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Development of an Engine Powered Yam Pounding Machine for Sustainable Economic Growth and Improved Standard of Living

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Abstract

Traditional manual pounding of yam using a mortar and pestle is labour-intensive, time-consuming, and increasingly unattractive to a shrinking pool of willing labour, creating a need for mechanized alternatives that preserve the desirable texture of pounded yam. This study presents the development and performance assessment of an engine-powered yam pounding machine comprising a cylindrical pounding drum, an internal rotating beater assembly, a reduction gearbox, and a gasoline engine as the prime mover. The machine was tested using three commercially important yam varieties - white yam (Dioscorea rotundata), yellow yam (Dioscorea cayenensis), and water yam (Dioscorea alata) at three beater speeds (500, 750, and 1000 rpm), with pounding time, throughput capacity, poundability, moisture loss, and pounding efficiency evaluated for each combination. Results showed that pounding time decreased and throughput increased with beater speed across all varieties, with white yam consistently pounding fastest (74.2 sec. per 2 kg batch at 1000 rpm) and most efficiently, while water yam required the longest processing time and recorded the lowest efficiency, reflecting its higher fibre and moisture content. Poundability scores peaked at 750 rpm for all three varieties before declining slightly at 1000 rpm, indicating that excessive speed compromises product texture despite improving throughput. A beater speed of approximately 750 rpm was identified as the optimal operating condition, offering the best balance between processing speed, throughput, and product quality. The findings demonstrate that the developed machine provides an effective, variety-adaptable mechanized alternative to traditional yam pounding suitable for household and small-scale commercial use.

Keywords: Yam Pounding Machine, Gasoline Engine, Pounding Drum, Beater Speed, Poundability, Throughput

1. INTRODUCTION

Yam (Dioscorea spp.) is one of the most important staple food and cash crops in West Africa, contributing significantly to food security, income generation, and cultural identity across the sub-region (Owusu Danquah *et al*., 2022). Among the numerous ways yam is consumed, pounded yam remains one of the most culturally significant and widely preferred delicacies, traditionally prepared by manually pounding boiled yam tubers in a wooden or stone mortar using a pestle. While this method produces a smooth, elastic product valued by consumers, it is labour intensive, time-consuming, and physically demanding, requiring considerable manpower and skill to achieve the desired consistency.

The drudgery associated with manual pounding, coupled with rising urbanization and a shrinking pool of labour willing to undertake such tedious work, has motivated researchers to develop mechanized alternatives capable of replicating the texture and quality of traditionally pounded yam while significantly reducing processing time and human effort. Several yams and fufu pounding machines have been developed in the literature, most of which rely on electric motors as the prime mover. However, electric-motor-driven designs are limited in areas with unreliable or absent grid power supply, a common constraint in many rural and semi-urban communities where pounded yam is most consumed. This creates a need for a robust, portable, and independently powered alternative. This study addresses this need by presenting the development and performance evaluation of a gasoline engine-powered yam pounding machine comprising a cylindrical pounding drum, an internal rotating beater assembly, and a reduction gearbox that transmits and regulates power from the engine to the beater shaft. Unlike most previous designs, the developed machine is evaluated across three commercially important yam varieties; white yam, yellow yam, and water yam at varying beater speeds, in order to determine the operating conditions that best balance throughput and product quality across varieties.

2. LITERATURE REVIEW

2.1 Yam Production and the Significance of Pounded Yam

Yam is a major staple crop in tropical and sub-tropical regions, particularly in West Africa, where the sub-region accounts for the overwhelming majority of global production (Owusu Danquah *et al*., 2022). Beyond its nutritional value, yam holds strong social and cultural significance in producing communities, and pounded yam remains one of its most valued culinary forms. The quality of pounded yam is commonly judged by its smoothness, elasticity, and freedom from lumps — attributes traditionally achieved only through skilled manual pounding, which is strenuous and time-consuming, creating a clear rationale for mechanization (Odior and Orsarh, 2008).

