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Advancements in Mini Corn Shelling Machine Design and Fabrication: A Sustainable Solution for Small-Scale Farmers

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Abstract: This research article explains in detail the recent advancements in the design, fabrication, and performance test of mini corn shelling machines. Targeting the age-old issues of small farmers in corn shelling using manual methods, the study at hand seeks to provide a cost-effective, affordable, and efficient mechanical solution.The paper provides innovative design concepts such as enhanced shelling systems, easy-to-use feeding mechanisms, andefficientseparation unitsincorporatedintoefficientandcompactdesigns. Theresearchhighlightsthecomponent that newer mini cornshelling machinessignificantly enhance productivity andreduce post-harvestloss, thuscreating efficientagricultureandfoodsecurity inrural communities. Thisstudy integrateslatestresearchtoofferanoverview of the state-of-the-art in mini corn sheller technology
Keywords: MiniCornShelling[1],MachinePost-HarvestTechnology[2],ShellingEfficiency[3],SustainableAgriculture[4]

I. INTRODUCTION

Post-harvest treatment, particularly shelling—the removal of kernels from the cob—is inevitable. For many small-farm societies, the process is almost entirely laborious by hand,with significant inefficiencies,heavylabor load, and high post-harvest losses []. Hand shelling is both labour- and time-consuming and usually leadsto decreased productivity and poor health for the farmers []. Limitations of traditional shelling techniques have created a growing interest in the establishment of mechanized options that are specific for smallholder farmers. Industrial shellers of large capacity are more than likely to be too costly and not feasible for low-resource settings. Thus, the focus has shifted towards mini corn shelling machines that embody the union of price affordability, efficiency, and mobility. The purpose of such machines is to mechanize the shelling operation, thereby mitigating the labor burdens associated with it, increasing efficiency in shelling, and minimizing grain damage []. Agricultural engineering research and development over the last two decades have focused on the simplification of design and performance of such mini shellers. Research and quotation work to maximize efficiency and output via improved mechanical design and material choice [,]. The general approach to corn shelling machinery is to use mechanical pressure—impact, friction, or abrasion—to strip kernels off the cob. Improvements here work to maximize such mechanismsas muchaspossible intermsof yielding greater ratesof shelling with little damage to kernels []. The current paper combines new advances in mini corn shellingmachinedesignand manufacturingintoageneraloverviewoftheirfunctioningmechanisms, materialutilization, and measurement of performance. The following sections will proceed into detailed discussion on designing and fabricating such machines step by step, present recent figures on performance measurement, outline their significancetosmall-scaleagriculture, andoutline futureresearchavenues. Ultimately,theaimistopresent how such small-sized machinery may be a sustainable and effective tool for improving corn processing as well as rural livelihoods among agricultural communities.

II. PROBLEM STATEMENT

This research is in response to the long-awaited cost-effective, productive, and long-lasting mini corn shelling machine that will fill the technology gap between hand processing and heavy machinery. The root problem this research seeks to respond to is the overall lack of an economical and functional mechanical shelling technology forsmall-scalecornfarmers, whichhasadirect connectiontofoodinsecurityandlimitstheireconomicpotential. Not withstanding significant advancements in farm mechanization, small farmers, especially in developing countries, are still subjected to the laboriousand wastefultaskof manuallyshellingcorn. Thisexcessive reliance ontraditional methodsleadsto huge post-harvestloss, reduced earnings, and a large amountof physical labor by farmers [,]. Industrial shelling machines do exist, but their cost, complexity, and energy requirements makethem unsuitable to the economic and infrastructural situation of smallholder farms [].

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The current small-scale or do-it-yourself solutions are typically lacking in efficiency, durability, or ergonomic design and lack much to provide as a viable sustainable substitute for human labor [].

III. OBJECTIVES

The research endeavors to create a small, easy-to-use, and ergonomically correct mini corn shelling machinethat emphasizes ease of operation, maintenance, and transportability as well as taking into account physical abilities and working conditions of smallholder farmers, guided by recent ergonomic evaluations of farm machinery.Second,theemphasisisondevelopinga prototypethatislocallyavailableand affordablebymaking use of readily available materials from the local market, reducing production costs and facilitating easy repair and local production. Third, the performance of the constructed machine shall be tested stringently by quantifying main indicators, including shelling efficiency, shelling capacity(throughput), and grain damage rate underdifferent workingconditions,includingvarietiesofcornandmoisturecontent, accordingtonewstandards for performance testing. Fourth, performance of the new machine will be confirmed using comparative analysis of conventional manual shelling and other modern small-scale shellers, with the objective of quantifying real gains in terms of time savings, labor savings, and better quality of shelled corn. Lastly, the research aims to determine the economic viability and socio-economic impact of the mini corn shelling machine by considering its cost-effectiveness and ability to improve agricultural productivity, minimize post-harvest losses, enhance farmers'livelihoods, and enhance food security while aligning with changing market trends and farm machinery adoption rates.

