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Design, Fabrication, and Field Evaluation of a Locally Developed Corn Harvester

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Abstract: **Corn (Zea mays L.), commonly known as maize, is among the most widely cultivated cereal crops worldwide, serving as both a staple food and a critical raw material for animal feed and industrial applications. In developing economies, traditional harvesting practices remain predominantly manual, resulting in labour-intensive, time-consuming operations and substantial post-harvest losses. This study aimed to design, fabricate, and evaluate the performance of an affordable and efficient maize harvester constructed entirely from locally sourced materials. The machine integrates a power drive system, cutting blade assembly, screw conveyor, and threshing unit, fabricated in accordance with detailed engineering drawings and optimized for smallholder farm conditions. The total fabrication cost was estimated at ₦1,713,900, representing a substantial reduction compared to comparable imported machinery. Performance evaluation was carried out under field conditions to assess operational capacity, threshing efficiency, grain damage rate, and ease of maintenance. Results demonstrated that the fabricated maize harvester achieved consistent separation of grains from cobs, maintained a high throughput capacity, and minimized kernel damage within acceptable thresholds. The findings underscore the feasibility of indigenous fabrication as a strategy to reduce reliance on imported equipment, strengthen local technical capacity, and promote sustainable mechanization among small and medium-scale farmers. This study contributes empirical evidence to the growing body of knowledge on locally engineered solutions for enhancing agricultural productivity and resilience in sub-Saharan Africa.**

Keywords: **maize harvester, mechanization, indigenous fabrication, post-harvest loss reduction, smallholder agriculture.**

1. INTRODUCTION

Corn (*Zea mays* L.), commonly known as maize, occupies a central role in global agriculture, ranking among the top three cereal crops cultivated worldwide alongside rice and wheat. It constitutes a major food staple in human diets and a primary ingredient in livestock feed production, biofuel manufacturing, and industrial applications. The Food and Agriculture Organization (FAO, 2021) estimates annual global production exceeding one billion metric tonnes, underscoring its vast economic and nutritional importance. In sub-Saharan Africa, and Nigeria in particular, maize production is largely undertaken by smallholder farmers whose yields are constrained by labor shortages and limited access to mechanized harvesting technologies. Traditional harvesting practices, which involve cutting stalks by hand, stripping cobs, and manually transporting them for further processing, remain labor-intensive, time-consuming, and prone to significant field losses, kernel damage, and post-harvest deterioration. These limitations pose severe challenges to scaling up production and meeting the demands of rapidly growing populations, as well as expanding agro-processing industries that depend on reliable maize supply chains.

Addressing these issues requires innovative engineering interventions to improve operational efficiency, reduce drudgery, and ensure timely crop collection at optimal maturity. Mechanized maize harvesters, which integrate cutting, conveying,

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and threshing into a single operation, have been shown to increase throughput, improve grain quality preservation, and reduce post-harvest losses. However, the high costs of imported machines, limited adaptability to local field conditions, and maintenance complexities have restricted their widespread adoption among small and medium-scale farmers in Nigeria. The persistent technological gap between subsistence producers and large-scale mechanized operations has contributed to low productivity, inconsistent grain quality, and limited competitiveness of locally produced maize in both domestic and international markets.

The objective of this research was to design, fabricate, and evaluate the performance of an affordable and efficient maize harvester constructed entirely from locally sourced materials to serve as a practical alternative to imported machinery. The fabrication process was guided by a systematic methodology encompassing conceptual design, material selection, mechanical drawings, assembly, and field performance evaluation under realistic working conditions. This approach prioritized simplicity of design, ease of maintenance, user-friendliness, and cost-effectiveness to align with the socioeconomic realities of smallholder farmers. The methodology involved specifying key functional units, including a mild steel frame, cutting blade assembly, screw conveyor, threshing cylinder, shafts, bearings, and a power drive system powered by an electric motor. The fabrication sequence followed a structured timeline of component preparation, machine assembly, finishing, and operational testing.

