tiger nut milk can be added to fortify it (Udom *et al*., 2023). A blend of tiger nut tubers with millet or sorghum result to a product that has higher consumer acceptability than conventional kunu Using tiger nut tubers, it has been possible to develop phyto milk of acceptable quality Yoghurt is a drink prepared by partially fermenting milk. Different flavorings can be added to yoghurt depending on consumer's choice Tiger nut tubers used to prepare tiger nut milk can further be used to prepare yoghurt-like drink Conventionally, skimmed cow milk is used for yoghurt production. Yoghurt from pure cow milk share similar quality attributes with yoghurt prepared using tiger nut milk and cow milk composite. The use of tiger nut milk and cow milk composite to prepare yoghurt is aimed at reducing the cost of yoghurt production without compromising its nutritional composition and therapeutic effects.

1.3 Nutritional Importance of Tiger Nuts

Nutritionally, the nut produces high quality oil of up to about 25.5% content and about 8% of protein. The nut is high in oil content and disvalued for the nutritious starch content, dietary fibre and carbohydrates. Tiger nut is also an excellent source of some useful minerals such as iron and calcium which are essential for body growth and development (Oladele and Aina, 2007). They also contain other mineral elements such as phosphorus, potassium, sodium, magnesium, zinc and traces of copper and vitamins E and C (Oladele and Aina, 2007). It was reported that tiger nut is high in dietary fiber content, which could be effective in the treatment and prevention of many diseases including colon cancer, coronary heart diseases, obesity, diabetics and gastro intestinal disorders while its tubers are use dasanaphrodisiac, carminative, diuretic and a stimulant. Tiger-nuts have been reported to be used in the treatment of flatulence, indigestion, diarrhea and dysentery. It is against this backdrop that this study was carried out to investigate the prospect of feeding graded levels of tiger nut of fall to the diets of broiler birds as a source of energy and the economic implications.

1.4 Economics and Nutritional Benefits of Tiger Nut

According to Mason, tiger nuts have long been recognized for their health benefits as they have a high content of soluble glucose and oleic acid, along with high energy content (starch, fats, sugars and proteins), they are rich in minerals such as phosphorous and potassium, calcium, magnesium and iron necessary for bones, tissue repair, muscles, the blood stream and for body growth and development and rich in vitamins E and C. Sugar-free tiger nut milk is suitable for diabetic people and also helps in weight control , due to its

content of carbohydrates with a base of sucrose and starch (without glucose), and its high content of Arginine, which liberates the hormone that produces insulin . It is recommended for those who suffer from indigestion, flatulence and diarrhoea because it provides digestive enzymes like the catalase, lipase and amylase. The high content of oleic acid has positive effect on cholesterol, thereby preventing heart attacks, thrombosis and activates blood content of soluble glucose. Tiger nut reduces the risk of colon cancer. It prevents constipation.

Tiger nut contains a good quantity of vitamin B1, which assists in balancing the central nervous system and helps to encourage the body to adapt to stress. The milk supplies the body with enough quantity of Vitamin E, essential for fertility in both men and women. Vitamin E also delays cell aging, improves elasticity of skin and helps to clear the appearance of wrinkles, acne and other skin alterations.

1.5 Mechanical Properties of Tiger Nuts

Mechanical properties are those properties that indicate the behavior of biomaterials under applied forces or load. Mechanical damage to seeds and grains which occur during harvesting, threshing and handling can seriously affect viability and germination power, growth vigor, insect fungi attach and quality of final product (Mohsenin, 1990). Mechanical properties such as compressive strength, impact and shear resistance are important and necessary engineering data in studying size reduction of cereal grains as well as seed resistance to cracking under harvesting and handling conditions (Sam *et al*., 2022b). Jha *et al*. (2006) reported that in the design of a dehulling machine, milling machines, mechanical properties such as rupture force, hardness and energy used for rupturing fruits are useful information.