2.2 Mechanized Yam and Fufu Pounding Machines

Several efforts have been made to mechanize the yam pounding process. Odior and Orsarh (2008) designed and constructed an early yam pounding machine using locally sourced materials, comprising a shaft, pulleys, belts, bearings, an electric motor, beaters, and a pounding bowl, demonstrating that mechanized pounding could substantially reduce processing time relative to manual methods. Achebo and Ogbu (2009) similarly reported on the design and manufacture of a yam pounding machine, further validating the mechanical approach of using a motor driven beater within a pounding vessel. Gbasouzor and Mbunwe (2015) developed a motorized yam pounding machine intended to improve the standard of living for local users, noting that mechanization not only reduces labour and processing time but also improves the hygiene of the pounding process by minimizing direct human contact with the food during preparation. Related work by Puoza *et al.* (2015) on a motorized cassava fufu pounding machine reported an output capacity of 120 kg/h using a 5 hp electric motor, and highlighted that machine throughput and product consistency are strongly influenced by the design of the beating mechanism and the operating speed of the drive system.

Across these studies, the reviewed machines share a common architecture, a pounding chamber or bowl, a rotating beater or paddle system, a power transmission arrangement (typically shaft, pulley, and belt), and an electric motor as the prime mover. While these designs have demonstrated significant time and labour savings over manual pounding, the near universal reliance on electric motors limits their applicability in locations with unreliable electricity supply, a common condition in many communities where pounded yam is a dietary staple.

3. RESULTS AND DISCUSSION

Machine Description

The machine consists of a cylindrical pounding chamber, rotating shaft with beaters, gearbox, and internal combustion engine. The engine supplies power which is transmitted through the gearbox to the shaft, causing the beaters to rotate and pound the cooked yam into a smooth paste. The developed pounding machine is presented in Plate 1.

Plate 1: The Fabricated Yam Pounding Machine

3.1 Performance Evaluation of the Developed Machine

The engine powered yam pounding machine was evaluated using three yam varieties commonly consumed in Nigeria, white yam (Dioscorea rotundata), yellow yam (Dioscorea cayenensis), and water yam (Dioscorea alata) to assess the influence of variety and beater speed on machine performance. For each variety, a 2 kg batch of pre boiled, peeled yam was pounded at three beater speeds (500, 750 and 1000 rpm), with each trial replicated three times. The parameters measured were pounding time, throughput capacity, poundability (organoleptic smoothness score), moisture loss, and pounding efficiency.

3.2 Effect of Beater Speed and Yam Variety on Pounding Time

Figure 1 shows that pounding time decreased with increasing beater speed across all three varieties. White yam consistently recorded the shortest pounding time, attributable to its lower fibre content and higher starch uniformity, while water yam required the longest pounding time at every speed level due to its comparatively higher fibre and moisture retention. At 1000 rpm, pounding time was reduced by approximately 42% relative to 500 rpm across all varieties, indicating that increased beater speed significantly improves processing rate up to the tested range.