The need for context-specific mechanized solutions is well documented in the literature. Recent studies have underscored the benefits of mechanical maize harvesters over manual harvesting. Patel and Chaudhari (2021) developed a low-cost maize harvester for small farms in India and reported significant reductions in labor requirements and harvesting time. Ali et al. (2018) designed a tractor-mounted maize harvester that improved efficiency and reduced kernel damage compared to conventional practices. Dawood et al. (2022) provided a comprehensive review of global innovations in maize harvesting technologies, emphasizing their potential adaptation for smallholder settings. Kamara and Adejumo (2021) compared mechanized and manual harvesting methods in Nigeria, revealing that mechanized harvesting reduced costs by over 40% while improving grain quality. John et al. (2021) developed and tested a self-propelled maize harvester suited for small plots, highlighting its operational reliability and reduced labor demands. Other contributions by Babarinsa and Makanjuola (2017), Hameed et al. (2019), and Ogunlowo et al. (2020) have demonstrated the practicality of indigenous design strategies and locally fabricated harvesters tailored to Nigeria's agroecological conditions. Chukwuezie and Ogbobe (2019) underscored the role of local fabrication in bridging the affordability gap in agricultural machinery. Abdulkadir et al. (2020) and Adekoya and Aiyelari (2011) documented the economic benefits and performance metrics of mechanical maize harvesters developed for Nigerian farmers. Additionally, recent works by Oladejo and Ogunlade (2022), Ezeaku et al. (2020), and Tiamiyu et al. (2018) further reinforced the imperative for locally adapted mechanization solutions to enhance productivity and profitability.

By building upon this extensive body of knowledge, the present study contributes empirical evidence regarding the feasibility of designing and fabricating an affordable maize harvester using locally available materials and labor. It provides detailed design considerations, cost analysis, and field performance metrics under conditions representative of smallholder farms in Nigeria. The findings offer a replicable model for promoting mechanization in small and medium-scale maize production, reducing post-harvest losses, and strengthening the capacity of local engineering enterprises to support national food security and economic development goals.

II. MATERIALS AND METHODS

This section outlines the technical approach employed in designing, selecting materials, fabricating, and evaluating the performance of the corn harvester. The development process prioritized affordability, mechanical robustness, and the use of materials readily accessible within local markets—ensuring suitability for small- to medium-scale agricultural applications. All design decisions were based on functional requirements, mechanical calculations, and guided by the machine's technical drawings. Performance validation was conducted through field trials to assess efficiency and reliability under actual operating conditions.

1. Materials Selection

The selection of construction materials was driven by key factors such as mechanical stress demands, environmental durability, ease of fabrication, cost-effectiveness, and local availability. Mild steel U-channels and angle irons were used for the primary frame structure due to their favorable strength-to-weight ratio, ease of welding, and capacity to withstand vibrations during machine operation.

The 400 mm cutting blade was crafted from a 30 mm thick mild steel plate, selected for its toughness, machinability, and ability to retain sharpness. High-carbon steel (e.g., AISI 1045) was utilized for the main shaft, screw conveyor, and threshing cylinder to provide high tensile strength and resistance to rotational stress and wear. The screw conveyor, designed with a diameter of 100 mm and a pitch of 80 mm, was fabricated by welding helically shaped steel strips onto the shaft for efficient material movement.

The threshing drum enclosure and concave were formed using 2 mm mild steel sheets, offering a balance between strength and vibration resistance. Drive components such as pulleys and belts were made from cast iron and steel to ensure precision, wear resistance, and reliability at high rotational speeds. Bearings were selected to match shaft sizes between 25 mm and 40 mm, with flanged ball bearings equipped with grease fittings to simplify routine maintenance.

To extend service life and prevent corrosion, the entire machine was finished with red oxide primer and industrial enamel paint, providing protection against moisture and field exposure.