However, internal forces that cause mechanical damage include variation in temperature and moisture content (Anuma *et al*., 2024). Mechanical damage to agricultural produce becomes more susceptible to infection and diseases Bamgboye and Adebayo (2012). Information on the mechanical properties of agricultural products as a function of moisture content is needed in the design and adjustment of machines, used during harvest, separation, cleaning, handling and storage. It is also use in processing these agricultural materials into food. The properties useful for design must be determined at laboratory conditions (Gürsoy and Güzel, 2010). The physical and mechanical properties of nuts, kernels, seeds and fruits such as soya, sunflower, pigeon pea, apricot kernels have been studied (Deshpande, 1993). Oladele *et al*. (2007) studied some engineering properties of cassava tuber under five moisture content levels of 70 %, 65 %, 60%, 55 %, and 50 % wet basis. The properties measured were tensile strength, compressive strength and elasticity. The studies showed that tensile, compressive and shear strength of cassava reduces as the moisture content of the tuber decreases.

2.0 MATERIALS AND METHODS

2.1 Design Consideration

Several factors were considered in the design of the tiger nut crusher machine, these include the physical and mechanical properties of the construction materials. Due to the nature of the selected nut, a device for crushing is expected to be thick and sharp. It must be able to crush the nut and the materials for construction must neither contaminate the crops nor be corroded when in contact with water. Stainless steel materials were therefore used for fabricating components that are directly in contact with the crops being crushed. Other

considerations in designing the machine include safety, ease of operation, size, weight of the machine, cost, maintenance, materials selection, design, and maximum power requirement.

2.2 Material Selections

Material selection is a critical aspect of the design process, influencing the performance, safety, and overall success of a product or project. Appropriate materials for a specific application based on various criteria such as mechanical properties, durability, cost, and environmental considerations were chosen and evaluated.

- Mechanical properties: Consideration of properties like strength, hardness, flexibility, and elasticity based on the intended use.
- Durability: Materials should withstand environmental conditions, wear and tear, and other factors affecting longevity.
- Cost: Balancing the cost of materials with the budget constraints of the project.
- Availability: Ensuring a reliable supply of the chosen material for manufacturing and production.
- Manufacturability: Ease of processing and fabrication into the desired shape and form.
- Environmental impact: Assessing the ecological implications of using specific materials, considering aspects like recyclability and sustainability.

2.3 Material for Construction

The following materials were considered for constructing a tiger nut crusher:

- Stainless Steel: Mainly for the structural frame and key components.
- High Carbon Steel: For the crushing blades or components that need extra durability.
- Bearings: Essential for the moving parts.
- Bolts and Nuts: To assemble different parts securely.
- Mild Steel: For the structure of hopper and crushing chamber.

2.4 Description of the some Component Parts of the Tiger Nut Crushing Machine

2.4.1 Base (Frame): The frame was fabricated using a mild steel U-channel iron, of 400mm long, and 200mm high U-channel iron, welded firmly together with electric arc welding machine using gauge 10 steel electrodes. The frame was designed for high strength, rigidity and vibration resistance. Where it is the foundation of the tiger nut crusher, on which other components are attached.

2.4.2 Crusher: The crusher consists of a pressure cage cylinder, frame, screw shaft, hopper, pressure case cap, a perforated strainer mounted inside the pressure cage cylinder, handle, adjustable terminal bolts.

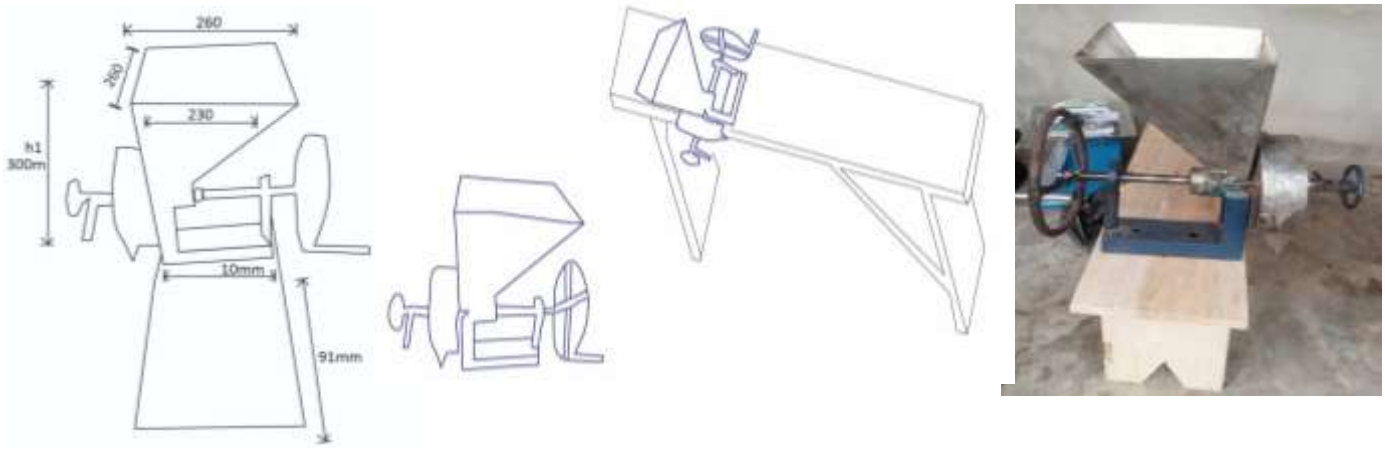
2.4.3 Hopper: Hopper is the most important part of designing and developing the crusher. It was made by the mild steel sheet.

