REQUEST FOR NASENI RESEARCH COMMERCIALIZATION GRANT

RESEARCH PROJECT TITLE:	Development of Semi-Automated Integrated Melon Seed Kernels Production System of Commercial Viability
SUMMITTED TO:	National Agency for Science and Engineering Infrastructure (NASENI)
NASENI THEMATIC FOCUS AREA:	Agriculture and Food Manufacturing
IMPLEMENTING INSTITUTION:	National Centre for Agricultural Mechanization, Ilorin
PRINCIPAL RESEARCHER:	Engr. Dr. Ozumba, Isaac C.
PROJECT DURATION:	Two (2) Year

EXECUTIVE SUMMARY

Processed melon seeds commonly known as *Agushi, Egusi* and *Ogili* in Nigeria is a widespread used ingredient for preparing traditional cuisine such as soup and stews. The demand for melon seed kernels on a commercial scale is on the rise for food, pharmaceutical, and cosmetic application. However, the traditional method of shelling and separating melon seeds is labor-intensive, time-consuming, and often results to low-quality kernels owning to its inherent morphological characteristics such as hard shell, brittleness and fragility of seed kernels. Also, there is paucity of appropriate, effective and integrated melon seed processing machines. Thus, this project aims to develop a semi-automated and integrated melon seed kernels production system that can efficiently process melon seeds (condition, shell, separate un-shelled and shells, convey, re-shell, wash and solar dry) into high-quality kernels for commercial use. The study will also cover machine performance evaluation and dissemination to promote its adoption by the end users. There is optimism that the implementation of the proposed project will create descent jobs, increase productivity, reduce labor costs, and improve kernel quality, food security, and enhance economic growth in Nigeria in line with UN sustainable development goals.

1. INTRODUCTION

1.1 Background

Melon (*Citrullus lanatus*), commonly known as *Agushi, Egusi and Ogili* in Nigeria is an extensively cultivated and consumed oil seed crop in Nigeria and West Africa (Bankole *et. al*., 2010; Egbe *et. al.*, 2015). According to Ajibola *et al*. (1990), melon seed consist about 50% oil by weight, 37.4% protein, 2.6% fibre, 3.6% ash and 6.4% moisture. The presence of unsaturated fatty acid in melon oil according to him makes it nutritionally desirable due to its hypochlolestrolic (lowering of blood cholesterol) effect. The nutritional value of melon per 100g is reported by Adekunle *et al.* (2009) to be 7.6g carbohydrate, 0.4g dietary fibre, 0.2g fat, 0.6g protein and 8.0g vitamin C. The use and demand for melon seed for domestic use and industrial vegetable oil production cannot be over emphasized. But great fatigue and drudgery is associated with melon seed processing. The most critical aspect in melon seed processing is shelling operation since melon seeds usually becomes more valuable when shelled.

1.2 Statement of the Research Problem

Nigeria is a major producer in West Africa and accounts for 65 percent of the total melon seeds production. The demand for melon seed kernels on a commercial scale is on the rise for food, pharmaceutical, and cosmetic application. However, the dominantly practiced traditional method of shelling and separating melon seeds is labor-intensive, time-consuming, and often results to low-quality kernels owning to its inherent morphological characteristics such as hard shell, brittleness and fragility of seed kernels. Currently, there is paucity of appropriate, effective and integrated melon seed processing machine in Nigeria leading to insufficient supply of melon seed kernels for food, pharmaceutical, and cosmetic application.

1.3 Objective of the Research

The specific objectives of the research are to:

i. Modify NCAM existing motorized melon seed sheller and separator in terms of capacity and automation,
ii. Develop melon seed kernels and un-shelled seed separator,
iii. Develop a conveyor for re-introduction of the separated un-shelled melon seed into the shelling machine,
iv. Develop melon seed kernel washer,
v. Synchronize the developed units of machines into a semi-automated integrated machine,
vi. Test and evaluate the developed system,
vii. Disseminate the outcome of the study through publications in reputable academic journals, and exhibition (trade and innovation fairs) for public awareness creation to promote its adoption by processors/ investors.

1.4 Justification of the Research

The outcome of this research would:

i. Arrest the drudgery and health hazards associated with traditional methods of shelling melon seeds,
ii. Improve melon seeds kernel quality, supply volume, human nutrition and food security,
iii. Create descent jobs and enhance economic growth in Nigeria in line with UN sustainable development goals.

2. LITERATURE REVIEW

Melon seeds shelling involves the removal of the outermost part (husk) from the melon kernel, where the seed (cotyledon) is made to be separated from the husk (Kassim *et al.,* 2011). Melon shelling is a very important procedure in melon processing since melon shells are not edible. Melon seeds can be shelled manually (using hand to shell the melon) or mechanically (using machine which could either be electricity powered or fuel engine powered). Traditionally, manual melon shelling affects the rate of productivity as it consumes time, thus increasing drudgeries (Esenamunjor and Ubabuike, 2021). Due to inherent morphological characteristics such as hard shell, brittleness and fragility of seed kernels, melon seeds are usually conditioned by seed soaking to soften the shell edges and reduce the brittleness of the kernel. Conditioning of melon seeds before shelling operation reduces seed breakage and promotes wholeness of melon seed kernels.

Quality kernels are obtained after shelling when there is no denaturing of the kernel to expose the oil cells. When oil cells of the kernels are exposed, it gives room to oxidation reaction leading to rancidity of the kernels. This is where hand shelling method has advantage over mechanical shelling method. Mechanical shelling systems seriously impacts already shelled kernels when re-introduced into the shelling machine to cause denaturing of the kernels. Thus, melon seed kernel and un-shelled melon seed separator is of great importance to enhance 100 percent shelling melon seeds without denaturing melon seeds kernels.

Several mechanical shelling systems for melon seeds were designed, constructed and tested by Odigboh (1979), Fadamoro (1999), Agberegha (2018), Iorpev *et al*. (2020), Esenamunjor and Ubabuike (2021) and others. Nevertheless, these works have limitations to be addressed. This project aims to bridge the gap by developing a semi-automated and integrated melon seed kernels production system that can efficiently condition, shell, separate un-shelled and shells of seeds, convey, re-shell, wash and dry melon seed kernels using solar drier.