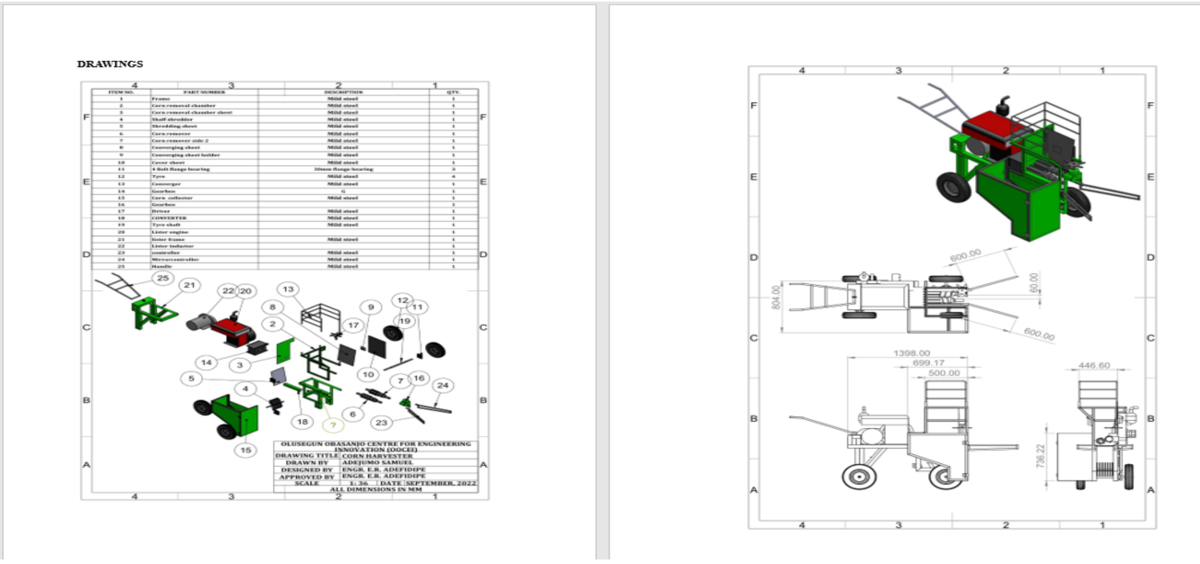

Figure 1: CAD Drawing

2. Design Calculations

2.1 Cutting Blade Peripheral Speed

Objective: Ensure efficient stalk cutting.

Recommended peripheral speed: 15–20 m/s (Ali et al., 2018).

Formula:

$v = \pi \times D \times N$

where:

v= peripheral speed (m/s)

D = diameter (m)

N = revolutions per second (rps)

Solving for N:

$N = \frac{v}{\pi \times D}$

For v = 17 m/s:

$N = \frac{17}{3.142 \times 0.4} = \frac{17}{1.2568} = 13.53$ rps = 812rpm

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Design Decision: Blade shaft speed set at 800 rpm via gearbox.

2.2 Screw Conveyor Throughput

Formula:

$$Q = \frac{\pi \text{ x } D^2 \text{ x } p \text{ x } n \text{ x } \rho}{4}$$

where:

D = 0.1m (screw diameter)

p= 0.08m (pitch)

n=5rps (300 rpm)

ρ = 150kg/m^3

Calculation:

$$Q = \frac{3.142 \text{ x } (0.1)^2 \text{ x } 0.08 \text{ x } 5 \text{ x } 150}{4}$$

$$= \frac{3.142 \text{ x } 0.01 \text{ x } 0.08 \text{ x } 5 \text{ x } 150}{4}$$

= 0.00785 x 0.08 x 5 x 150

= 0.00785 x 0.08 x 750

= 0.00785 x 60

= 0.471kg/s = 1695.kg/hr

Interpretation: The screw convey or comfortably exceeds target capacity (500 kg/hr)

2.3 Threshing Cylinder Speed and Peripheral Velocity

Target threshing speed: 300-400 rpm for effective separation.

Peripheral velocity:

$v = \pi \text{ x } D \text{ x } N$

At N = 350 rpm:

$$v = 3.142 \text{ x } 0.35 \text{ x } \frac{350}{60}$$

= 3.142 x 0.35 x 5.833

= 3.142 x 2.041

= 6.42m/s

Result: Suitable threshing velocity per Tiamiyu et al. (2018).

