DESIGN AND DEVELOPMENT OF AN IMPROVED PALM KERNEL SHELLING MACHINE AND SEPARATOR

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1. Executive Summary

The Design and Development of an Improved Palm Kernel Shelling Machine and Separator presents a transformative opportunity for Nigeria's agro-processing sector, with direct implications for national economic growth. By increasing palm kernel recovery rates, reducing breakage losses, and improving processing efficiency, the innovation will significantly enhance value addition in the palm oil value chain, an industry that remains one of Nigeria's most strategic non-oil sectors. On a macroeconomic scale, higher productivity and processing capacity will contribute to the Gross Domestic Product (GDP) by boosting agricultural output, stimulating industrial growth, and creating multiplier effects across transportation, packaging, and export. At the sub-national level, the adoption and commercialization of the machine will expand Internally Generated Revenue (IGR) as states capture more taxes and levies from increased agro-processing activities and the establishment of small- and medium-scale enterprises (SMEs). From an investment standpoint, the machine's affordability, reliance on locally sourced materials, and job creation potential in fabrication, operation, and maintenance ensure a high Return on Investment (RoI), making it attractive to both private investors and public agencies. Ultimately, this project will strengthen Nigeria's economic diversification agenda, reduce import dependency, and drive inclusive growth by empowering smallholder farmers and SMEs to exploit the nation's vast palm oil resources fully.

2. Problem Statement

At present, palm kernel shelling in Nigeria is dominated by manual cracking and the use of rudimentary or outdated locally fabricated machines. Manual methods often involving stones or simple tools are widespread among smallholder farmers due to their low cost and accessibility, but they are highly inefficient, labour-intensive, and result in significant kernel losses and breakage. Some mechanical, pneumatic, and hydrocyclone-based technologies have been introduced in research and industrial contexts, achieving much higher separation efficiencies (74–96%) and improved product quality compared to traditional methods [1]. However, these advanced systems are often imported, expensive and inaccessible to the majority of small and medium-scale enterprises (SMEs) in rural Nigeria. Locally fabricated machines, while more affordable, are typically limited in efficiency, lack integrated separation mechanisms, and contribute to high rates of kernel breakage. This gap highlights the pressing need for an affordable, efficient, and scalable solution that combines shelling and separation into one compact system. Addressing this challenge through the design and commercialization of an improved palm kernel shelling machine with integrated separation will bridge the divide between low-cost but inefficient traditional practices and high-performing but unaffordable advanced technologies, empowering smallholders and SMEs while strengthening Nigeria's agro-processing capacity [2].

3. Key Innovation/Uniqueness:

The key innovation of this technology lies in its ability to integrate shelling and separation into a single compact machine, eliminating the need for multiple equipment and thereby simplifying operations. Unlike conventional systems, it delivers higher efficiency with a significantly lower breakage rate, ensuring better product quality and reduced losses. A major uniqueness is the use of affordable, locally sourced materials, which not only lowers production costs but also makes the machine more accessible and sustainable within local contexts. Furthermore, its scalable design allows adaptability across different user levels, ranging from smallholder farmers to small- and medium-scale enterprises (SMEs), making it a versatile and impactful solution for diverse agricultural needs.

4. Anticipated Impact:

This innovation is designed to increase palm kernel recovery rates by over 30%, significantly boosting productivity and value addition in the palm oil sector. By providing affordable mechanization, it will empower local farmers and small- to medium-scale enterprises (SMEs) to enhance efficiency and competitiveness, bridging the gap between traditional methods and modern processing. Beyond its technical benefits, the initiative will create employment opportunities in fabrication, operation, and maintenance, thereby stimulating local economies. Importantly, it will also contribute to reducing Nigeria's dependency on imported agricultural products by strengthening the nation's agro-processing capacity and promoting self-sufficiency.