3. MATERIALS AND METHODS

The research site will be located at the National Centre for Agricultural Mechanization Ilorin on Latitude 8.5°N and Longitude 4.55°E. Materials for fabrication of the machine will be locally sourced from material shops in Ilorin, Nigeria. The selection and procurement of materials for fabrication of the machines will be based on their strength, suitability, accessibility and cost effectiveness. Stainless steel electrodes, sheets, rods, fasteners and flat bars shall be procured for the fabrication of food contact components while mild steel electrodes, angle bar, and metal sheets will be used for non-food contact components of the machines. Other materials such as electric motors, v-belt and pulleys will also be purchased.

Equipment, tools, and machines at the workshops and laboratories of the National Centre for Agricultural Mechanization Ilorin will be used during fabrication activities and laboratory investigations. Equipment such as lathe, milling, drilling, angle grinder, welding, bending, rolling, and gluten machines will be used in the research.

2.1 Design of Machine Parts

Each component of the machines will be designed based on the values of relevant physical and mechanical properties of melon seeds in literature after validation. All the shafts will be designed by using ASME Code equation for solid shaft design (Hall *et al.*, 1961), and the power requirement will be determined by the method reported in Ogundipe *et al* (2011), Hibbeler (2011) and Shittu and Ndrika (2012).

2.2 Machine Description

The integrated machine will consist of a control panel, melon seed sheller with separator, melon seed kernels and un-shelled seed separator, conveyor belts, melon seed kernel washer, and electric motors. The major unit machine will be the modified existing NCAM melon seed sheller and separator which will be connected in series with the other developed unit machines to form an automated process line.

i. Control panel: The control panel will be an electric gadget for supplying electric current to the unit machines as well as regulating the operating speed of the unit machines. It will consist of variable frequency drives (VFDs) for speed and torque adjustment, start/stop buttons, sensors and transducers and the casing.

ii. Melon seed sheller with separator: This machine (Figure 1) will be able to continuously and simultaneously shell conditioned melon seeds (soaked with water and aerated) and separate the seed kernels from the shells by a blower and vibrating screen. It will consist of a primary and secondary hopper, precise metering device, shelling chamber, blower/ shells exit chute, blower, vibrating screen, melon seed kernel chute, electric motor and frame. The difference between the existing machine and the proposed improvement include higher capacity of hoppers, shelling mechanism, and separation mechanism.

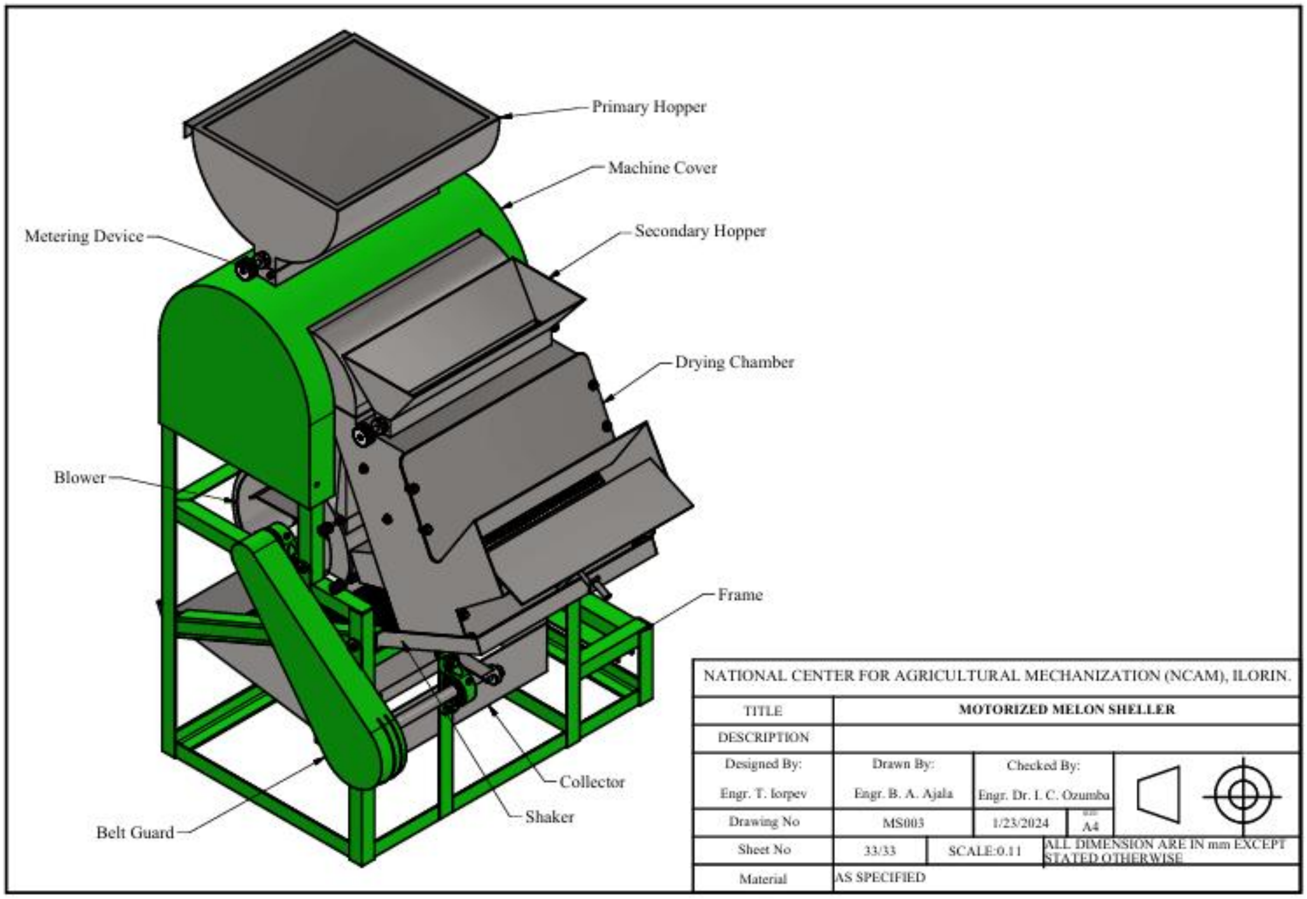

Fig. 1: Engineering drawing of proposed improved version of the existing motorized melon sheller with separator.

