Development and Performance Evaluation of a Multi-Purpose Grain Thresher for Maize, Sorghum, Millet, and Beans

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ABSTRACT

Post-harvest grain losses caused by inefficient threshing technologies remain a critical constraint to agricultural productivity in developing economies. This study reports the development and performance evaluation of the Yalwa Multi-Purpose Grain Thresher, designed to process maize, sorghum, millet, and beans using a single adaptable system. The machine incorporates an interchangeable sieve mechanism to accommodate grains with different physical characteristics without requiring a completely separate machine for each crop. Fabrication was carried out at the Department of Agricultural Engineering Technology Workshop, Ramat Polytechnic, Maiduguri, under the leadership of Engineer Issa Yelwa, with technical support staff. Performance evaluation was conducted using maize, sorghum, millet, and beans, with appropriate sieve sizes used for each crop. The maximum recorded threshing efficiency was 92%, indicating effective grain detachment and separation. The machine produced grains of satisfactory quality with low visible damage. The results indicate that the machine has potential for small- and medium-scale farming applications and provides a locally fabricated approach to reducing post-harvest losses and improving grain-processing efficiency. For subsequent trials, performance should be evaluated under controlled combinations of crop moisture content, feed rate, drum speed, sieve aperture, and crop variety, with throughput, grain breakage, unthreshed grain, material losses, energy or fuel consumption, and downtime recorded alongside threshing efficiency.

Keywords: Multi-purpose grain thresher; post-harvest losses; threshing efficiency; agricultural mechanization; interchangeable sieve.

INTRODUCTION

Cereal and legume crops such as maize, sorghum, millet, and beans constitute a major component of food systems in sub-Saharan Africa, serving as primary sources of nutrition and household income. Despite increased efforts to improve crop production, post-harvest losses continue to undermine food security, with threshing identified as one of the loss-prone operations in the grain value chain (FAO, 2019). In many rural farming communities, threshing is still performed using traditional manual methods that are labor-intensive, inefficient, and associated with grain losses, contamination, and physical drudgery (Ajav & Adejumo, 2015). Although mechanical threshers have been introduced to address these challenges, many available designs are crop-specific and lack operational flexibility. Mechanical thresher performance is affected by operating and crop conditions. Important variables include drum speed, feed rate, crop moisture content, sieve aperture, crop variety, and the physical properties of the material being processed. These variables can influence grain detachment, separation, grain damage, losses, throughput, and energy demand. Interchangeable sieve systems provide a practical design strategy for adapting a threshing machine to crops with different grain dimensions and separation requirements (Ndirika & Oyeleke, 2020).

This study therefore presents the design, construction, and performance evaluation of the Yalwa Multi-Purpose Grain Thresher, developed to thresh maize, sorghum, millet, and beans. The primary objective is to develop a versatile and efficient grain threshing machine capable of reducing post-harvest losses and improving grain-processing efficiency. Post-harvest grain losses due to inefficient threshing methods remain a major constraint to small- and medium-scale farming productivity in developing countries. Existing mechanical threshers are often designed for single crops, are expensive, or do not adapt well to varying grain sizes and types. This creates high labor demand, grain losses, and poor grain quality. There is therefore a need for versatile, cost-effective, and efficient threshing machines suitable for diverse crops. The main objectives of this study are:

i. to design and fabricate a multi-purpose grain thresher capable of threshing maize, sorghum, millet, and beans.
ii. to evaluate the performance of the Yalwa Multi-Purpose Grain Thresher, including threshing efficiency and grain quality.
iii. to demonstrate the feasibility of a locally fabricated, adaptable thresher for small- and medium-scale farmers.

The machine is therefore significant in reduce post-harvest losses and improve grain quality; enhance labor efficiency and reduce drudgery; Provide a locally fabricated and adaptable technology for diversified farming systems and contribute to sustainable agricultural mechanization in resource-constrained farming systems.

LITERATURE REVIEW

Threshing is a critical post-harvest operation involving separation of grains from crop heads, panicles, or pods. Traditional threshing methods, including manual beating and trampling, remain prevalent in many developing regions but are characterized by low efficiency, high labor demand, and significant grain losses (FAO, 2019). Mechanical grain threshers operate primarily through impact, rubbing, or combined mechanisms, with design variations influenced by crop type, grain size, and moisture content (Singh et al., 2017). Several researchers have reported the design and evaluation of mechanical threshers for specific grain crops. Ajav and Adejumo (2015) developed a motorized grain thresher and reported improved efficiency and reduced labor requirement compared with traditional methods. Ogunlade et al. (2016) evaluated mechanical threshers and observed that threshing efficiency and grain damage are influenced by operating conditions such as drum speed and concave clearance. Kumar et al. (2018) developed a multi-crop thresher and reported that adaptability remains a challenge because of differences in grain size and physical properties. The sieve unit is a critical component in grain threshers because it influences separation efficiency and grain cleanliness. Ndirika and Oyeleke (2020) reported that appropriate selection of sieve aperture size improves grain separation and reduces losses. Adjustable and interchangeable sieve designs are therefore practical solutions for multi-crop threshing. Improper sieve sizing can increase grain loss and chaff contamination and reduce overall machine efficiency (Khurmi & Gupta, 2018).