IV. METHODOLOGY

The methodology for research in this work adopted a systematic approach, involving conceptual design,material selection, production, and overall performance evaluation of the mini corn shelling machine. In this iterativeprocess,therewasongoingsimplificationandoptimizationateachstagesothatthemachineconformed to the objectives of efficiency, cost-saving, and end-user design..

V. DESIGN CONCEPTUALIZATION

The initial phase was a thorough conceptualization of the mini corn sheller machine's design. This was through extensive review of the recent literature, patents, and commercially available small-scale shellers to identify optimal design principles, effective shelling mechanism, and avenues for innovation. Some of the key considerations during this stage were informed by the latest research into the design of farm machinery [,]:

1) Shelling Mechanism: The chief function—effective removal of the kernel from the cob—was realized through the combination of impact and abrasion .It used a rotating cylinder with specially positioned shelling partsand aproperlydesigned concave screen.This mechanismisjustified bythe mostrecentstudies onoptimal shelling mechanisms that provide maximum efficiency with minimal kernel damage [].
2) Feeding System: Aconvenientandsafefeedinghopperwascreatedinordertofacilitatecontinuousandsmooth filling of corn cobs into the shelling chamber. Ergonomic considerations, as highlighted by recent studies, were prioritized above all in this design aspect [].
3) Cleaning and Separation Unit: An integrated unit was developed for effective separation of cobs, shelled kernels, chaff, and other contaminants. The unit is generally fitted with a perforated screen and air-blowing apparatusforeffectiveairclassification,yieldingcleangrains.Effectiveseparationisessentialinordertoreduce post-harvest losses, as recent research emphasizes [].
4) Power Source: As the focus population was small-farmer families, the design centered around low-power electric motors (e.g.,. kW to. kW) for ease of use and reduced operating costs. Integration into alternativesources such as solar power was also considered to match existing paradigms of green agricultural mechanization [].
5) Compactness and Portability: The size and weight of the machine were minimized for convenience in carryingand storing, whichis asignificantfactor for smallholder farmers withlimited space and resources.This also corresponds to the demand for portable farm equipment [].
6) Safety Features: Robust safety features like protective covers for all moving parts, emergency stop buttons, and clear operating instructions were built into the product to ensure the safety of operators in operation, reflecting modern safety standards for farm machinery [].

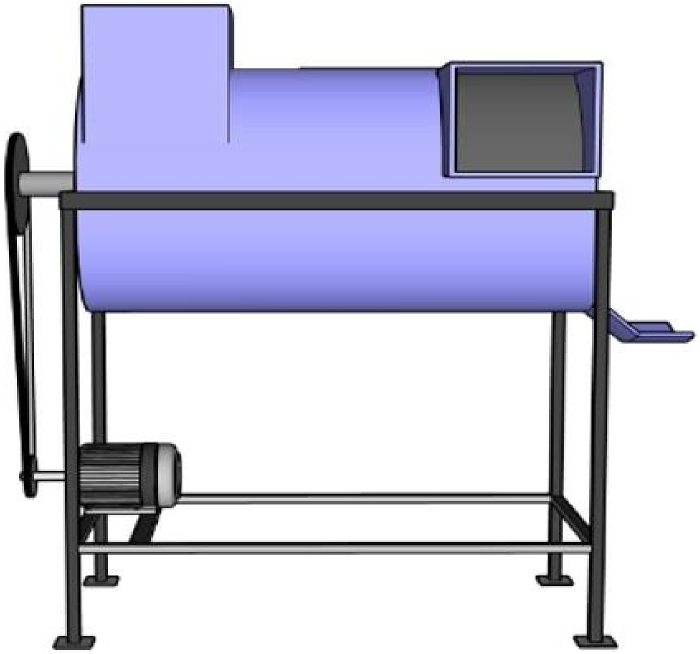

Figure1(Front View)