5. Introduction

5.1. Alignment with NASENI's Vision and Mission

This project aligns with NASENI's mandate of advancing science, technology, and engineering to support Nigeria's industrialisation and self-reliance. It directly supports NASENI's strategic goals of *Creation* (indigenous design), *Collaboration* (working with farmer cooperatives and local industries), and *Commercialisation* (market-ready solution for agriculture).

5.2.Challenge Context

The NASENI Innovation Challenge prioritizes manufacturing and agriculture solutions that enhance productivity and reduce waste. Our proposed machine addresses inefficiencies in palm kernel processing, a critical agricultural subsector—making it a perfect fit for the challenge.

5.3.Target Beneficiaries:

This project is strategically tailored to impact multiple stakeholders across Nigeria's agricultural value chain. The primary beneficiaries include:

- Smallholder palm oil farmers, who will gain access to affordable mechanization that increases kernel recovery and reduces losses.
- SMEs in agro-processing, which will benefit from improved efficiency, scalability, and competitiveness in palm kernel processing.
- Fabricators and local machine manufacturers, who will experience increased demand for machine production, maintenance, and parts supply, thereby creating sustainable jobs.
- End-consumers, who will ultimately enjoy reduced costs of palm kernel products as efficiency gains and local production lower market prices.

5.4. Current Solutions and Gaps

Manual cracking is inefficient and time-consuming, while existing mechanical shellers are costly, have high kernel breakage rates, and often lack integrated separators. Imported machines are unaffordable and unsuitable for local conditions. This innovation will address these gaps with a cost-effective, efficient, and locally adaptable solution.

6. Project Description and Innovation

The innovation of the proposed project can be explained in four details:

- Concept and design: The machine integrates a rotary shelling mechanism with a vibrating separator unit. Adjustable clearance ensures minimal breakage across different kernel sizes.
- Technological aspect: The design incorporates optimized force application and airflow-based separation for higher precision. Locally sourced materials will be used to enhance affordability and repairability.
- Uniqueness and competitive Advantage: Unlike most existing machines, this design combines shelling and separation in one system, reducing labour and operating costs.
- Scalability and adaptability: The machine can be fabricated at different capacities (50–500 kg/hr) to serve smallholder farmers, cooperatives, and industrial processors.

7. Goal and Objectives

The goal of the project is to enhance palm kernel processing efficiency in Nigeria through an innovative shelling and separating machine.

The SMART objectives of the project include:

- Design and prototype an improved palm kernel shelling and separating machine within 6 months.
- Test and optimize performance to achieve >85% shelling efficiency and <10% kernel breakage in 9 months.
- Deploy and field-test prototypes with at least 3 farmer cooperatives within 12 months.
- Commercialize through partnerships with local fabricators by month 18.

8. Methodology/Approach:

8.1. Project segmentation

The project will be executed in various phases, as outlined below:

- Phase 1: Design and simulation (Months 1–3). This activity will include initial design concepts and simulation of project components.
- Phase 2: Prototype fabrication (Months 4–6). The activity will focus on developing physical prototypes based on the design from Phase 1.
- Phase 3: Laboratory and field testing (Months 7–12). In this phase, thorough testing will be conducted to evaluate the performance of the prototype.
- Phase 4: Optimization and commercialization plan (Months 13–18). Analyses of the test results, product optimization and strategy planning will be implemented for the commercialization of the products.

8.2. Feasibility and risk mitigation

This section outlines the potential risks associated with the project and the strategies for mitigating them.

- Risk of component wear. Continuous shelling operations may cause wear on critical parts such as the rotary shelling mechanism. The risk will be mitigated by adopting an appropriate material selection to utilize durable materials, thereby enhancing the lifespan and durability of the components with reduced maintenance frequency.
- Financial risks. High upfront costs can pose challenges for individual farmers and small enterprises. To minimize this, the project will leverage partnerships with cooperatives, farmer associations, and microfinance institutions to promote shared ownership and financing models.
- Adoption risks. Resistance to adopting new technologies may arise due to user unfamiliarity or mistrust. To mitigate the adoption risk, farmers will be engaged at the early

stage of the design process to enable the design of user-friendly, simple to operate and easy to maintain products.