iii. Melon seed kernels and un-shelled seed separator: This equipment will perform the work of separating un-shelled melon seeds from the seed kernels for the purpose of re-introduction into the shelling machine during operation. The equipment will consist of a hopper, vibrating zig-zad- patterned-inclined plane, electric motor, and a frame.

iv. Conveyor belts: Incline belt conveyors with baffles will be used for conveyance of melon seed materials in the process line for the safety of the melon seed kernels.

v. Melon seed kernel washer: This equipment will be used for proper washing of melon seed kernels before drying. The equipment will be a rotating cylinder in a water bath for effective and gentle washing of the products.

vi. Electric motors: Geared 3-phase electric motors with horse power ranging from 1 to 5 hp will be use to drive the process line.

2.3 Machine Evaluation

All the integrated machines will be evaluated individually as well as the process line to ascertain it(s) performance parameters. During performance evaluation, moisture level of samples will be adjusted by using the method reported in Solomon and Zewdu (2008). The performance evaluation of the developed machines will be carried out to obtain its shelling efficiency, separation efficiency, seed breakage percentage and machine capacity using Equations 1 – 4 (Chougule and Gunale, 2021) for extension and adoption purposes.

$$\text{Shelling Efficiency} = \frac{Weight\ of\ cashew\ nuts\ shelled}{total\ weight\ of\ cashew\ nuts\ fed} \times 100 \quad (1)$$

$$\text{Separation Efficiency} = \frac{Weight\ of\ cleaned\ kernels}{Total\ weight\ of\ kernels\ collected} \times 100 \quad (2)$$

$$\text{Percentage Seed Breakage} = \frac{Weight\ of\ broken\ \ kernels\ obtained}{Total\ weight\ of\ kernels\ obtained} \times 100 \quad (3)$$

$$\text{Machine Capacity} = \frac{Weight\ of\ kernels\ obtained}{Time} \quad (4)$$

4. RESEARCH GANTT CHART

The research is scheduled to be completed in twenty-four (24) months as presented in the Gantt chart in Table 1.

Table 1: Research work implementation Gantt chart

Activities	Duration in Years and Months																							
	First Year												Second Year											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Literature search and review																								
Designing, drawing and simulation of the machines																								
Procurement of fabrication materials																								

Fabrication of the machines																								
Testing of the machine and adjustment																								
Data analysis																								
Writing and publication of outcomes																								
Dissemination of research outcome																								

5. INNOVATION NOVELTY

The novelty of this research will be the development of an appropriate and efficient semi-automated integrated melon seed kernel production line with the capacity to carryout melon seed destoning, conditioning, shelling, separation in two stages, washing and drying using solar powered equipment.

6. ESTIMATED RESEARCH BUDGET

The estimated budget for the implementation of this research work is **₦63,463,500** (Sixty-Three Million, Four Hundred and Sixty-Three Thousand, Five Hundred Naira) only. The details are presented in Annex I for ease of reference.

7. RESEARCH TEAM

The research team comprises of a Principal Researcher and the other five (5) members. The list of the members is presented in Annex II.

8. PROPOSAL ENDORSEMENT

This proposal is endorsed by:

……………………………………………………………

Engr. Dr. Kamal, A. R. **FNSE, FNIAE**
NCAM Executive Director/CEO

9. RELEVANT EXISTING PUBLICATION

A research paper relevant to this proposed research was published in respect to the existing NCAM motorized melon seed sheller with separator in an academic peer review journal. The journal published paper is attached in Annex III for ease of reference.

REFERENCES

Adekunle, A. S., Olujeagbon, I. O. and Olusegun, H. D. (2009). Development and Performance Evaluation of Manually and Motorised Operated Melon Shelling Machine Using Impact Technique. Journal of Engineering Service and Technology Review,2,12.

Agberegha, O. (2018). Design, Fabrication and Performance Test of Melon Shelling Machines. European Journal of Mechanical Engineering Research, 5(3):9-27.

Ajibola, O. O., Eniyemo, S. E., Fasina, O. O., Adeko, K. A. (1990). Mechanical Extraction of Oil from Melon. Journal of Agricultura Engineering research, 45:1.

Bankole, S. A., Adenusi, A. A., Lawal, O. S., Adesanya, O. O. (2010). Occurrence of Aflatoxin B1 in Food Products Derivable from ‘egusi’ Melon Seeds Consumed in South-western Nigeria. Food Control 21:974-976.

Chougule, S. M. and Gunale, R. B. (2021). Design of Cashew Nut Shelling Machine. International Journal of Scientific Research and Engineering Trends. 7(3):1411-1414.

Egbe, D. E., Mayah, T. F., Ebot, E. G., Egbe, P. A., Abraham, J. P. (2015). Performance Evaluation and Improvement on a Melon Seed Shelling Machine. World Journal of Agricultural Sciences and Engineering 1:1-10.

Esenamunjor, T. C. and Ubabuike, U. H. (2021): Performance Evaluation of a Melon Shelling Machine with Different Power Sources. FUOYE Journal of Engineering and Technology (FUOYEJET), 6(2):67-71.

Fadamoro, I. (1999). Design and Construction of a Manually Operated Melon Sheller. Mechanical Engineering Dept., University of Ilorin, Nigeria.

Hall, A. S., Laughlin, H. G. and Holowenko, A. R. (1961). Schuam’s Outline of Theory and Problem of Machine Design. McGraw-Hill Book Company, New York. pp. 113-290.

Hibbeler, R. C. (2011). Mechanics of Materials. Eighth Edition in SI Units. Pearson Education South Asia Pte Ltd, Singapore. pp. 190-279.