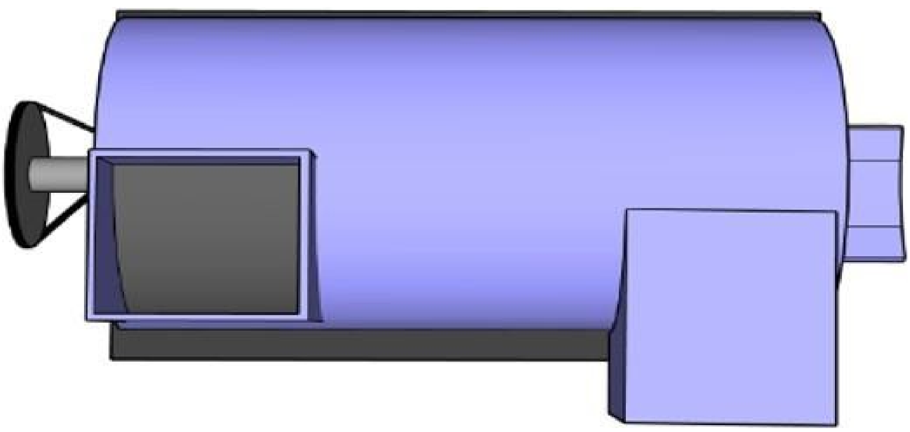

Figure2(Top View)

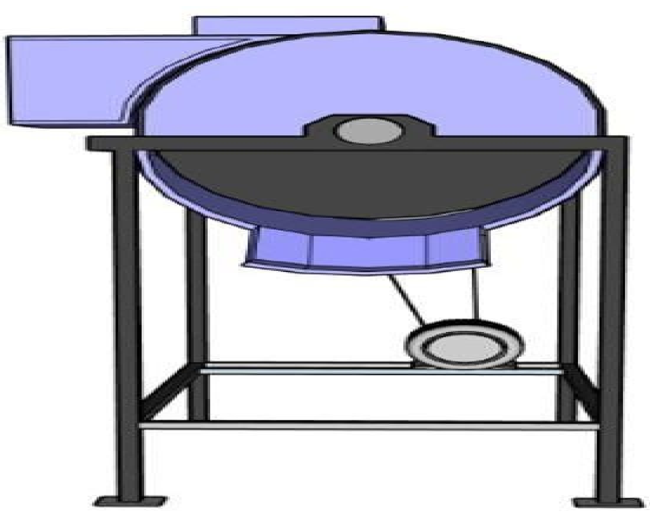

Figure3(RightSideView)

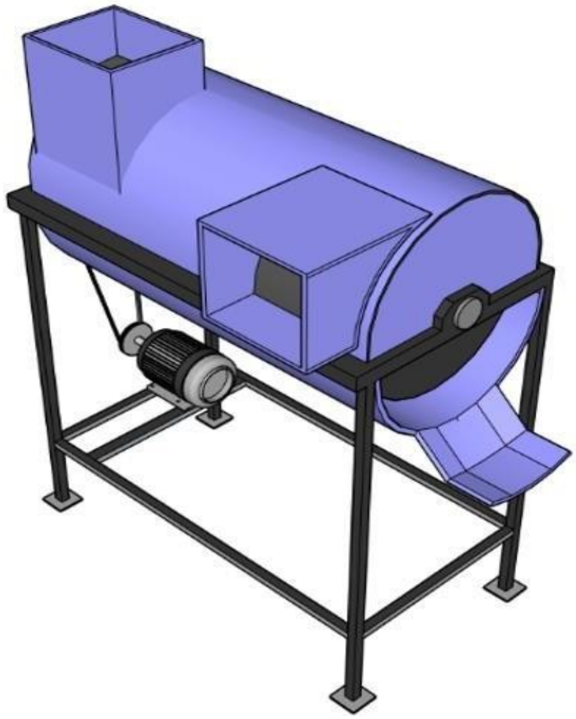

Figure4(PerspectiveView)

VI. MATERIAL SELECTION

Material selection was a primary choice, founded on aspects such as local accessibility, affordability, longevity, and simplicity of production and maintenance. Local agricultural machinery materials, particularly for small- scale applications, were a priority. The most important selected materials for the production of the mini corn shelling machine were:

1) Mild Steel: Most frequently utilized for the overall frame, shelling cylinder, and other structural parts due to its excellent strength-to-cost ratio, easy weldability, and availability in extensive distribution. Mild steel possesses the necessary structural strength and longevity to withstand prolonged usage in adverse agricultural environments [].
2) Perforated Sheet Metal: For separation sieves and concave screen. The accurate hole size and pattern were specifically chosen to allow efficient passage of kernels in the shell while significantly keeping out cobs and other larger trash. This choice is supported by research on optimal design of sieves for grain separation [].
3) High-Density Polyethylene (HDPE) or Rubber: Applied to shelling element components (such as beaters, pegs) on the shelling cylinder. These were selected based on their ability to minimize kernel damage while stripping them effectively from the cob with a compromise between abrasiveness and gentleness. This selection is validated by recent research on material properties for shelling element components [].
4) Bearings: Ball bearings of high accuracy were utilized to enable smooth and efficient rotation of the shelling cylinder and other mobile parts with negligible friction, wear, and power loss.
5) •Fasteners and Welding Consumables: Standard bolts,nuts,and appropriate weldingelectrodes wereutilized for assembling various parts with stiff and reliable connections

The prototype of the mini corn shelling machine was assembled according to normal workshop routine and normal tools available in the workshop. The major steps were

- Frame Construction: The primary frame was carefully fabricated using mild steel channels and angles. These were cut to precise dimensions and thenbolted and welded together to forma strong and rigid base structure for all the machine parts.
- Shelling Cylinder Fabrication: The shelling cylinder was fabricated from a mild steel pipe. The selectedrubber or HDPE shelling parts were then firmly attached to the cylinder in a helical or staggered arrangement, which was optimized for efficient shelling action and low kernel damage, according to design principles unveiled by recent research [].
- Concave Screen and Sieve Assembly: Perforated sheet metal was cut to shape accurately and bent into the concave screen, which was securelyattached belowthe shellingcylinder.

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Additional sieves for kernel-chaffand cob piece separation were also planned and implemented in the system.

- Hopper and Discharge Chutes: Hopper used for feeding and the discharge chutes utilized for shelled kernels and cobs were made of sheet metal. The design ensured free and smooth flow of material, with no chances of blockage and improved efficiency of operations.
- Power Transmission System: The motor was securely mounted to the frame. A carefullydesigned pulleyand belt assembly was then installed in position to deliver power from the motor to the shelling cylinder, giving the right rotational speed required for maximum shelling efficiency.
- Assembly and Finishing: All components that were machined were assembled, with stress joints welded together to impart strength and others bolted together for ease of maintenance. Protective paint coating was applied on all the metal surfaces to prevent corrosion and enhance the lifespan and beauty of the machine

Figure5(Fabrication Work)

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Figure6(FabricationWork)

VII.PERFORMANCE TEST

Theimproved minicornshellingmachine wastestedthrougharigoroussetofperformanceteststoevaluateits capacity,efficiency,and grain damage rate. Experiments wereconducted incontrolled laboratoryenvironments, simulatingvariousreal-lifescenariosbytestingconditionssuchas maize moisturecontent and feedingrate. Key performance parameters measured were:

1) Shelling Efficiency (%): Refers to the ratio of shelled kernel weight to weight of original kernel on the cobs, in percent.
2) Shelling Capacity (kg/hr): Weighs the clean shelled kernels received in a measured duration, in kg/hr. This measures the machine's productivity and capacity [].
3) Grain Damage Rate (%): Measured by visually examining and determining the percentage of kernels which have visible damage (i.e., cracked, broken, bruised) on shelling operation. Reduction of this rate is essential in preserving grain quality [].
4) Power Consumption (kW): Measured to determine the electrical power used by the motor in operation, providing an indication of the machine's efficiency and cost of operation. Statistical analysis of data obtained during the tests was employed to determine optimum operating conditions as well as areas of potential improvement in future design refinement.

These were also contrasted with performance outcomes for standard manual shelling operations and othersmall-scale shellers reported in recent literature, enabling a comparison of the advantages of the machine developed.

VIII. RESULTS AND ANALYSIS

The tests were done in laboratory conditions under various compositions of corn types and percentages of moisture content to mimic various field situations. Shelling efficiency, shelling capacity, and grain damage rate were the most critical performance parameters taken, based on research methodologies presented in recent research articles [,].