The sieve unit is a critical component in grain threshers, as it directly influences separation efficiency and grain cleanliness. Ndirika and Oyeleke (2020) reported that appropriate selection of sieve aperture size significantly improves grain separation and reduces losses. Adjustable and interchangeable sieve designs have been recommended as practical solutions for achieving multi-crop threshing functionality. Studies have shown that improper sieve sizing can lead to increased grain loss, chaff contamination, and reduced overall machine efficiency (Khurmi & Gupta, 2018). Consequently, the integration of interchangeable sieves has become a key design consideration in modern multi-purpose threshers. Although several threshing machines have been developed and evaluated, there remains a need for locally fabricated, cost-effective, and adaptable multi-purpose threshers suitable for small- and medium-scale farmers. Many reported designs either lack sufficient versatility or are economically inaccessible to rural users. This study addresses this need by developing and evaluating the Yalwa Multi-Purpose Grain Thresher with an interchangeable sieve system and locally available materials and fabrication techniques.

MATERIALS AND METHODS

The design and fabrication of the Yalwa Multi-Purpose Grain Thresher were carried out at the Department of Agricultural Engineering Technology Workshop, Ramat Polytechnic, Maiduguri, Nigeria. Construction materials included mild steel sheets, angle iron, steel shafts, bearings, pulleys, belts, bolts, nuts, and interchangeable sieves with varying aperture sizes. Mild steel was selected because of its mechanical strength, availability, ease of fabrication, and economic suitability for locally manufactured agricultural machinery (Khurmi & Gupta, 2018). The Yalwa Multi-Purpose Grain Thresher comprises a feeding hopper, threshing drum, concave, interchangeable sieve unit, blower assembly, grain outlet, chaff outlet, supporting frame, and power-transmission system. The threshing drum operates through combined impact and rubbing to detach grains from crop heads or pods. The interchangeable sieve system enables the machine to accommodate grains of different sizes and physical properties. Grains are manually fed into the hopper and conveyed into the rotating threshing drum. Grain separation occurs through impact and friction between the drum and concave. The threshed grains pass through the concave onto the sieve unit, where size-based separation occurs, while the blower removes lighter chaff materials. Clean grains are discharged through the grain outlet.

Figure 1: *YMPGT Grain thresher before finishes*

Performance tests were conducted using maize, sorghum, millet, and beans. A known mass of each crop was fed into the machine, and threshing efficiency was determined as the ratio of threshed grains to total grain input, expressed as a percentage (Ajav & Adejumo, 2015). Appropriate sieve sizes were used for each crop during testing. The maximum recorded threshing efficiency was 92%. For a more comprehensive engineering evaluation, the performance-test protocol includes crop moisture content, feed rate, drum speed, sieve aperture, crop variety, throughput capacity, threshing efficiency, percentage of unthreshed grains, grain breakage, material losses, energy or fuel consumption, operating time, and machine downtime. These variables are recorded for each crop and operating condition so that their effects on machine performance can be quantified.

The principal indicators calculated are as follows:

$$Threshing\ efficiency\ (\%) = \frac{\text{mass of threshed grain}}{\text{total grain input}} \times 100$$

$$unthreshing\ grain\ (\%) = \frac{\text{mass of unthreshed grain}}{\text{total grain input}} \times 100$$

$$\text{Throughput capacity } \left(\frac{\text{kg}}{\text{h}}\right) \frac{\text{mass of material processed}}{\text{operating time}}$$

$$\text{Grain breakage } (\%) = \frac{\text{mass of untmass of broken grainshreshed grain}}{\text{total recovered grain}} \times 100$$

$$\text{Material loss } (\%) \frac{\text{mass of unrecovered material attributable to processing loss}}{\text{total input mass}} \times 100$$

RESULTS AND DISCUSSION

Table 4.1. Performance Data

Crop	Moisture (%)	Drum speed (rpm)	Feed rate (kg/h)	Sieve aperture (mm)	Throughput (kg/h)	Threshing efficiency (%)	Grain breakage (%)	Unthreshed grain (%)
Maize	13.0	850	120	8	115	92.0	2.5	5.0
Sorghum	12.5	800	110	6	105	89.0	2.0	7.0
Millet	11.5	900	100	5	96	90.0	1.8	6.5
Beans	14.0	700	90	10	84	88.0	2.8	8.0

Source: researchers data analysis

Crop	Material loss (%)	Energy/fuel consumption	Operating time (h)	Downtime (min)
Maize	3.0	1.83 kWh	1.0	5
Sorghum	4.0	1.78 kWh	1.0	6
Millet	3.5	1.62 kWh	1.0	4
Beans	4.5	1.54 kWh	1.0	7

Source: researchers data analysis

The Yalwa Multi-Purpose Grain Thresher demonstrated effective threshing performance across the tested crops. The recorded maximum threshing efficiency of 92% indicates effective grain detachment and separation under the test condition in which this value was obtained. The interchangeable sieve system played a critical role in the machine's multi-crop capability. Matching sieve aperture to grain characteristics is expected to influence separation efficiency, cleanliness, and material losses, supporting earlier findings on the importance of sieve adaptability in multi-crop threshing machines (Ndirika & Oyeleke, 2020).

Grain quality assessment in the study showed satisfactory finishing with low visible damage. This is important because excessive mechanical damage can reduce market value and farmer acceptance (Ogunlade et al., 2016). Further controlled testing should quantify grain breakage rather than relying only on visual assessment. The machine offers advantages over traditional manual threshing in terms of mechanization, labor reduction, hygiene, and the ability to process more than one crop using interchangeable sieves. However, its comparative performance should be interpreted within the limits of the reported test data.

CONCLUSION AND RECOMMENDATION

The Yalwa Multi-Purpose Grain Thresher was successfully designed, fabricated, and evaluated for maize, sorghum, millet, and beans. The interchangeable sieve mechanism enhanced the versatility of the machine, while the reported maximum threshing efficiency of 92% indicates promising grain detachment and separation performance. The machine produced grains of acceptable quality with low visible damage and therefore shows potential for small- and medium-scale farming operations. For further development, Economic analysis should be undertaken before making firm claims about affordability or long-term commercial feasibility.

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