Iorpev, T., Ozumaba, I. C., Onah, R. O. and Adejumo, O. A. (2020). Performance Evaluation of a Melon Seeds Shelling and Separation Machine. AZOJETE,16(3):611-620. www.azojete.com.ng

Kassim, M. J., Umogbai, V. and Itodo, I. N. (2011). Development and Evaluation of a Melon Shelling and Cleaning Machine. Journal of Emerging trends in Engineering and Applied Sciences. 2(3):383-388.

Odigboh, E. U. (1979). Impact Egusi Shelling Machine. Transaction of the ASAE, 22 (5): 1264-1269.

Ogundipe, O. S., Oyelade, O. A. and Farounbi, A. J. (2011). Development and Performance Evaluation of a Cassava Chipping Machine, Journal of Agricultural Engineering and Technology (JAET), 19 (2):59-72.

Olalusi, A. P. and Adewole, C. A. (2020). Development of a Melon Seed Sheller and Separator. Journal of Agricultural Engineering and Technology, 28(1), 1-10.

Shittu1 S. K., Ndrika, V. I. O. (2012). Development and performance tests of a melon (Egusi) seed shelling machine 1(2): 1-11

Solomon, W. K, and Zewdu, A. D. (2008). Moisture-dependent Physical Properties of Niger (*Guiconia abyssinica Cass*.) Seed. Industrial Crops and Products, 29 (2009):165-170.

ANNEX I
Estimated Research Budget

S/N	Description	Quantity	Unit Cost, ₦	Amount, ₦
A.	**Cost of machine development**			
1.	Control panel development	1	2,310,000	2,310,000
2.	Melon seed sheller with separator	1	12,000,000	12,000,000
3.	Melon seed kernels and un-shelled seed separator	1	5,800,000	5,800,000
4.	Conveyor belts	4	860,000	3,440,000
5.	Melon seed kernel washer	1	2,500,000	2,500.000
6.	Geared electric motor	6	650,000	3,900,000
	Sub-total			**27,452,500**
B.	**Others / Miscellaneous**			
7.	Engineering drawing of machines	8	200,000	1,600,000
8.	Report writing, printing and binding	3	250,000	750,000
9.	Paper publication	3	720,000	2,160,000
	Sub-Total			**4,510,000**
C.	**Personnel Cost (conference attendance, dissemination / others)**			
10.	Principal Researcher's and Institution allowance	1	3,000,000	3,000,000
11.	Conferences and Exhibitions participation	2	10,000,500	20,001,000
12.	Other Team Members allowances	5	1,500,000	7,500,000
13.	Craftsmen allowances	4	200,000	800,000
14.	Data analyst allowance	1	200,000	200,000
	Sub-Total			**31,501,000**
	TOTAL COST			**63,463,500**

ANNEX II

Research Team

S/N	Name	Rank	Highest Qualification	Area of specialization	Organization
1.	Engr. Dr. Isaac Chinedu OZUMBA **(Principal Investigator)**	Director of Engineering	PhD	Agricultural and Biosystem Engineering	National Centre for Agricultural Mechanization, Ilorin, Nigeria.
2.	Engr. Terhemba IORPEV	Principal Research Officer	M.Eng.	Crop Processing & Storage	National Centre for Agricultural Mechanization, Ilorin, Nigeria.
3.	Engr. Dr. Abdufagar R. KAMAL	Executive Director	PhD	Farm Power & Machinery	National Centre for Agricultural Mechanization, Ilorin, Nigeria.
4.	Engr. Dr. Segun Yinka ADEMILUYI	Director Engineering	PhD	Agronomy	Crop Processing & Storage
5.	Engr. Dr. Olusola. A. OGUNJIRIN	Director Engineering	PhD	Farm Power & Machinery	National Centre for Agricultural Mechanization, Ilorin, Nigeria.
6.	Engr. Dr. Christiana. Alami ADAMADE	Professor	PhD	Agricultural and Biosystem Engineering	National Centre for Agricultural Mechanization, Ilorin, Nigeria.

ANNEX III
Relevant Existing Publication

ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY & ENVIRONMENT

AZOJETE September 2020. Vol. 16(3):611-620

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ORIGINAL RESEARCH ARTICLE

PERFORMANCE EVALUATION OF A MELON SEEDS SHELLING AND SEPARATION MACHINE

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ARTICLE INFORMATION

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Evaluation,
Melon seed,
Performance,
Separator,
Sheller

ABSTRACT

The scarcity of information on the performance of most machines developed in Nigeria impedes the commercialization of proven indigenous technologies. A newly developed melon seeds shelling and separation machine with the capability to continuously shell conditioned melon seeds and simultaneously separate the seed cotyledons from it shells was evaluated. The machine extracts heat exclusively from the exhaust gases of a gasoline prime mover by heat conduction principle, mildly dry the shelled melon seed mixture before effecting separation of the cotyledons from it shells by aerodynamic and screening principles. Based on preliminary studies, performance evaluation of the machine was carried out at 900, 1500 and 2100 rpm operating speed and 14, 20 and 26% db moisture content of white edge (Serewe) melon seed variety. The data obtained were analysed using IBM SPSS statistic software version 25. Results of Analysis of Variance (ANOVA) at P ≤ 0.05 showed that, shelling efficiency and machine capacity varies significantly with the operating speed, moisture content of the seeds, and their interactions; while separation efficiency and seed breakage percentage varies significantly with the operating speed and moisture content of the seeds but not significant with their interactions. An optimal performance of 96% shelling efficiency, 95% separation efficiency, 2.67% seed breakage percentage and 54.23 kg/h machine capacity, was obtained at 2100 rpm operating speed and 20% db seed moisture level. The performance of the machine is satisfactory and therefore recommended for commercialization and adoption by melon seed processors.