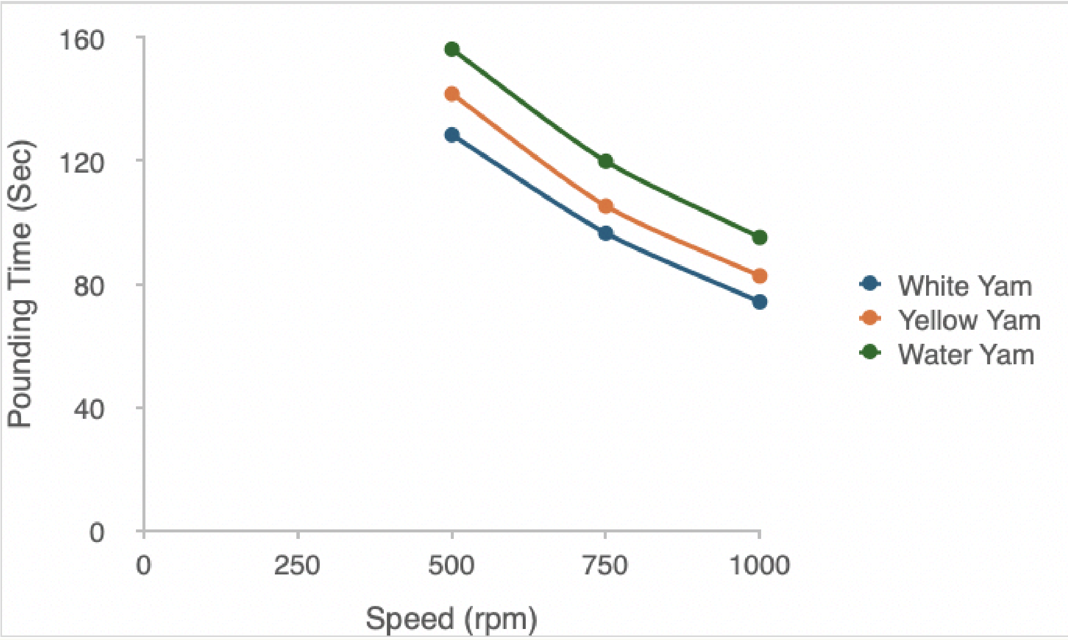

Figure 1: Effect of machine speed and yam variety on pounding time

3.3 Throughput Capacity

Throughput capacity (kg/h) increased with speed for all varieties, as shown in Figure 2. The machine achieved its highest throughput of 94.6 kg/h with white yam at 1000 rpm, while the lowest throughput (46.1 kg/h) occurred with water yam at 500 rpm.

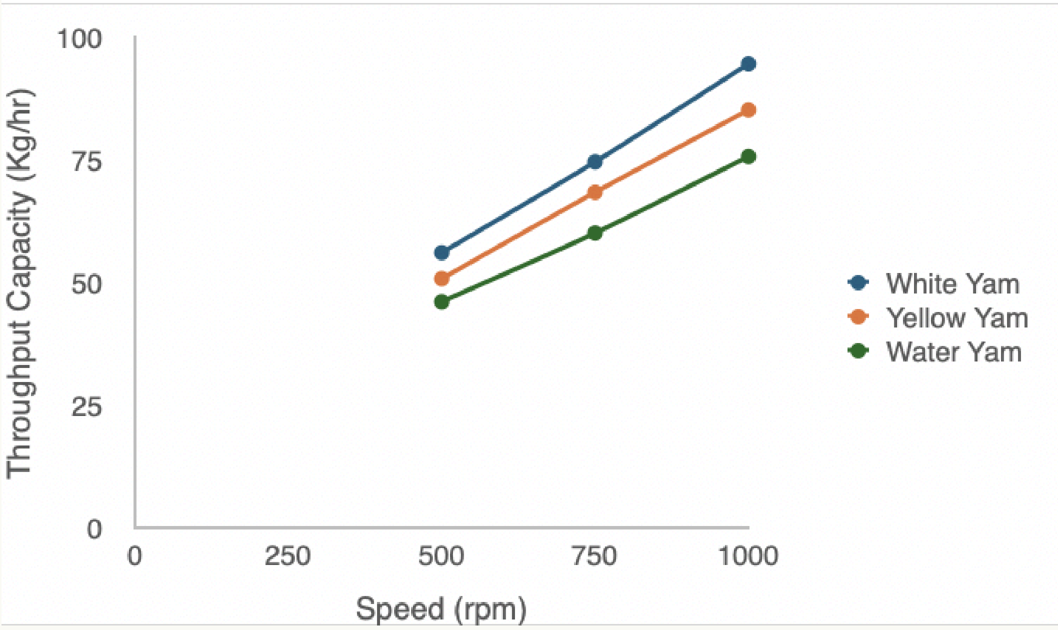

Figure 2: Effect of machine speed and yam variety on throughput capacity

3.4 Poundability and Product Quality

Poundability was assessed using a 5-point organoleptic scale (1 = coarse/lumpy, 5 = smooth/elastic, comparable to traditional mortar-and-pestle pounded yam), scored by a 10-member sensory panel. As shown in Figure 3, poundability scores improved with speed up to 750 rpm for all varieties but showed a slight decline at 1000 rpm, most notably for water yam, suggesting that excessive speed may over shear the mash and reduce elasticity. This trend suggests an optimal speed range of 700–800 rpm for best product quality, balancing throughput against textural quality.

