Design And Fabrication Of Pedal Operated Groundnut Shelling Machine

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Abstract- *Groundnut shelling is an essential post-harvest operation that converts dried pods into marketable kernels, but small farmers commonly depend on hand shelling or costly powered machines. This study presents the design, fabrication, structural validation and experimental evaluation of a revised pedal-operated groundnut shelling machine developed as a low-cost intermediate technology for rural and small-scale users. The machine consists of a hopper-fed rotary drum, stationary perforated concave, chain-and-sprocket transmission, 25 mm main shaft, welded mild-steel frame, pedal crank, fan-assisted separation unit and collection arrangement. Human power is transmitted through the pedal crank to the shelling shaft; the drum-concave pair cracks pods by rubbing and compression, while the outlet and fan arrangement separate lighter shells from heavier kernels. Design calculations were performed for pedal torque, power, chain drive ratio, shaft stress and drum peripheral speed. Structural safety was verified through finite-element/static simulation of the frame, shaft, shelling drum, pedal crank, bearing bracket and complete assembly. The maximum equivalent stress in the full assembly was 93.6 MPa, which is below the 250 MPa yield reference, and the corresponding factor of safety was 2.67. Experimental trials for 1-10 kg batches showed shelling efficiency between 89.2% and 91.3%, cleaning efficiency between 84.5% and 86.2%, and mechanical damage between 4.3% and 5.4%. The results confirm that the pedal-operated configuration can reduce drudgery, avoid electricity dependence and deliver acceptable shelling performance when speed, feed rate and concave clearance are controlled.*

Keywords: groundnut shelling; pedal-operated machine; agricultural mechanization; finite element analysis; chain drive; shelling efficiency; small-scale processing.

Highlights

- A revised pedal-operated sheller was developed for electricity-free groundnut processing.
- The drum-concave shelling unit was integrated with chain drive and fan-assisted separation.
- Frame, shaft, drum, pedal crank and bearing bracket were checked through structural analysis.
- The complete assembly remained safe with maximum stress of 93.6 MPa and factor of safety of 2.67.
- Experimental trials showed up to 91.3% shelling efficiency and mechanical damage below 5.4%.

I. INTRODUCTION

Groundnut is an important oilseed and food crop used for edible kernels, oil extraction, roasted products, confectionery, livestock feed and small-scale food-processing activities. The post-harvest value of groundnut depends strongly on the conversion of pods into clean kernels because shelling affects grading, storage, packing, oil recovery and market price. At the village and small-farm level, shelling is still frequently performed by finger pressure, hand rubbing, rolling, beating or simple hand tools. These methods require little capital, but they are slow, monotonous and physically tiring. They also produce mixed output containing clean kernels, broken kernels, shell particles and partially shelled pods, which increases the time required for manual sorting and winnowing.

Powered decorticators and motorized shellers can improve throughput, but their cost, electricity dependency, maintenance needs and safety requirements may limit adoption by small farmers and rural micro-enterprises. A pedal-operated sheller provides an intermediate solution because leg power can produce continuous rotary motion for longer periods than hand cranking, while the machine remains independent of grid electricity and fuel. The mechanical challenge is to convert limited and variable human power into effective shelling action without excessive vibration, kernel breakage, misalignment or structural failure. The present study develops a revised pedal-operated groundnut shelling machine based on a drum-concave shelling mechanism. The work combines conventional machine design, CAD modelling, finite-element/static structural analysis, fabrication and experimental testing. The novelty lies in linking a low-cost rural processing machine with structural validation of the main frame, shaft, shelling drum, pedal crank and bearing bracket, followed by batch-wise shelling performance evaluation.

II. LITERATURE REVIEW AND RESEARCH GAP

Existing studies on groundnut shellers show that successful shelling depends on crop properties and machine variables such as pod size, moisture content, feed rate, shelling speed, concave clearance, drum surface, sieve opening and airflow. Drum-concave systems are widely used because they can be fabricated using standard workshop operations and can provide continuous shelling. However, literature also indicates that capacity alone is not a sufficient performance measure. A technically useful sheller should be evaluated through shelling efficiency, cleaning efficiency, damaged kernel percentage, unshelled pod percentage, operator effort, reliability and ease of maintenance.

The reviewed literature reveals five main gaps: limited structural validation of low-cost prototypes, inadequate discussion of human-powered transmission design, fixed clearances despite crop variability, weak shell-kernel separation in several small machines, and insufficient reporting of ergonomic and safety features. These gaps justify the present approach, in which the machine is designed not only for shelling but also for strength, stability, maintainability and measurable output quality.