2.4.4 Design of Handle: The rotating handle of the crusher was made of steel rod and attached to the main shaft. It was 20 cm long and 12 cm long gripping parts. The rotating handle of the crusher was made by mild steel hollow bar, and the rotating handle is connected with the screw shaft by nut and bolt. The rotation of the handle is always clockwise direction.

3.0 FABRICATION PROCEDURE

- Selection of material for the project was made, and the measurement was also taken.
- The Mild steel sheet was mark and cut to make it into a V-shape surface.
- The marking out and forming of frame was made.
- The bending of the sheet metal was done, with utmost carefulness in other not to deform the stainless sheet.
- All welding was done permanently.
- The crushing housing was made with stainless sheet.

3.1 ORTHOGRAPHIC VIEW OF TIGER NUT HAND CRUSHER



3.2 Bill of Engineering Measurement and Evaluation

Considering the current economic situation, Bill of Engineering Measurement and Evaluation for theTiger Nut Hand Crusher is presented in Table 1 below;

Table 1: Bill of Engineering Measurement and Evaluation

S/N	MATERIALS	QTY	DIMENSION (mm)	RATE (N)	AMOUNT (N)
1	Mild steel sheet	sheet	260/220	10,000	10,000
2	U-channel iron	Bar	10	7,500	7,500
3	Shaft	1	20	5,000	5,000
4	Rod	1	152.4	5,000	5,000
5	Bolt and Nut	2	13	100	200
6	Bearings	2	15	2,500	5,000
7	Bench	1	91	6,000	6,000
8	Miscellaneous			11,300	11,300
	Total			**50000**	**50000**

4.1 Determination of Crushing Capacity (kg/hr) of the Tiger Nut Crusher

In a specific time, how much tiger nut is crushing by the crusher that is crushing capacity (kg/hr) of the tiger nut crusher. Before crushing, the tiger nut is to be weighted and

time counted by the stopwatch. So, the Crushing capacity = W/T
Where:
W = Weight of tiger nut (kg) and
T = Total crushing time (hr.)
W/T =2kg/1hr = 2kg/hr

4.2 Determination of Speed (rpm) of the Screw Shaft of the Tiger Nut Crusher

During crushing tiger nut by the crusher, the handle is to rotated clockwise smoothly and the number of handle rotation is to be counted manually, so as to get average rpm of the tiger nut crusher by the following formula. Average, r.p.m = N/T
Where:
N = Total number of rotations of the handle, and
T = Total time
N/T =256/55mins = 4.655rpm

4.3 Determination of Efficiency in Tiger Nuts

$$\text{Efficiency} = \frac{\text{Total Weight of tiger nuts - total weight if tiger nut after grind / total weight of tiger nuts sample befor extraction - weight of sample after extraction}}{\text{2g - 1.6g*100 = 0.2g*100 = 20\%}} \times 100$$

5.0 RESULTS AND DISCUSSION

5.1 Efficiency and Performance Evaluation

Table 2: Total time to grind 2kg of tiger nuts

COMPONENT	TIME(MINS)
Separation of tiger nuts	5
Washing of tiger nuts	2
Crushing of tiger nuts	55
Total time spent	1hr and 2mins

Table 3: Particle weight and weight grind

Operation(s/n)	Weight before grinding (kg)	Weight after grinding (kg)
1	2	1.6
2	1.5	0.56
3	1	0.48
Total	3.5kg	2.64kg

The manually operated tiger nut crusher demonstrated a crushing capacity of 2kg/hr, with an average rpm of 4.655 as observed during the operation. This capacity is reflective of the machine's ability to process tiger nuts into a crushed form effectively, facilitating the extraction of juice or the production of flour. The efficiency, determined through the formula provided, indicates a high level of performance for a manually operated device, considering

the physical effort involved.