1.0 Introduction

Melon (Colocynthis citrullus L.) with a vernacular name "Egusi" (Oyolu, 1977) is one of the important oil-seed crops widely grown and consumed in tropical Africa (Shittu and Ndrika, 2012). The crop is an annual herbaceous climbing plant of the cucurbitaceous family which has the best yield on sandy free draining soils. Its fruits are pods which contain many seeds (Onwuka and Nwankwojike, 2015). The seeds are extracted and processed to produce major products such as melon seed kernels/cotyledons, melon seed flour and melon seed oil (Onwuka and Nwankwojike, 2015). The common varieties of the crop in Nigeria include: Bara, Serewe, and Sofin. A seed of Bara variety is 16 x 9.5 mm in size with 100-seed weight of about 14g and it is dominant in the Northern and Western regions of Nigeria. Serewe seed variety is 15 x 9 mm in size with 100-seed weight of about 12g and it is indigenous to the Eastern part of Nigeria (Olusegun and Adekunle, 2008).

Melon seeds meals are highly nutritious due to its nutritional content. The seeds contain about 50% oil by weight, 37.4% protein, 2.6% fibre, 3.6% ash and 6.4% moisture (Ajibola et. al., 1990). Adekunle et al. (2009) found the quantity of melon seed oil to consist of 50% unsaturated fatty acids (35% Linoleic, and 15 % Oleic) and 50% saturated fatty acid (Stearic and Palmitic acid) which is responsible for its hypocholestrolaric (blood cholesterol lowering) effect and thus, nutritionally desirable. Consequently, its products are found to reduce the chances of developing terra-arterial or heart disease (Ajibola et. al., 1990; Iorpev et. al., 2016). The seed has amino acid content profile that can be compared favorably with that of soya beans and even white of egg (Oyenuga and Faluga, 1975).

Melon seeds are raw materials for the production of egusi soup, margarine, salad, "robo cake", baby food, livestock feeds, local pomade, soap and poultry litter material (Bankole et al., 2005; Shittu and Ndrika, 2012).

Shelling and separation operation is an important postharvest activity during processing of melon seeds to it finished products (Yekinni et al., 2017). Manual shelling of melon seeds is laborious, tedious and time consuming. Ogbonna and Obi (2007) reported that about two hours are required to manually shell/dehull 1kg of melon seeds. In Nigeria, some research works have been carried out on mechanical shelling and separation of melon seeds. Although, the attempt by Kassim et al. (2011) among others on the development of an integrated melon seeds shelling and separation machine have poor separation efficiency (Onwuka et al., 2015). Hence, the need to carry out performance evaluation of the newly developed melon seeds shelling and separation machine at the National Centre for Agricultural Mechanization (NCAM), Ilorin.

The paper seeks to provide relevant information on the performance of this indigenously designed and developed machine to enhance awareness that would lead to commercialization of the melon seeds shelling and separation machine.

2 MATERIALS AND METHODS

2.1 Materials

The study was carried out at the crop processing shed and the laboratory of National Centre for Agricultural Mechanization, Ilorin using the newly developed melon seeds shelling and separation machine. Figures 1a, 1b and 1c show the various views of the machine. Other materials used include serewe melon seeds variety (figure 2a), laboratory oven (LAB-TECH™), tachometer (0.05+1digit, Lotron DT-2236B), digital weighing balance (0.1g, Camry EHA251), digital stop watch (0.01s, Kadio KD-6128), clean water, plastic bowls and polyethylene bags.

(a)Left end view (b) Front view (c) Right end view

Figure 1: Melon Seeds Shelling and Separation Machine

(a) Unshelled Serewe Melon Seed Variety (b) Shelled and Separated Melon Seeds Cotyledons
Figure 2: Serewe Melon Seeds Variety

2.1.1 Description of the machine

The melon seeds shelling and separation machine labelled in Figure 3 consist of five (5) major units: shelling chamber, exhaust gases heat exchanger chamber, drying chamber, blower unit and oscillating screening unit. All these component units are anchored by a rigid frame. The machine has the ability to shell conditioned (soaked) melon seeds, exclusively extract heat from the exhaust gases of the prime mover (gasoline engine), channel hot air to the drying chamber to mildly dehydrate moist shelled melon seeds, blow off the lighter shells of the seeds and sieve out the heavier shells to produce neat cotyledons of melon seeds. The hopper through which conditioned (soaked) melon seeds are fed into the machine is an inverted pyramidal frustum with a feed control fabricated from a 2 mm thick stainless steel sheet metal. All melon seed contact surfaces in the machine are made from stainless steel material. The machine is powered by a 5Hp gasoline engine.

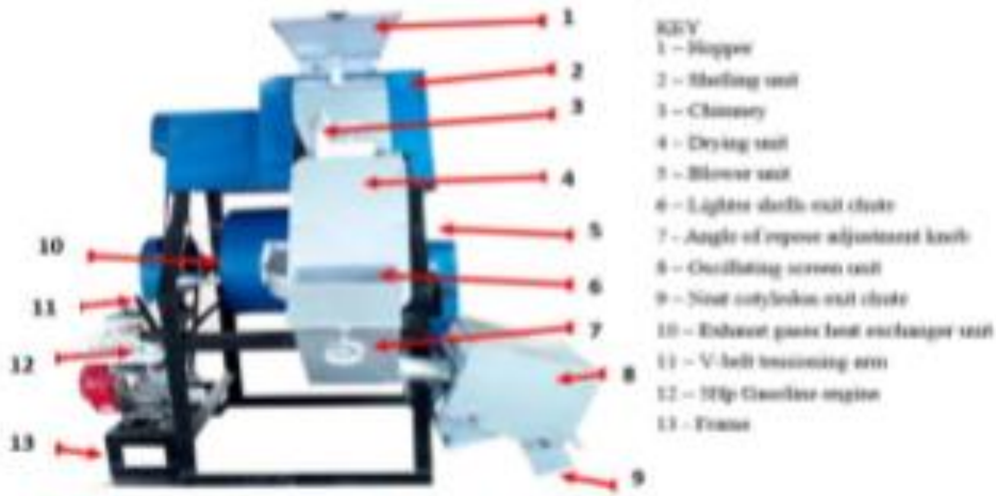

Figure 3: A Labelled Picture of Melon Seeds Shelling and Separation Machine

2.1.2 Working principle of the machine

Conditioned melon seeds are fed into the hopper at the beginning of an operation and then closed to avoid splashing of the content of the hopper. The feed control valve is adjusted and the seeds flow under gravity into the shelling chamber. Shelling of the seeds is effected by impact and shear forces generated between the rotating and stationary shelling drums. Simultaneously, cold air sucked through a heat exchanger by an axial fan is heated up and the hot air flows against the direction of moist shelled melon seeds moving on slanted interlocked drying trays in the drying chamber. The drying air of about 60°C inside the drying chamber evaporates the surface water of shelled melon seeds before aerodynamic separation. The lighter shells are blown-off before the final removal of the thicker shells at the oscillating screen to discharge neat melon seeds cotyledons.