8.3. Sustainability plan

The long-term sustainability of the improved palm kernel shelling and separating machine will be ensured through a multi-pronged strategy that balances financial viability, stakeholder engagement, and continuous product enhancement.

- Revenue generation: Sustainability will be supported by income from direct machine sales as well as after-sales services, including the supply of spare parts and routine maintenance, ensuring a steady revenue stream for both fabricators and distributors.
- Strategic partnerships: Collaboration with farmer cooperatives and agro-based SMEs will drive large-scale adoption, promote shared ownership models, and enable expansion into new markets while spreading financial risks.
- Continuous improvement: A feedback mechanism will be established to capture user experiences, enabling iterative design improvements and technology upgrades that maintain relevance, efficiency, and competitiveness over time.

9. Impact and Commercialization

9.1. Alignment with national priorities

This project directly aligns with Nigeria's socio-economic development agenda by:

- Contributing to food security and agro-industrialisation through improved efficiency and reduced post-harvest losses.
- Supporting job creation and rural development, consistent with Nigeria's economic diversification priorities.
- Promoting environmental sustainability by reducing waste and encouraging the use of affordable, locally sourced materials.

9.2. Commercialization strategy

A comprehensive commercialization framework has been designed to ensure large-scale adoption and long-term viability:

- Market analysis: Nigeria's market potential includes over 2 million smallholder palm oil farmers and over 200 cooperatives, presenting a robust and growing demand for affordable processing technologies.

- Go-to-market strategy: Distribution will be achieved through direct sales to farmer cooperatives, partnerships with agro-machinery distributors, and leveraging government agricultural extension programs.
- Business model: Revenue will be generated from machine sales complemented by after-sales services such as training, maintenance, and spare parts supply.
- IP strategy: Protection of intellectual property through a patent application for the machine's mechanical design and a trademark for brand identity to strengthen market competitiveness.
- Future funding/investment: Expansion will be supported by attracting private investors and fostering collaborations with agribusiness development agencies to scale production and distribution nationwide.

10. Project Team

The project team comprises mechanical engineers, agricultural technologists, and local fabricators with hands-on expertise in agro-processing equipment. The team has prior experience in prototyping and deploying small-scale farm machinery. The team members with their respective roles are outlined below:

- Project lead: Engr. Dr. Anamu Ufoma Silas - Oversees design, development, and implementation.
- Mechanical engineers: Responsible for machine design and prototyping.
    1. Engr. Adejugbe Idowu Tolulope
    2. Engr. Oyegunwa Olufemi Ayoola
- Agricultural technologist: Ensures alignment with palm processing needs.
    3. Engr. Haruna Abdulahi
- Fabricators: Handle local production and assembly.
    4. Engr. Jolly Aigbovbiosa Osagie
    5. Iliya Daylop Daboro
- Business/commercialization manager: Leads market deployment strategy.
    1. Mr. Otebiyi Olusola

11. Estimated Budget and Budget Justification

11.1 Estimated budget

The project budget is categorized into key cost components, which include project planning and design, materials procurement, fabrication and assembly, testing and evaluation, and overhead and contingency costs, to ensure transparency and effective allocation of resources:

Table 1. Project Planning and Design

Item	**Description**	**Estimated Cost (₦)**
Literature review and feasibility study	Review of existing palm kernel machines, data collection, and performance benchmarks	200,000
Design and simulation	CAD modeling, stress analysis, and performance simulations	250,000
Technical documentation	Preparation of drawings, specifications, and manuals	150,000
Subtotal		**600,000**

Table 2. Materials Procurement

Component	Material Used	Estimated Cost (₦)
Hopper, entry regulator, body frame, separator barrel	Mild steel (due to strength and availability)	350,000
Shafts and keys	Mild steel (high strength, machinability)	230,000
Gears	Cast iron (durability and wear resistance)	200,000
Hammer mill and blades	Mild steel (removable and replaceable)	250,000
Bearings, bolts, nuts and fasteners	Standard mechanical fittings	150,000
Prime mover (5 hp electric motor or engine)	To power cracking and separating units	450,000
Miscellaneous (paint, lubricants, welding and rods,)	Consumables for fabrication	170,000
Subtotal		**1,800,000**