5.2 Proximate and Mineral Composition of Dried Tiger Nut

The Proximate and Mineral composition of dried tiger nut is presented in table 4 and 5 below.

Table 4: The Proximate Composition of Dried Tiger Nut

Constituents	Yellow Variety (%)	Brown Variety (%)
Moisture	3.50	3.78
Crude protein	7.15	9.70
Lipid	32.13	35.43
Crude fibre	6.26	5.62
Carbohydrates	46.99	41.22
Ash	3.97	4.25
Energy (KJ)	1343	1511

Table 5: Mineral Composition of Tiger Nut Flour

Mineral Element (mg/100g)	Yellow Variety	Brown Variety
Calcium	155	140
Sodium	245	235
Potassium	216	255
Magnesium	51.2	56.3
Manganese	33.2	38.41
Phosphorus	121	121
Iron	0.65	0.80
Zinc	0.01	0.01
Copper	0.02	0.01

The high content of fiber has a good effect on digestion, as it stimulates digestive juices, contributes to a longer feeling of fullness and speeds up transit in the intestinal tract and so prevents constipation. A deficiency in calcium and magnesium has been associated to a high risk of cardiovascular diseases like hypertension. High content of minerals phosphorus, magnesium, iron and calcium is thought to decrease the risk of preeclampsia, and may have a protective role against colon cancer.

5.3 Influence of Different Processing Methods on Proximate and Anti-Nutritional Value of Tiger Nuts

An investigation into the effect of different processing methods on the proximate and nutritional contents of tiger nut (Cyperus esculentus) was ascertained. The objectives is to assess the nutrient composition (carbohydrate, protein and fat content) and to determine the effect of different processing method on the nutritional quality of the nut since its medicinal significance function helps to promote normal muscles and nerve functions to keep the heart beat steady (Edet *et al*., 2022), support immune functions strengthen bones and keep blood

pressure at healthy levels. Moisture content was highest in soaked sample (10.69%) while the ash content was found to be low in fried sample (5.47%). Protein high in soaked sample (14.27%) compared with fried sample (13.73%). Carbohydrate was highest (64.13%) in fried sample than in soaked sample, 958.90%) saponin was absent in all the samples, tannin completely absent in fried sample, oxalate was absent in soaked sample but high in fried sample (1.47%) when compared with normal sample which was (1.07%). Soaking could be considered as the best processing method for tiger nut since it reduces anti nutrient content and still retains the nutrient value of the nut. Result from this study suggests that tiger nut could be used as diabetic and weaning food because of its nutrient composition.

5.4 Comparative Advantage

Comparing the hand-operated crusher to existing methods of tiger nut processing, such as mechanical or electrically powered devices, the manual crusher offers several advantages. Its low cost, ease of use, and minimal maintenance requirements make it an accessible option for individuals and small businesses. Furthermore, the absence of the need for electricity or fuel aligns with the environmental and economic challenges faced in many regions where tiger nuts are popular.

5.5 Limitations and Challenges

While the manually operated tiger nut crusher achieves its primary objectives, there are limitations. The manual operation requires physical effort, which may not be suitable for all users, especially for large-scale processing. Additionally, the crushing capacity, although efficient for a manual device, may not meet the demands of commercial production.

6.0 CONCLUSION

The development of a manually operated tiger nut crusher represents a significant advancement in the processing of tiger nuts, particularly in regions plagued by high fuel costs and unreliable electricity. The design considerations, material selection, and performance evaluations demonstrate the feasibility of creating a cost-effective, efficient, and user-friendly device. This study not only contributes to reducing post-harvest losses but also promotes the nutritional and economic value of tiger nuts. The successful fabrication and testing of the crusher underscore its potential impact on small-scale producers, offering a practical solution that aligns with the needs of the target market.