2.2 Methods

2.2.1 *Sample cleaning*

Six (6) kilograms of serewe melon seeds variety was procured from Makurdi and the seeds were manually de-stoned to prevent the damage of the shelling mechanism and cotyledons.

2.2.2 *Moisture determination*

The initial moisture content of the melon seed was determined at the Food Processing Laboratory of National Centre for Agricultural Mechanization, Ilorin using oven drying method. The samples were oven dried at a temperature of 103 ± 2°C until constant weight of the samples were obtained (Kashaninejad et al., 2005; Obi and Offorha, 2015). The initial moisture content values of the seeds were used to calculate the required amount of water needed to adjust seed moisture to 14, 20, and 26% db levels for the study.

2.2.3 *Seed conditioning*

The de-stoned melon seeds were randomly divided into 27 samples, each weighing 200g. Each sample was thoroughly mixed with a calculated amount of water using Equation 1 according to Obi and Offorha, (2015). The contents were then kept in an air tight polyethylene bag in a refrigerator at 3°C for 7 days to enable proper moisture distribution and equilibration (Enoch et al., 2008; Obi and Offorha, 2015). The samples were then aerated under a shed for 20 minutes based on preliminary studies to get the seeds inflated.

$$M = W_s\left(\frac{M_2 - M_1}{100 - M_2}\right) \quad (1)$$

Where,
M = Mass of distilled water (kg)
W_s= Mass of sample (kg)
M_1 = Initial moisture content (%)
M_2= Final moisture content (%)

2.2.4 *Machine Testing*

The machine was tested with no load and an abnormal noise due to friction was corrected by alignment of components and application of grease in conformity with NCAM (1990).

Under loading, the variables in Table 1 were considered during the evaluation of the machine. Each treatment was replicated thrice to check for experimental errors. The conditioned and labelled samples were fed into the machine at varying operating speeds and timed.

Table 1: Variables for Machine Performance Evaluation

Variables	Values
Seed moisture content (% db)	14, 20, 26
Shelling speeds (rpm)	900, 1500, 2100
Performance indicators	Shelling efficiency, separation efficiency, seed breakage percentage, throughput capacity, machine capacity.

2.2.5 *Statistical analysis*

The products collected were sorted, weighed and analyzed using IBM SPSS statistic software version 25 and equations 2, 3, 4, 5, 6, and 7 (Shittu and Ndrika, 2012; Simonyan and Yiljep, 2008) to get its performance parameters.

Shelling efficiency, $\eta_s = \left(\frac{M_{sus} + M_{sbs}}{M}\right)100 \quad (2)$

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Separation efficiency, $\eta_s = \left(\frac{M_{cuc}+M_{cbc}}{M_{cuc}+M_{cbc}+M_{sc}}\right)100$ (3)

Breakage Percentage, $S_b = \left(\frac{M_{cbc}}{M}\right)100$ (4)

Throughput capacity, $C_t = \frac{M}{T}$ (5)

Machine capacity, $C_m = \frac{M_{cuc}+M_{cbc}}{T}$ (6)

Where,
M_{cuc} = Mass of clean unbroken cotyledon in product collected at outlet chute (Kg)
M_{cbc} = Mass of clean broken cotyledon in product collected at outlet chute (kg)
M = Total mass of seed fed through the machine's hopper (Kg)
M_{sc} = Mass of shells/chaff in cotyledons collected at outlet chute (kg)
T = Time taken to complete operation (h)

3 RESULTS AND DISCUSSION

Table 2 shows the mean values of performance characteristic of the machine at various moisture content and operating speed levels considered. The results show that the mass of shelled melon seeds produced by the machine increased with increase in seed moisture levels at various operating speed levels, while the mass of broken seeds decreased with increase in seed moisture levels at different operating speed levels of the machine. The results show that the mass of shelled melon seeds produced by the machine increased with increase in seed moisture content levels at various operating speed levels. Also, the mass of broken seeds decreased with increase in seed moisture content levels at different operating speed levels of the machine. A similar result was reported by Shittu and Ndrika (2012). Additionally, the mass of melon seeds shelled and mass of broken seeds increased with operating speed at various moisture levels considered.

The performance indicators of the machine are presented in Table 3. It is clear that shelling efficiency, separation efficiency, seed breakage percentage and machine capacity ranges from 55.10 – 96.20%, 86.93 – 96.13%, 1.34 – 2.95%, and 34.30 – 54.60 kg/h respectively. This level of performance achieved in the study could be attributed to the unique design of the various unit of the machine and the operating conditions considered in the study.

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Table 2: Means Values of Machine Performance Characteristic at Various Speed and Moisture Levels

Speed (rpm)	Moisture (% db)	$M\ (g)$	$M_{cus}\ (g)$	$M_{cbc}\ (g)$	$M_{sc}\ (g)$	$T\ (s)$
900	14	200	107.00 (0.057)	3.20 (0.100)	16.57 (0.285)	11.14 (0.120)
900	20	200	137.94 (0.400)	3.06 (0.100)	24.14 (0.173)	14.59 (0.092)
900	26	200	150.85 (0.250)	2.69 (0.382)	31.00 (0.312)	16.11 (0.142)
1500	14	200	140.96 (0.929)	5.90 (0.550)	8.19 (0.451)	11.47 (0.201)
1500	20	200	168.06 (0.583)	5.00 (0.300)	12.83 (0.142)	13.84 (0.105)
1500	26	200	181.01 (0.289)	4.33 (0.276)	18.15 (1.023)	15.98 (0.200)
2100	14	200	144.77 (0.361)	6.43 (0.225)	6.08 (0.355)	9.97 (1.501)
2100	20	200	186.66 (0.833)	5.34 (0.476)	9.61 (0.585)	12.75 (0.110)
2100	26	200	187.66 (0.361)	4.74 (1.153)	16.16 (0.345)	14.85 (0.302)

NB: Values in parenthesis are standard deviation values with ± sign.

