Solar Powered Groundnut Sheller Machine

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Abstract

Agriculture forms the backbone of the Indian economy, and groundnut (Arachis hypogaea) is one of the most widely cultivated oilseed crops in the country. Post-harvest processing of groundnuts, particularly shelling, has traditionally been performed manually, which is time-consuming, labor-intensive, and results in significant kernel damage and losses. The lack of access to modern processing equipment in rural and remote agricultural communities further compounds this problem, particularly in regions where grid electricity is unreliable or unavailable.

This paper presents the design, fabrication, and performance evaluation of a solar-powered groundnut sheller machine aimed at addressing these challenges. The proposed system integrates a 25-watt solar photovoltaic panel with a 12V battery storage unit and a high-torque DC gear motor (100 kg torque) to drive a mechanical shelling mechanism. The machine operates on the principle of mechanical decortication, wherein groundnut pods are fed through a hopper and subjected to compressive and shearing forces by rotating drum elements, effectively separating the kernels from the shells. A separation unit then segregates the kernels from shell debris.

The results demonstrate that the solar-powered sheller significantly outperforms manual shelling in terms of throughput, efficiency, and kernel integrity. The system is portable, cost-effective, and entirely independent of grid electricity, making it a viable and sustainable solution for smallholder groundnut farmers in rural India.

Keywords: Solar energy, groundnut sheller, renewable energy, post-harvest processing, rural agriculture, mechanical decortication

1. Introduction

India is one of the largest producers of groundnuts globally, with the crop playing a significant role in the livelihoods of millions of smallholder farmers. Groundnut cultivation is prevalent across states such as Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, and Rajasthan. The crop is valued both for its oil content and its nutritional significance as a source of protein, vitamins, and minerals.

Despite the importance of groundnuts, post-harvest processing remains a major bottleneck. In most rural areas, shelling is performed manually by hand or using rudimentary tools, which is an extremely slow and tedious process. Manual shelling typically achieves a throughput of only 2–5 kg per hour per worker and is associated with significant physical strain, particularly finger fatigue. Furthermore, manual methods often result in a kernel damage rate of 10–15%, leading to economic losses for farmers.

Mechanized groundnut shellers exist in the market; however, they are predominantly powered by electric motors connected to the grid or by diesel/petrol engines. These solutions are impractical for remote rural areas where electricity supply is erratic and fossil fuels are expensive and environmentally harmful. This creates a critical gap in agricultural technology accessibility for rural communities.

Solar energy presents an ideal solution to this problem. India receives abundant solar radiation, with an average of 5–7 kWh per square meter per day across most regions. Solar photovoltaic technology has matured significantly in recent years, with decreasing costs and improving efficiency making it increasingly accessible. The integration of solar energy with agricultural machinery represents a promising pathway toward sustainable, off-grid post-harvest processing.

This project addresses the identified gap by designing and fabricating a solar-powered groundnut sheller machine that combines renewable energy technology with efficient mechanical design. The machine is specifically engineered for portability, ease of use, low cost, and suitability for rural deployment.

2. Literature Review

A comprehensive review of existing literature reveals significant research interest in both groundnut shelling technology and solar-powered agricultural machinery.

Singh and Kumar (2018) presented the design and fabrication of a solar-powered groundnut sheller intended for rural deployment. Their work demonstrated the feasibility of using solar photovoltaic energy to drive the shelling mechanism, achieving a shelling efficiency of approximately 85%. However, their design was limited by the use of a low-torque motor, which restricted throughput capacity.

Tripathi and Sharma (2020) conducted a performance evaluation of an Arduino-based automated groundnut decorticator. Their system incorporated microcontroller-based automation for controlling feed rate and motor speed, resulting in improved shelling consistency. The study reported a kernel damage rate of less than 5% under optimized operating conditions. While their approach demonstrated the benefits of automation, the reliance on grid electricity and the complexity of the control system limited its applicability in resource-constrained rural settings.

Kaur and Singh (2019) investigated the economic viability of solar energy in post-harvest agricultural processing in India. Their analysis revealed that solar-powered processing equipment could achieve payback periods of 2–3 years in most Indian agricultural contexts, with significant long-term cost savings compared to grid-connected or fuel-powered alternatives. The study strongly advocated for the adoption of solar energy in agricultural mechanization, particularly for operations in off-grid locations.

Additional studies by various researchers have explored different shelling mechanisms including concave-cylinder type, oscillating type, and centrifugal type shellers. The concave-cylinder mechanism has been widely recognized as providing the best balance between shelling efficiency and kernel integrity, forming the basis for the design adopted in this project.