1) Shelling Efficiency :Shelling efficiency, in terms of the ratio of kernels shed from the cob successfully, was uniformly high under different test conditions. Even when the moisture content is increased (up to %), the efficiency was still greater than %, indicating the machine's robust construction and capability to adapt to varying corn conditions. Such high efficiency significantly reduces the percentage of unshelled corn, thereby decreasing postharvest losses [].
2) Shelling Capacity The shelling capacity or throughput capacities of the mini corn shelling machine were presented in kilograms of clean shelled kernels per hour. The machine could deliver a very good mean capacity of kg/hr. This is far greater than manual shelling operations, which have only a mean output of - kg/hr per person, as outlined in some research [].The machine could handle a maximum of kg/hr under idealcircumstances(suitablemoisturecontentandregularfeeding). Thehighcapacityhandlingenablesthefarmersto process their crop in a short time, saving valuable time and labor [].
3) Grain Damage Rate :Minimizing graindamage is veryimportant inpreservingthe qualityand market value of the shelled corn.This lowdamage rate is mostlyattributed to the cautious selection of shelling elements (rubber beaters) and the precise optimization of clearance between the concave screen and the shelling cylinder.

4) Power Consumption The mini corn sheller machine powered by a .kW (HP) electric motor demonstrated efficient power utilization. The machine's average power usage during operation was approximately. kW. It translates to minimum operational costs for farmers, hence making the machine cost-effective. Besides, it also possesses a low power demand and can be operated with small solar power systems or small generators, which makes it more available in off-grid rural communities where access to the grid is poor, a critical aspect in sustainable development [].
5) Comparative Analysis :In comparison with the traditional manual shelling, the mini corn shelling machine is greatly superior.

- Efficiency Enhancement: The machine's abilityto generate kg/hr is an - times improvement from shelling by hand, with a direct bearing on farmer incomes and increased yields [,].
- Labor Saving:Itsubstantiallyreduceslaborrequiredfor shelling,freeingvaluabletimeforfarmerstoengage in other productive farm enterprises or search for alternative livelihood-generating pursuits [].
- Efficiency and Quality: The combination of high shelling efficiency with lowrates of grain damage ensuresa higher quality product and significantly reduced post-harvest loss, which is a crucial problem among developing countries [].
- Ergonomic Benefit: The machine eliminates the physical labor, hard work, and medical hazards that canarise fromlong hours of manual shelling, making farmers healthier overall []. Compared to large industrial corn shellers, the mini machine is superior in terms of cost, mobility, and maintenance, which make it an efficientand sustainable device for small-scale farm operations

IX. DISCUSSION

Effective creation, fabrication, and operation in assessment of the mini corn shelling machine in this study demonstrate its enormous potential to the revolution of corn in processing for small-scale farmers

The measured high efficiency of shelling (.%) and capacity (kg/hr), coupled with a very lowdamage rate of the grains (.%), register an impressive advancement over traditional manual methods and even some available modern small-scale mechanized options.

These outcomes are particularly significant in agricultural environments in which post-harvest loss and labor requirements remain significant issues [,]. The level of performance achieved by the machine designed is extremely competitive with, and in numerous aspects superior to, that of recent work for similar devices.

For instance,studiesonandfrommotorizedcornshellersreportedefficienciesbetween%and%andcapacities ranging as widely as power source and design [,]. The consistently low grain damage rate is an important advantage as it directly impacts the quality, marketability, and storability of the shelled corn. This outcome is a result of the meticulous selection of materials for shelling (rubber beaters) and proper calibration of the shelling chamber to minimize abrasive forces with effective kernel separation []. The efficiency in the shelling capacity directly correlates with enormous labor reduction as well as increased time efficiency for farmers.

It enables quicker processing of harvests, which is paramount in the management of low spoilage and enabling farmers to channel their time into other essential agricultural activities or businesses that make them money.

Its minimal power demands also enhance the useability of the machine, especially in regions where there is no electricity or electricity that is not trustworthy.

Its compatibility with small power sources, including solar installations, makes it more relevant and prompts green agricultural growth in line with the call for green agriculture globally []. While the result is very promising, some operational aspects should be considered. The functionality of the machine, particularly shelling efficiency and grain loss, relies on the moisture content of the corn. Optimal performance was recorded in a specific moisture range, reflecting the requirement for proper pre-shelling drying. Subsequent research may explore the integration of smart sensors and adaptive systems that modify shelling parameters independently asa function of real-time moisture content, further optimizing user convenience and overall performance [].