III. MATERIALS AND METHODS

3.1 Machine configuration

The proposed sheller consists of a welded mild-steel support frame, hopper, shelling drum, stationary semicircular concave/jali plate, main shaft, P-205 pedestal bearings, pedal crank, chain-and-sprocket transmission, fan-assisted separation arrangement, shell outlet and kernel collection tray. The operator supplies energy through pedalling. The driving sprocket transmits motion through a roller chain to the driven sprocket mounted on the shelling shaft. Groundnut pods enter through the hopper and are cracked in the clearance between the rotating drum and the fixed concave. The mixture of kernels and shells then moves toward the discharge/separation region.

3.2 Design assumptions and inputs

The design adopted dried groundnut pods as the process material, a moderate human pedalling speed of approximately 60 rpm, mild steel/structural steel for fabricated members, a 25 mm main shaft, locally available bearings and sprockets, and a drum-concave mechanism suitable for fabrication by cutting, welding, drilling, turning and assembly. The design emphasizes low cost, safe operation, easy replacement of wear components, stable support, proper alignment and reduced dependence on electricity.

Table 1. Main design inputs adopted for the pedal-operated sheller.

Parameter	Value	Use in design
Pedal design force	3 00 N	Torque input
Crank radius	0.175 m	Crank torque
Pedal speed	60 rpm	Power calculation
Main shaft length	13 in (330 mm)	Shaft bending span
Shaft diameter	25 mm	Stress check
Drum diameter	12 in (304.8 mm)	Peripheral speed
Large sprocket	44 teeth; 6 in dia.	Speed ratio
Small sprocket	13 teeth; about 40 mm dia.	Driven speed
Pedestal bearing	P-205	Bearing support
Hopper depth	8 in (203 mm)	Feed storage

A. 3.3 Complete visual documentation of methodology, design and analysis

This section places the complete set of source visuals, CAD views, ANSYS contours, fabrication photographs and result graphs immediately after the methodology so that the design development, analytical validation and prototype testing sequence can be followed before the detailed calculation and discussion sections. The original source figure identity is retained inside each caption, while the journal-paper figure numbering is updated sequentially.

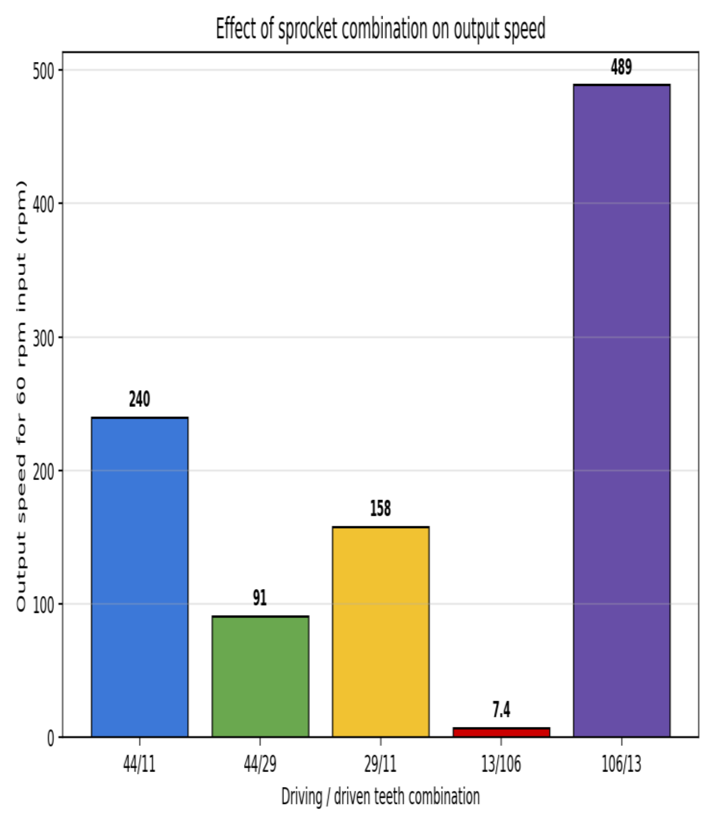

Figure 1: Output speed obtained from different sprocket combinations.

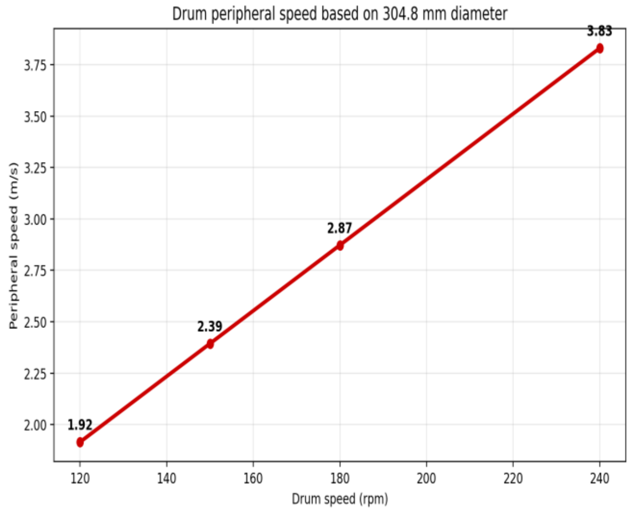

Figure 2. Drum peripheral speed for selected rpm levels.