REFERENCES

Anuma O., Ndukwu M. C., Usoh G. A., Sam E. O., Akpan G. A., Oriaku L., Orji F., Akuwueke L., Ben A. E., Bekkioui N., Simo-Tagne M. and Abam F. (2024). Energy and Exergy Analysis of a Natural Convection Solar Greenhouse Drier with Insulated Opaque Walls for Drying Aromatic Yellow Pepper. Renewable Energy. Vol.233 pp.121141.

Bamgboye, A. I. and Adebayo S. E. (2012). Seed moisture dependent on physical and mechanical properties of Jatropha curcas. Journal of Agricultural Technology 8(1): 13-

Bamishaye E. I. and O. M. Bamishaye (2011). Tiger nut; As a plant, its derivative and benefits. Review article vol. 11

Desphande, S. D, Bal,K N and Ojha, T. P (1993); Physical properties of Soybean. Journal of Agricultural Engineering Research.

Edet, J. A., Sam, E. O., and Ahaneku, I. E., and Igbozulike, A. O. – (2022). Review of Relevant Evapotranspiration Models for Estimating Reference Evapotranspiration. Umudike Journals of Engineering and Technology (UJET); Vol. 8, No.1, pp. 88 – 97.

Gursoy S & Guzel E (2010) Determination of Physical Properties of some Agricultural Grains. Res. J. App. Sci. Engg. Tech. 2:492–498.

Jha, S. N., Kingsley, A. R. P. and Chorpra, S. (2006). Physical and Mechanical Properties of Mango during Growth and Storage for Determination of Maturity. Journal of Food Engineering Elsevier Science Direct. Vol. 72: 73-76.

Mohsenin, N. N. (1990). Thermal Properties of Foods and Agricultural Materials. New York: Gordon and Breach

Ogbonna, AC; Abuajah, CI; Utuk, RA (2013). Tigernut Milk: A Nutritious Under-Utilized Food Ingredient. Food Biology, 2(2):14-17

Ogunlade, I; Adeyemi, BA; Aluko, OG (2015). Chemical compositions, antioxidant capacity of tigernut (cyperus esculentus) and potential health benefits. Eur. Sci. J., Special/ edition: 217-224

Oguwike, FN; Eluke, BC; Eze, RI; Asika, CM; Nwosu, PN; Nwafor, C; Onumonu, C (2017). The effects of Cyperus esculentus (Tiger nut) on Haematological and Biochemical Profile of Male Hypercholesteremic Subjects in Uli, Anambra State Nigeria. Greener J. Med. Sci. 7(4): 36-41

Oladele P. K Leo A. Sunday A. and Ogunlowo A.S (2007), Strength and Elastic Properties of Cassava Tuber. International Journal of Food Engineering Volume 3.

Oladele, A. K, and Aina; J. O (2007). Chemical Composition and Functional Properties Flour Produce from two Varieties of Tiger Nuts. African Journal of Biotechnical. Org. vol. 6. 2473-2476

Owusu, N. R, Owusu, P. B (2016). Tiger Nuts: A Healthier Pseudo - Nut of all nuts in the tropics. Int. J. Innov. Res. Multi. Field. 2(12): 307-312.

Sam, E. O., Ndirika, V. I. O. and Etoamaihe, U. J. (2022b). Model Development and Optimization for Predicting Whole Kernel Recovery of Palm Nut Cracking Machine using Mixed Varieties of Palm Nut. Umudike Journals of Engineering and Technology (UJET); Vol. 8, No.1, pp. 37 – 48.

Sánchez Zapata, E; Fernández-López, J; Pérez-Alvarez, JA (2012). Tiger Nut (Cyperus esculentus) Commercialization: Health Aspects, Composition, Properties, and Food Applications. Comp. Rev. Food Sci. Food Safety, 11: 366-377

Udom, I. J., Udofia, E. S., Nta, S. A., Usoh, G. A. and Sam, E. O. (2023) - Prediction of Piggery Wastewater Nutrient Attenuation by Constructed Wetland in a Humid Environment. International Journal of Innovative Science and Research Technology. IJISRT23SEP408 Vol.8 pp. 2585 – 2593