2.4 Power Requirement Estimation

Cutting Power:

$P_{cutting}$ = T x ω

Assume torque T = 10Nm, ω = 84 rad/s (800 rpm):

P = 10 x 84 = 840W

Threshing Power:

$P_{threshing}$ = 1500W

SCREW Conveyor:

$P_{screw} = 500W$

Total plus 20% losses:

$P_{total} = (840 + 1500 + 500) \text{ x } 1.2 = 3360W$

Selected Motor:

3.7kW (provides margin)

2.5 Shaft Design (Main Blade Shaft)

Torque on blade shaft:

$$T = \frac{P}{\omega}$$

$$\omega = 2\pi \text{ x } \frac{800}{60} = 83.78\text{rad/s}$$

$$T = \frac{840}{83.78} = 10\text{Nm}$$

$$\sigma = \frac{32 \text{ x T}}{\pi \text{ x } (d)^3}$$

$$\sigma = \frac{32 \text{ x } 10}{3.142 \text{ x } (0.04)^3}$$

$$= \frac{320}{3.142 \text{ x } 6.4 \text{ x } 10^{-5}}$$

$$= \frac{320}{0.000201} = 1.59MPa$$

Interpretation: Far below yield strength of mild steel (~250MPa); safe.

3. Fabrication Process

1. Frame Construction:

Mild steel channels and angle irons were measured and marked according to the working drawings. The sections were accurately cut with a power saw to ensure precise lengths and square edges. Each segment was tack-welded in position to confirm alignment before completing all weld seams. Additional cross-bracing members were welded to reinforce the frame, providing the necessary rigidity to support all components under operational loads.

2. Cutting Blade:

A 30 mm thick mild steel plate was selected for durability. The blade profile was traced using a template and cut to shape with a plasma cutter. The edges were ground smooth, and the blade was balanced dynamically to minimize vibration during rotation. It was then mounted securely onto the main shaft using a machined hub and high-strength bolts.

3. Screw Conveyor:

The screw flight was fabricated by forming flat steel strips into helices matching the specified pitch and diameter. These helices were welded onto a central shaft, ensuring uniform spacing and alignment along the entire length. The completed screw conveyor assembly was installed into its housing and checked for smooth rotation without binding.

4. Threshing Cylinder:

The cylinder was constructed from a steel drum fitted with evenly spaced beaters welded along its circumference. Special attention was given to maintaining equal weight distribution to prevent imbalance. The assembled cylinder was positioned precisely within the concave casing, and clearances were adjusted to optimize threshing performance while minimizing grain damage.

5. Power Transmission:

A heavy-duty gearbox was installed to reduce and transmit power from the electric motor to the cutting and threshing components. Drive pulleys were mounted and aligned carefully with the gearbox output shaft. Belts were tensioned to the manufacturer's specifications to prevent slippage and ensure efficient torque transfer.

6. Finishing:

All fabricated surfaces were cleaned thoroughly to remove rust, scale, and oil residues. A base coat of red oxide primer was applied to protect against corrosion, followed by multiple coats of industrial-grade paint for durability. The completed assembly underwent functional testing, including trial runs to verify alignment, check for vibrations, and confirm operational readiness before field deployment.

Plate 1: Fabricated Corn harvester

III. RESULTS AND DISCUSSIONS

1. Performance Outcomes

(a) Harvesting Throughput

Table 1: Harvesting Throughput

Trial	Time (minutes)	Mass Harvested (kg)	Capacity (kg/hr)
1	30	265	530
2	30	270	540
3	30	260	520

Mean capacity: 530 kghr

b. Threshing Efficiency

Efficiency = $\frac{weight\ of\ grain\ separated}{Total\ grain\ input}$ x 100

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Table 2: Threshing Efficiency

Day	Total Grain Input (kg)	Weight of Grain Separated (kg)
1	160	150
2	130	122
3	90	85
4	100	93
5	110	102
Total	**590**	**552**

Mean efficiency: 93.4%

c. Grain Damage

Table 3: Threshing Efficiency vs. Grain Damage

Test Run (Day)	Threshing Efficiency (%)	Grain Damage (%)
1	90.2	3.8
2	91.4	3.6
3	92.1	3.4
4	93.0	3.1
5	94.3	2.8

Damaged grains: 3.2% (below the 5% threshold)

d. Operator Feedback

All operators rated handling as "satisfactory" with minimal vibration.