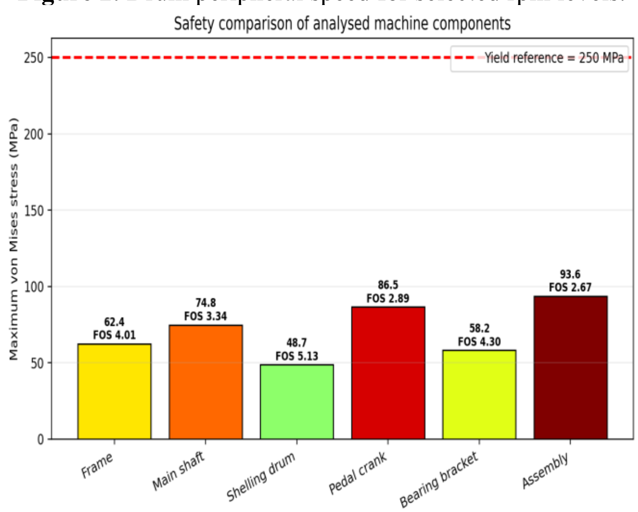

Figure 3: Safety comparison of analysed machine components.

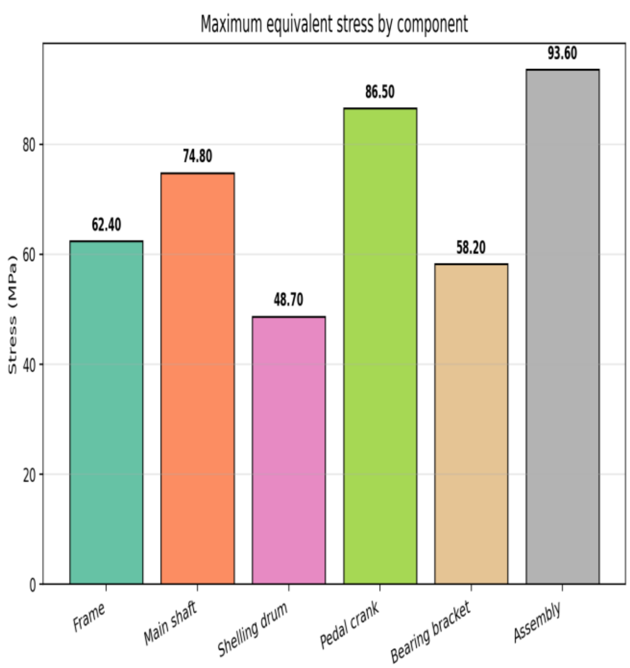

Figure 4: Maximum equivalent stress comparison.

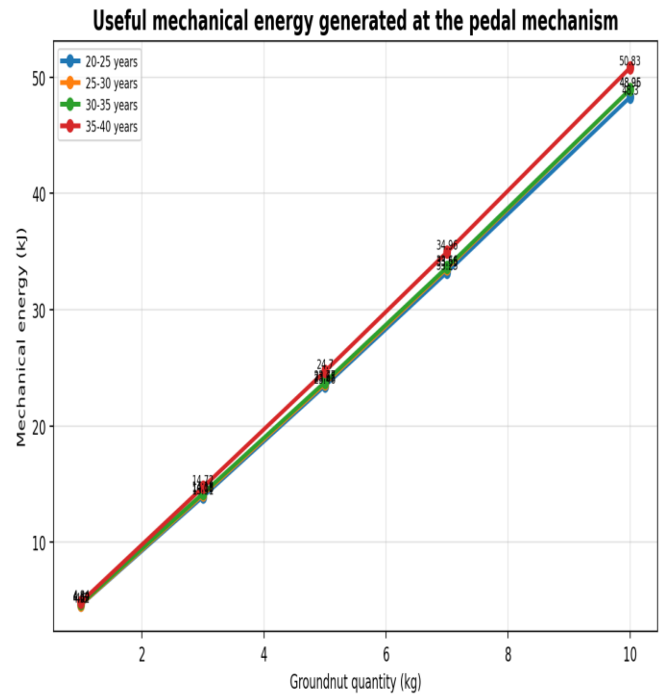

Figure 5: Useful mechanical energy generated for each shelling quantity.