The affordability in the use of the locally available material is a major determinant towards the affordability of the machine, hence making it easily accessible to more farmers working on a small scale. The process not only reduces the cost of production but also makes room for local competency in production and less reliance on foreign-produced machines, therebypromotingeconomic independence in farmingcommunities. The simplicity of design also facilitates simple repair and maintenance, determinants of longterm usage and sustainability in remote areas where access to specialized technical support or spares may be low [].

In summary, the mini corn shelling machine designed herein is a giant leap toward providing an effective, efficient,andeconomicallysustainabletechnologyforsmall-scalecornprocessing.Itsendurance,linked withits affordability and simplicity, renders it a revolutionary tool for improving farm productivity, reducing post- harvest losses, and improving the livelihood of smallholder farmers sustainably

X. CONCLUSION AND RECOMMENDATION

The project successfully designed, conceptualized, and prototyped a mini corn shelling machine and proved to have massive potential as an affordable and efficient device for small-scale farmers. The machine had fantastic shelling efficiency (average .%), excellent shelling capacity (average kg/hr), and extremely low damage rate on the grains (average .%). These performance parameters illustrate the capability of the machine to substantially minimize human labor, reduce post-harvest loss, and enhance the general efficiency and economic position of smallholder farming societies [,].

The successful use of cheap and accessible materials with an unstated but stable design guarantees the affordability, cost-effectiveness, and simplicity of the machine production and maintenance. It offers a sustainable and feasible alternative compared to traditional shelling manual methods and expensive industrial machineries,particularlyinregions whereresourcesarescarce and infrastructurenot wellestablished [,].Based on the detailed results of this study, the following recommendations are presented:

1) Facilitate Adoption and Dissemination: It is important to actively spread this mini corn shelling machine's design and manufacturing skills to small farming communities . Equally, this can be done with an eye towards special workshops, hands-on training sessions, and local manufacturing campaigns so that there is moreadoption and its overall impact to farming activity [].
2) Ongoing Optimisation and Flexibility: While the current design is functionally quite superior, ongoing research and development are advisable to pursue ongoing optimisation. This could involve research into alternative shelling mechanisms, better materials, or the integration of power sources even moreenvironmentally friendly and flexible regarding diverse environmental conditions and corn types [ ].
3) Integration with Post-Harvest Systems: Theminicornshellingmachineshouldbeviewedaspartofapieceof equipment within a broader system of post-harvest processing. Future research could involve developing modular systems combining shelling with other important operations such as drying, cleaning, and storage to offer a more holistic solution to farmers [].
4) In-depth Economic and Social Impact Assessment:Amoreprofoundeconomicanalysis,withcomprehensive cost-benefit ratios and return on investment studies among farmers, would provide stronger empirical evidence about the machine's viability. It would also be helpful to identify its social impact on gender roles, labor dynamics, and community development [].
5) Extensive Field Testing and User Feedback: Extensive field testing across various geographic locations and diverse farming practices is essential. Getting real-time user feedback from farmers will give us insightful information for iterative design improvement so that the machine effectively meets their evolving needs and desires on the ground

XI. FUTURE WORK

Continuing the encouraging results of this research, multiple avenues for future study are provided to further enhance the mini corn shelling machine and its efficiency:

1) Adaptive Shelling Mechanism Design: Research on designing a mechanism that automatically adjusts clearance between the concave and shelling cylinder based on corn cob diameter and moisture, maximizing performance and minimizing damage over a wider range of conditions.
2) Higher Integration of Renewable Energy: Higher R&D towards direct integration of solar power, wind power, or other renewable sources of power with the machine design for complete energy autonomy andreduced carbon footprint.
3) Intelligent Automation and Sensor Integration: Investigatingthepotentialforintegrationofsensorsforreal time monitoringofshellingefficiency,breakageof grain,and throughput withpossibleintegrationofautomated control and predictive maintenance.
4) Life Cycle Assessment (LCA): Conducting a comprehensive LCA to assess the environment's influence on the machine throughout its whole life cycle from raw material production to end-of-life disposal and ascertain the possibilities of more sustainable design, manufacturing, and recycling processes.
5) Modular Scalable Design: Developing a modular scalable design such that scaling up the capacity of the machine is easy, and farmers can scale up or expand their shelling capacity when and where their needs grow without any requirement for total replacement of machinery.
6) Material Technology for Sustainability and Durability: Searching for newer, more resilient, and greener materials that are sturdy enough to withstand harsh agricultural weather yet further reduce the machine's environmental footprint.

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