Table 3. Fabrication and Assembly

Activity	Description	Estimated Cost (₦)
Cutting and machining	Lathe, milling, and drilling of components	200,000
Welding and joining	Frame, hopper, and assembly welding	150,000
Heat treatment	For shafts and hammer mill durability	80,000
Assembly and fitting	Putting together cracking and separating units	150,000
Subtotal		**580,000**

Table 4. Testing and Evaluation

Item	Description	Estimated Cost (₦)
Test samples	Palm kernels (various sizes, ~12,000 nuts)	130,000
Performance testing	Efficiency, throughput, and durability tests	200,000
Data analysis and optimization	Adjustment, tuning, and recalibration	200,000
Subtotal		**530,000**

Table 5. Overheads and Contingency

Item	Description	Estimated Cost (₦)
Transportation and logistics	Movement of materials and machine	300,000
Utilities (Electricity, water, etc.)	Workshop utilities during fabrication	250,000
Contingency (10%)	Unexpected costs	560,000
Subtotal		**1,110,000**

Table 6. Total Project Cost

Category	Subtotal (₦)
Project planning and design	600,000
Materials procurement	1,800,000
Fabrication and assembly	580,000
Testing and evaluation	530,000
Overheads and contingency	1,110,000
Total Estimated Budget	**₦4,620,000**

11.2. Budget justification:

The budget allocation ensures cost-effectiveness and sustainability by prioritizing the use of locally available materials to reduce procurement costs while promoting local manufacturing. Investment in fabrication and testing is emphasized to guarantee durability, efficiency, and adaptability of the machine to various scales of operation. The inclusion of overhead and contingency ensures the project remains resilient to price fluctuations and unexpected challenges. This structured allocation maximizes value for money while supporting long-term scalability and commercialization.

12. Monitoring & Evaluation

12.1. Evaluation plan

Project progress will be monitored on a quarterly basis against clearly defined milestones covering design, fabrication, testing, and commercialization phases. Field performance will be evaluated through farmer feedback and kernel recovery efficiency tests to ensure the machine meets practical user needs and industry standards.

12.2. Key Performance Indicators (KPIs)

The following indicators will be tracked to measure project success:

- Shelling efficiency: ≥ 85%
- Kernel breakage rate: ≤ 10%
- Technology adoption: At least 20 cooperatives adopting the machine within two years
- Job creation: 100+ direct and indirect jobs generated in the first year post-commercialization

12.3. Data collection methods

Performance data will be gathered through multiple approaches:

- Prototype testing logs to capture operational efficiency and technical adjustments.
- Farmer surveys to document usability, satisfaction, and socio-economic impact.
- Adoption rate tracking to monitor the spread and uptake of the technology among cooperatives and SMEs.

12.4. Reporting

Progress will be documented in quarterly reports submitted to NASENI, with a comprehensive final project evaluation prepared after 18 months. Reports will highlight achievements against KPIs, and recommendations for scaling and commercialization.

References

[1] P.P. Ikubanni, R.A. Ibikunle, O.O. Agboola, F.A. Oyedare, O.M. Adewuyi, O.B. Hassan, P.C. Nwachukwu, A.A. Adeleke, E. Omotosho, Performance Evaluation and Optimization of a Palm Kernel Cracker–A Taguchi-Grey Relational Analysis Approach, Math. Model. Eng. Probl. 12 (2025) 1409–1422. https://doi.org/10.18280/mmep.120431.

[2] A. O.M, K.-K. D.B, B. L.I, Palm Kernel Separation Efficiency and Kernel Quality from Different Methods Used in Some Communities in Rivers State, Nigeria, J. Food Technol. Res. 4 (2017) 46–53. https://doi.org/10.18488/journal.58.2017.42.46.53.