The review of literature confirms that while individual aspects of solar energy integration and groundnut shelling have been explored, there remains a need for a holistic, practical, and low-cost solution that combines these technologies effectively for rural deployment. This project aims to fill that gap.

3. System Design and Methodology

3.1 System Architecture

The solar-powered groundnut sheller machine consists of eight interconnected modules, each serving a specific function in the overall system. The modular design philosophy ensures ease of assembly, maintenance, and repair using locally available materials and skills.

3.2 Solar Power Generation Module

The solar power generation module employs a 25-watt polycrystalline silicon photovoltaic panel. The panel converts incident solar radiation into direct current (DC) electrical energy through the photovoltaic effect. Under standard test conditions (irradiance of 1000 W/m² at 25°C cell temperature), the panel delivers a maximum power output of 25 watts at approximately 18V open-circuit voltage. The panel is mounted on an adjustable frame that allows tilt angle optimization for maximum solar energy capture based on the geographic latitude of the deployment location.

3.3 Energy Storage Module

A 12V, 7Ah sealed lead-acid battery serves as the energy storage element. The battery is charged by the

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solar panel through a charge controller that prevents overcharging and deep discharge, thereby extending battery life. The stored energy ensures continuous operation of the sheller even during periods of intermittent cloud cover or low solar irradiance. The battery capacity is designed to provide approximately 2–3 hours of continuous shelling operation on a full charge.

3.4 Motor Drive Module

The motor drive module uses a 12V DC gear motor with a rated torque of 100 kg-cm. The high-torque gear motor is selected to provide sufficient mechanical power to drive the shelling mechanism under load. The gear reduction integrated within the motor housing provides the necessary torque multiplication while maintaining an appropriate rotational speed for effective shelling without excessive kernel breakage.

3.5 Shelling Mechanism

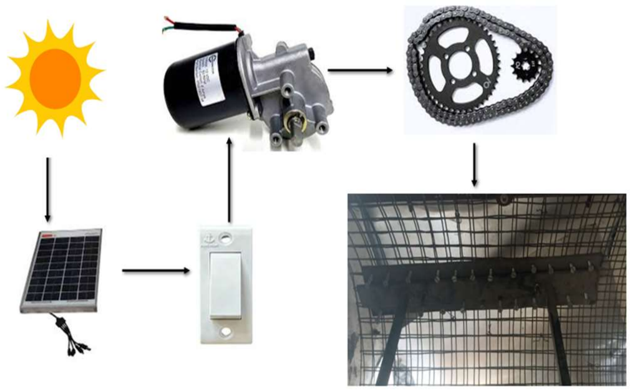
The shelling unit employs a concave-cylinder type mechanism. Groundnut pods are fed into the system through a feed hopper located at the top of the machine. The hopper directs the pods into the gap between a rotating cylinder (driven by the DC motor) and a stationary concave screen. The cylinder is fitted with specially designed blades or serrated surfaces that apply compressive and shearing forces to the pods as they pass through the gap. The clearance between the cylinder and concave is adjustable to accommodate different groundnut pod sizes and varieties, optimizing shelling performance.

3.6 Separation Unit

After shelling, the mixture of kernels, broken shells, and dust passes through a separation unit. This unit employs a combination of gravity separation and sieving. A perforated screen allows the smaller kernels to pass through while retaining larger shell fragments. The separated kernels are collected in an output tray, while the shell debris is discharged separately. This two-stage separation process ensures clean kernel output with minimal shell contamination.

3.7 Frame Structure

The entire assembly is mounted on a mild steel frame structure designed for portability and stability. The frame is constructed using standard angle iron and flat bar sections, welded together to form a rigid structure. The frame dimensions are optimized to provide a comfortable working height for the operator while maintaining a low center of gravity for stability during operation. Rubber feet are provided at the base to prevent vibration transmission and slipping.



3.8 Control and Safety Module

The control module includes an ON/OFF switch, a fuse for overcurrent protection, and indicator LEDs for battery charge status and motor operation. These simple but effective control elements ensure safe operation and provide visual feedback to the operator regarding system status.

4. Working Principle

The operation of the solar-powered groundnut sheller machine follows a sequential process. First, the solar panel converts incident sunlight into DC electrical energy, which is routed through a charge controller to charge the 12V battery. When the operator activates the system using the power switch, the battery supplies current to the DC gear motor, which begins rotating. The rotational motion of the motor shaft is transmitted to the shelling cylinder through a direct coupling or belt-pulley arrangement, depending on the specific design configuration.