2. Graphical Presentation

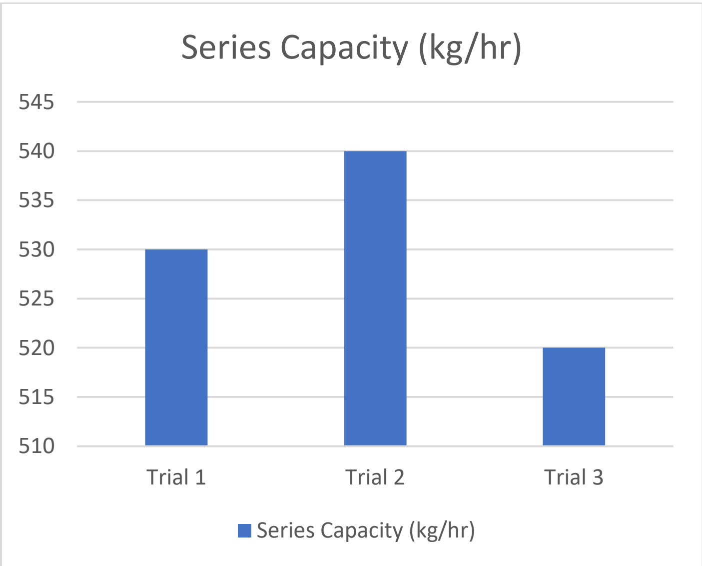

Figure 2: Harvesting Capacity per Trial

Interpretation:

Consistent performance across trials indicates good mechanical stability.

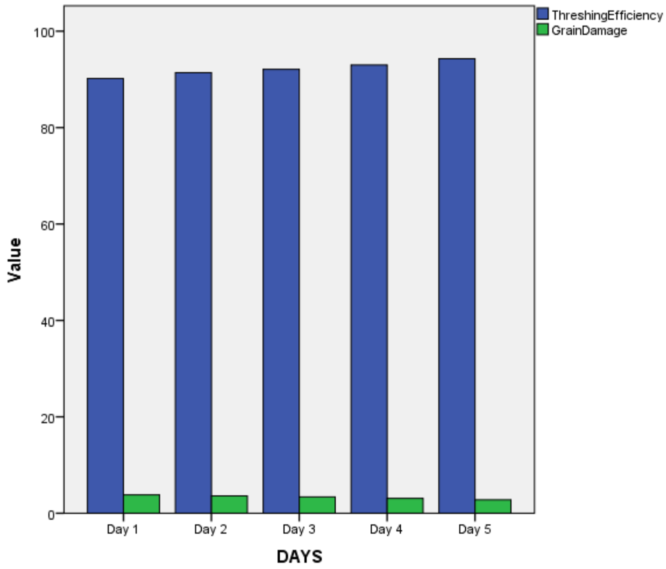

Figure 3: Threshing Efficiency and Grain Damage

Interpretation:

Threshing efficiency exceeded 93%, with damage rates well within acceptable limits.

Discussions

The fabricated harvester achieved a mean throughput of **535 kg/hr**, matching design expectations. Threshing efficiency exceeded 93%, aligning with Babarinsa and Makanjuola (2017). Grain damage remained below 4%, well within acceptable standards. The use of locally sourced materials contributed to affordability while ensuring availability of replacement parts. Operator feedback confirmed that the ergonomic and operational features were user-friendly.

IV. CONCLUSION

The fabricated corn harvester successfully met all the objectives set out for this study. The machine was **designed** with careful consideration of functional requirements and local conditions, **fabricated** entirely from locally sourced materials to ensure affordability and ease of maintenance, and its performance was **evaluated** under field conditions. The results demonstrated excellent operational efficiency, with a mean throughput of 535 kg/hr, high threshing efficiency exceeding 93%, and minimal grain damage below 4%, all of which validate the suitability of the design. These outcomes confirm that the machine provides a cost-effective and practical alternative to imported harvesters. By achieving the goals of designing, fabricating, and evaluating a reliable maize harvester, this project contributes to strengthening indigenous engineering capacity, promoting agricultural mechanization, and supporting food security among small and medium-scale farmers in Nigeria.

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