Table 3: Mean Values of Machine Performance Parameters

S (rpm)	Moisture (% db)	Sh. E (%)		Se. E (%)		BP (%)		Cm (kg/h)	
900	14	55.10	(0.854)	86.93	(0.058)	1.76	(0.100)	35.62	(0.580)
900	20	70.60	(0.400)	85.40	(0.173)	1.63	(0.029)	34.83	(0.351)
900	26	73.77	(0.252)	83.20	(0.200)	1.34	(0.081)	34.30	(0.173)
1500	14	73.43	(0.929)	94.72	(0.664)	2.95	(0.050)	46.07	(0.252)
1500	20	86.53	(0.583)	93.10	(0.100)	2.50	(0.300)	45.00	(0.173)
1500	26	92.67	(0.289)	91.08	(0.076)	2.17	(0.208)	41.77	(1.626)
2100	14	75.60	(0.361)	96.13	(0.321)	3.22	(0.225)	54.60	(0.529)
2100	20	96.00	(0.200)	95.00	(0.200)	2.67	(0.076)	54.23	(0.961)
2100	26	96.20	(0.361)	92.20	(0.529)	2.37	(0.153)	46.67	(0.416)

NB: Values in parenthesis are standard deviation values with ± sign.

3.1 Effect of Moisture Content and Operating Speed on Shelling Efficiency

Table 3 indicates that the shelling efficiency of the machine increases with an increase in seed moisture content and operating speed which is in agreement with works reported by Shittu and Ndrika (2012), Sobowale et al., (2015) and Onwuka and Nwankwojike, (2015) . This is because when moisture content of melon seeds samples increases, a cavity filled with fluid is created between the seed cotyledon and the shell which tends to increase the shelling efficiency. It was then observed that, moisture content of the seeds and the operating speed level are critical factors influencing shelling efficiency. The maximum shelling efficiency obtained was 96.20% at 26% db moisture level and 2100 rpm operating speed level.

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3.2 Effect of Moisture Content and Operating Speed on Separation Efficiency

From Table 3, separation efficiency increases with operating speed but decreases with an increase in moisture level. It can be explained that, an increase in operating speed generates enough air draft which is higher than terminal velocity of melon shells but less than that of the seed cotyledons to increase separation. The obtained result is a contrast of Onwuka and Nwankwojike (2015). This means that, at higher moisture content level, the designed efficiency of the drying unit is exceeded and thus, causing a decrease in separation efficiency. The maximum separation obtained was 96.13% at 14% db moisture level and 1200 rpm operating speed level.

3.3 Effect of Moisture Content and Operating Speed on Seed Breakage Percentage

The seed breakage percentage decreases with increase in moisture level but increases with increase in operating speed levels as shown in Table 2. This is in agreement with the works reported by Shittu and Ndrika (2012), Sobowale et al., (2015) and Onwuka and Nwankwojike, (2015). The highest seed breakage percentage obtained was 3.22% at 2100 rpm and 14% db moisture content level, while the lowest was 1.34% at 900 rpm operating speed and 26% db moisture content level. This performance is better than the 15.13% minimum seed damage percentage achieved by Sobowale et al., (2015) at 1500 rpm operating speed and 18.32% db moisture level.

3.4 Machine Capacity

Table 2 shows that the maximum value of machine capacity obtained was 54.60 kg/h. This capacity is comparatively lower than the 192 kg/h machine capacity of a melon seed shelling machine without a separating unit developed by Shittu and Ndrika (2012) and higher than the 7.95 kg/h machine capacity of the melon seed shelling and separation machine developed by Sobowale et al., (2015). The designed residency time/delay of moist shelled melon seeds mixture in the drying chamber and at the oscillating screen is responsible for the obtained level of machine capacity.

Table 4 is a summary of analysis of variance (ANOVA) results. The result shows that, at 5% percent level of significance, shelling efficiency and machine capacity varies significantly (p-value of 0.0001) with the operating speed, moisture content of the seeds, and their interactions; while the separation efficiency and seed breakage percentage varies significantly with the operating speed and moisture content of the seeds but not significant with their interactions.

Table 4: ANOVA Result Summary of Machine Performance

Parameter	Source of variation	F	Pr > F
Shelling Efficiency	S	4563.176	0.0001
	M	3492.591	0.0001
	S*M	41.873	0.0001
Separation Efficiency	S	2106.024	0.0001
	M	307.244	0.0001
	S*M	1.218	0.3381
Seeds Breakage Percentage	S	134.977	0.0001
	M	40.793	0.0001
	S*M	1.971	0.1421
Machine Capacity	S	1263.883	0.0001
	M	103.301	0.0001
	S*M	23.166	0.0001

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The results of Duncan post-hoc test in Tables 5 and 6 present specific information on how the effect of different levels of operating speed and moisture content on shelling efficiency, separation efficiency, seed breakage percentage and machine capacity significantly differ from each other.