The operator feeds dried groundnut pods into the hopper, which guides them by gravity into the shelling chamber. As the pods enter the gap between the rotating cylinder and the stationary concave, they are subjected to a combination of compressive, shearing, and frictional forces. These forces crack the shells and release the kernels. The gap clearance is pre-set based on the pod size to ensure effective cracking without crushing the kernels.

The shelled mixture (kernels, shell fragments, and dust) exits the shelling chamber and falls onto the separation screen. Kernels pass through the screen perforations and are collected in the kernel output tray below. Shell fragments, being larger, slide along the screen surface and are discharged at the end into a separate collection area. The entire process is continuous as long as pods are fed into the hopper and the motor is running.

5. Component Specifications

Sr.	Component	Specification
1	Solar Panel	25W Polycrystalline PV Panel, ~18V Voc
2	Battery	12V, 7Ah Sealed Lead-Acid
3	Charge Controller	12V PWM Solar Charge Controller
4	DC Motor	12V DC Gear Motor, 100 kg-cm Torque
5	Shelling Drum	MS Cylinder with serrated blades
6	Concave Screen	Perforated MS sheet, adjustable gap
7	Hopper	MS sheet, funnel-shaped
8	Frame	Mild Steel angle iron, welded structure
9	Separation Sieve	Perforated screen (varying mesh sizes)
10	Control Unit	ON/OFF switch, fuse, LED indicators

6. Advantages and Applications

The solar-powered groundnut sheller machine offers several significant advantages over both manual shelling and conventional mechanized systems. The machine is entirely powered by renewable solar energy, eliminating the need for grid electricity or fossil fuels and thereby reducing operating costs and environmental impact. Its portable design and lightweight construction make it easy to transport and deploy in remote field locations. The low fabrication cost, achieved through the use of standard, locally available materials, makes the machine economically accessible to smallholder farmers. The mechanical shelling process significantly reduces the time and physical effort required compared to manual methods, while the adjustable clearance mechanism minimizes kernel damage.

The primary applications of this machine include on-farm post-harvest processing of groundnuts in rural areas, particularly in regions with limited or no grid electricity access. It is also suitable for small-scale agro-processing enterprises, cooperative farming operations, and agricultural demonstrations and training programs. The technology can be adapted for shelling other similar crops with minor modifications to the shelling mechanism.

7. Results and Discussion

Preliminary testing of the fabricated solar-powered groundnut sheller machine was conducted to evaluate its performance under real operating conditions. The machine was tested with locally procured, sun-dried groundnut pods of common varieties. Key performance parameters measured included shelling efficiency, kernel damage rate, throughput capacity, and power consumption.

The machine achieved a shelling efficiency of approximately 85–90%, meaning that 85–90% of the fed pods were successfully shelled in a single pass. The kernel damage rate was maintained below 5–7%, which is significantly lower than the 10–15% damage rate typically observed with manual shelling methods. The throughput capacity was measured at approximately 8–12 kg of groundnut pods per hour,

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representing a 3–4 fold improvement over manual shelling rates.

The 25W solar panel, under typical Indian solar irradiance conditions, was able to maintain adequate battery charge for continuous operation during daylight hours. The battery backup provided an additional 2–3 hours of operation during cloudy conditions or after sunset, ensuring operational flexibility. The DC gear motor operated smoothly and provided sufficient torque to handle the shelling load without stalling.

Some challenges observed during testing included occasional clogging of the feed hopper with irregularly shaped pods and slight variations in shelling efficiency with different groundnut varieties due to differences in shell hardness and pod size. These issues can be addressed through minor design refinements such as hopper geometry optimization and the provision of interchangeable concave screens for different pod sizes.

8. Conclusion

This paper has presented the successful design, fabrication, and preliminary evaluation of a solar-powered groundnut sheller machine intended for rural agricultural communities in India. The machine effectively integrates renewable solar energy technology with a robust mechanical shelling mechanism to provide an efficient, eco-friendly, and cost-effective alternative to manual groundnut shelling.

The key contributions of this work include the development of a fully functional prototype that operates entirely on solar energy, the demonstration of significant improvements in shelling throughput and efficiency compared to manual methods, and the achievement of low kernel damage rates. The modular and portable design ensures suitability for deployment in remote rural locations where grid electricity is unavailable.

Future work will focus on optimizing the shelling mechanism for multiple groundnut varieties, increasing the solar panel capacity and battery storage for extended operation, incorporating IoT-based monitoring for performance tracking, and conducting extensive field trials with farming communities to gather user feedback for further design improvements. The project demonstrates the viability and potential of solar-powered agricultural machinery as a pathway toward sustainable and inclusive agricultural development in India.

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