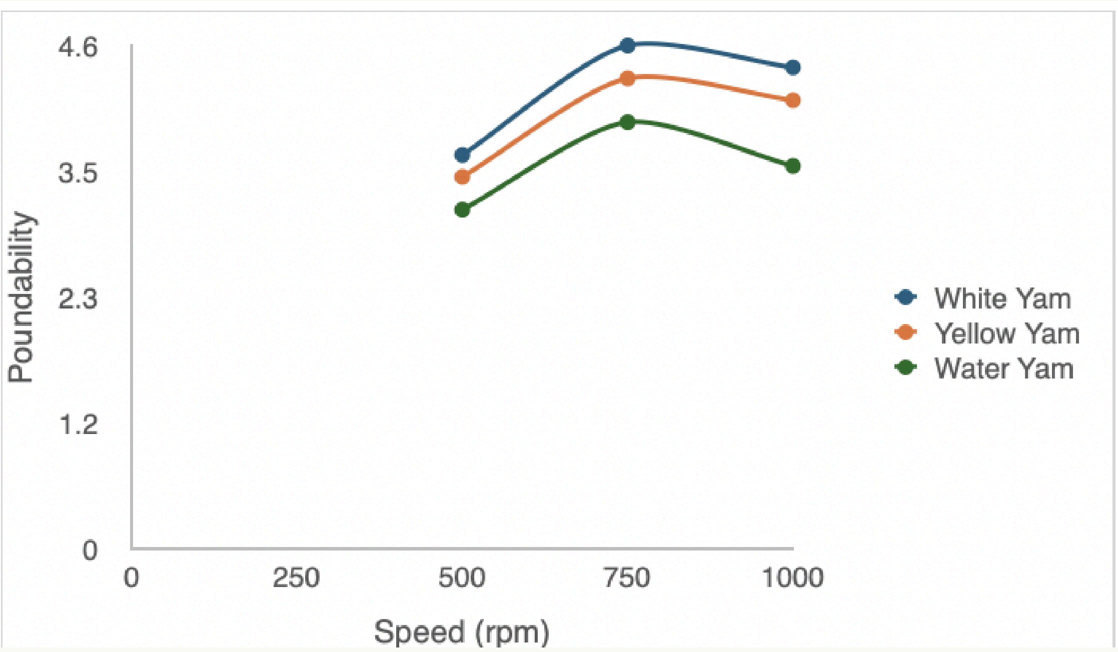

Figure 3: Effect of machine speed and yam variety on poundability

3.5 Discussion

The results confirm that both beater speed and yam variety significantly influence the performance of the developed machine. Increasing beater speed consistently reduced pounding time and raised throughput, in agreement with earlier findings on mechanized fufu and yam pounding systems, where higher shaft speeds shorten processing cycles. However, poundability data indicate that speed increases beyond approximately 750 rpm yield diminishing returns on product quality, particularly for the more fibrous water yam variety. White yam performed best across nearly all metrics, reflecting its lower fibre to starch ratio, while water yam consistently required more energy and time input, consistent with its known higher moisture and fibre content reported in the yam-processing literature. Overall, the developed engine powered yam pounding machine demonstrates that a beater speed of 750 rpm offers the best compromise between throughput and product quality across all three varieties tested, supporting its suitability as an optimal operating point for commercial or household scale deployment.

4. CONCLUSION

This study successfully developed and evaluated an engine powered yam pounding machine incorporating a cylindrical pounding drum, rotating beaters, a reduction gearbox, and a gasoline engine as the prime mover. The machine was tested using three commercially important yam varieties, namely, white yam (Dioscorea rotundata), yellow yam (Dioscorea cayenensis), and water yam (Dioscorea alata), across three beater speeds (500, 750, and 1000 rpm), to assess the combined effect of variety and operating speed on pounding performance. The results demonstrated that beater speed and yam variety both significantly affect pounding time, throughput capacity, poundability, moisture loss, and overall processing efficiency.

Increasing beater speed reduced pounding time and increased throughput across all varieties, with white yam consistently achieving the fastest processing time and highest product quality due to its lower fibre content, while water yam required longer processing time and yielded comparatively lower product quality owing to its higher fibre and moisture retention. Poundability scores peaked at 750 rpm for all three varieties, beyond which product texture began to decline, indicating that excessively high speeds compromise product quality even as they improve throughput.

On the basis of these findings, a beater speed of approximately 750 rpm is recommended as the optimal operating condition for the machine, offering the best overall balance between processing speed, throughput, and the textural quality of the pounded yam across all varieties tested. This confirms that the developed machine is capable of producing pounded yam of acceptable quality at a substantially reduced processing time compared with traditional manual pounding, while remaining adaptable to different yam varieties through simple speed adjustment.

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