Table 5: Comparison Summary of Effect of Speed Levels on Performance Indices using Duncan Multiple Range Test

Speed, rpm	ShE, %	SeE,%	BP,%	MC, kg/h
900	66.4889	85.1778	1.5800	34.9167
1500	84.2111	92.9667	2.5389	44.2778
2100	89.2667	97.4444	2.7500	51.8333

Means with the same letters are not significantly different at p ≤ 0.05 using the DNMRT
ShE-Shelling efficiency, SeE-Separation efficiency, BP-Breakage percentage, MC-Machine capacity

Table 6: Comparison Summary of Effect of Moisture Levels on Performance Indices using Duncan Multiple Range Test

Moisture Content, %	ShE,%	SeE,%	BP,%	MC, kg/h
14	68.0444	92.5944	2.6433	45.4278
20	84.3778	91.1667	2.2667	44.6889
26	87.5444	88.8278	1.9589	40.9111

Means with the same letters are not significantly different at p ≤ 0.05 using the DNMRT
ShE-Shelling efficiency, SeE-Separation efficiency, BP-Breakage percentage, MC-Machine capacity

Tables 5 and 6 revealed that the means are significantly different at P ≤ 0.05. The effect of each operating speed and moisture content level on shelling efficiency, separation efficiency, seed breakage percentage and machine capacity significantly differs from each other. Thus, the most suitable operating speed levels obtained without a close significant substitute for shelling efficiency, separation efficiency, seed breakage percentage and machine capacity were 2100, 2100, 900 and 2100 rpm respectively, while on the other hand 26, 14, 26, 14% db respectively were the most suitable moisture levels for the various performance parameters.
Hence, an optimal performance of 96% shelling efficiency, 95% separation efficiency, 2.67% seed breakage percentage and 54.23 kg/h machine capacity was obtained at 2100 rpm operating speed and 20% db seed moisture level.

4 CONCLUSION

The performance of an indigenously designed and developed melon seeds shelling and separation machine powered by a gasoline engine was studied to enhance its commercialization and further research works. The results of the study showed that shelling efficiency of the machine increases with an increase in seed moisture content and operating speed; separation efficiency increases with increase in operating speed but decreases with increase in moisture content level; while seed breakage percentage decreases with increase in moisture level but increases with increase in operating speed levels. An optimal condition of 2100 rpm operating speed and 20% db seed moisture level produced 96%, 95%, 2.67%, and 54.23 kg/h shelling efficiency, separation efficiency, seed breakage percentage and machine capacity respectively.

Therefore, this machine could be recommended for commercialization and adoption by melon seed processors.

REFERENCES

Adekunle, AS., Ohijeagbon, IO. and Olusegun, HD. 2009. Development and performance evaluation of manually and motorised operated melon shelling machine using impact technique. Journal of Engineering and Technology Review, 2: 12-17.

Ajibola, OO., Eniyemo, SE., Fasina, OO. and Adeko, KA. 1990. Mechanical extraction of oil from melon seeds. Journal of Agricultural Research, 5:1-7.

Bankole, SA., Osho, A., Joda, AO. and Enikuomehin, OA. 2005. Effect of drying method on the quality and storability of 'egusi' melon seeds (Colocynthis citrullus L.). African Journal of Biotechnology, 4: 799-803.

Enoch, GA., Rose, F., Harmane, TA., Raymond, SA., Osmane, C. and Adam, A. 2008. Importance and practices of bitter melon crops in Sociolinguistic areas in Benin. Biotechnology, Agronomy, Society and Environment Journal, 12: 393–403.

Iorpev, T., Ozumba, IC., Adejumo, OA. and Ogini, F. 2016. Development and evaluation of aerothermal-machine for separating melon seeds cotyledon from its shells. Proceedings of the 37th National Conference and Annual General Meeting of the Nigerian Institution of Agricultural Engineers at Minna, 4 – 7th October 2016, 37(2): 648-655.

Kashaninejad, M., Mortazavi, A., Safekordi, A. and Tabil, LG. 2005. Some physical properties of pistachio (Pistacia vera L.) nut and its kernel. Journal of Food Engineering, 72: 30–38.

Kassim, MJ., Umogbai, V. and Itodo, IN. 2011. Development and evaluation of a melon shelling and cleaning machine. Journal of Emerging Trends in Engineering and Applied Sciences, 2(3): 383-388.

NCAM 1990. Test code for powered maize shellers. Draft of Nigerian Industrial Standard. National Centre for Agricultural Mechanization, Ilorin, Nigeria, pp. 110.

Obi, OF. and Offorha, LC. 2015. Moisture-dependent physical properties of melon (Citrullus colocynthis L.) seed and kernel relevant in bulk handling. Cogent Food and Agriculture, 1: 1-18.

Ogbonna, PE. and Obi I. 2007. Effect of time of planting and poultry manure application in growth and yield of egusi melon in a derived savannah in agro- ecology. Agro-Science, 6: 33-39.

Olusegun, HD. and Adekunle, AS. 2008. The Design, construction and testing of melon sheller. Global Journal of Engineering and Technology, 1(4): 473-481.

Onwuka, OS. and Nwankwojike, BN. 2015. Design and development of integrated melon processing machine. Innovative System Design Engineering, 6(12): 41-52.

Oyenuga, VA. and Faluga, BL. 1975. Some aspects of biochemistry and nutritional value of the water melon seed (Citrullus vulgaris, schrad). Journal of Science, Food and Agriculture, 2(6): 843-854.

Oyolu, C. 1977. Quantitative and qualitative study of seed types in egusi (Colocynthis citrullus). Tropical Science, 24(2): 93-98.

Shittu, SK. and Ndrika, VIO. 2012. Development and performance tests of a melon (egusi) seed shelling machine. Agricultural Engineering International, The CIGR Journal, 14: 1-11.

Simonyan, KJ. and Yiljep, YD. 2008. Investigating grain separation and cleaning efficiency distribution of a conventional stationary rasp-bar sorghum thresher. Agricultural Engineering International. The CIGR Ejournal Manuscript Pm 07028. Vol. X. pp. 5-7.

Sobowale, SS; Adebiyi, JA. and Adebo, OA. 2015. Design, construction and performance evaluation of a melon seeds sheller. Journal of Food Process Technology, 6: 463-467.

Yekinni A., Rabiu T., Bajela G., Adigun I., Saheed R., Lamidi, S. and Ademolu, O. 2017. Modification and development of a manually operated and motorized melon seed shelling/ separating machine. World Journal of Engineering Research and Technology, 3(6): 67-82.