IV. DESIGN CALCULATION AND POWER TRANSMISSION

The pedal crank converts the operator force into torque. For a crank radius of about 0.17-0.175 m, a normal pedal force of 150 N produces approximately 25.5-26.25 N.m torque, while a 300 N design force produces approximately 51-52.5 N.m torque. At 60 rpm, the estimated power rises from about 160 W under comfortable pedalling to about 320-330 W under design load. These values are appropriate for checking chain transmission, shaft strength and structural supports.

*Table 2. **Pedal force, torque and power load cases.***

Load case	Pedal force (N)	Torque T = F x 0.17 (N.m)	Power at 60 rpm (W)	Design meaning
A	150	25.5	160	Normal comfortable pedalling
B	200	34.0	214	Moderate continuous pedalling
C	300	51.0	320	Structural design load
D	500	85.0	534	Proof or accidental overload check

The chain-and-sprocket arrangement is selected because it provides positive transmission without belt slip. A speed ratio must balance capacity and kernel protection. Low ratios produce gentle shelling but lower throughput, whereas high ratios can increase shelling intensity and mechanical damage. The design report therefore compares several sprocket options and favours moderate speed multiplication for testing.

Table 3. Chain and sprocket speed-ratio options.

Driving teeth	Driven teeth	Speed ratio	Output speed for 60 rpm input	Design note
44	11	4.00	240 rpm	High speed; monitor damage
44	29	1.52	91 rpm	Gentle speed; low damage
29	11	2.64	158 rpm	Moderate speed; preferred trial
13	106	0.123	7.4 rpm	Torque increase but very slow
106	13	8.15	489 rpm	Too aggressive for direct shelling

Shaft strength was evaluated under combined bending and torsion. The preliminary calculation shows that the shaft remains safe across normal, moderate, design and proof-overload conditions. Even under proof overload, the estimated von Mises stress is 103.3 MPa with a factor of safety of 2.42 relative to a 250 MPa yield reference. Thus, the 25 mm shaft diameter is structurally acceptable, provided that bearing alignment, keyway geometry and sprocket seating are properly maintained during assembly.

Table 4. Preliminary shaft stress check for different load conditions.

Condition	Chain force / torque	Bending stress (MPa)	Torsional stress (MPa)	Von Mises stress (MPa)	Approx. FOS
Normal service	510 N / 25.5 N.m	27.4	8.3	31.0	8.07
Moderate working	680 N / 34.0 N.m	36.6	11.1	41.3	6.05
Design load	1020 N / 51.0 N.m	54.9	16.6	62.0	4.03
Proof overload	1700 N / 85.0 N.m	91.5	27.7	103.3	2.42

V. CAD modelling and structural analysis

CATIA/SolidWorks modelling was used to define the frame, shaft, drum, hopper and support geometry before structural analysis. Static structural analysis was then applied to the critical machine components. The material was modelled as mild steel/structural steel with density of 7850 kg/m3, Young modulus of 200 GPa, Poisson ratio of 0.30 and yield strength of 250 MPa. Loads included pedal force, chain reaction, bearing reaction, component self-weight and shelling contact load as applicable to each component. The required outputs were maximum equivalent stress, maximum deformation and factor of safety.

Table 5. Material properties used for structural analysis.

Property	Adopted value
Material	Mild steel / structural steel
Density	7850 kg/m3
Young modulus	200 GPa
Poisson ratio	0.30
Yield strength	250 MPa
Ultimate strength	410 MPa
Analysis type	Linear static structural

*Table 6. **Structural analysis result summary.***

Component	Max stress (MPa)	Max deformation (mm)	FOS	Design interpretation
Frame	62.4	0.82	4.01	Safe; focus on weld quality
Main shaft	74.8	0.18	3.34	Safe; check keyway and alignment
Shelling drum	48.7	0.26	5.13	Safe; maintain concentricity
Pedal crank	86.5	1.35	2.89	Safe but most sensitive
Bearing bracket	58.2	0.42	4.29	Safe; check bolt holes
Assembly	93.6	1.55	2.67	Acceptable global response

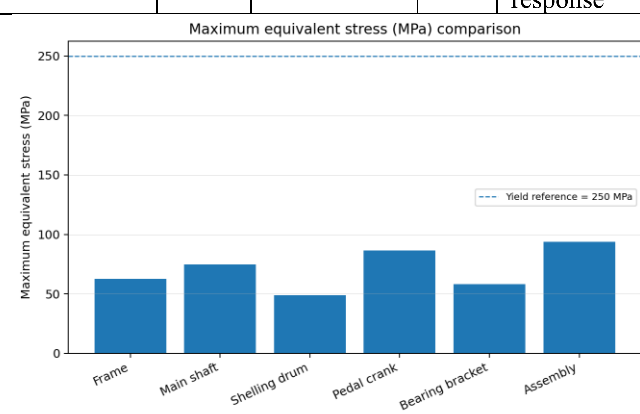

Figure 6. Journal-format comparison of equivalent stress for analysed components.

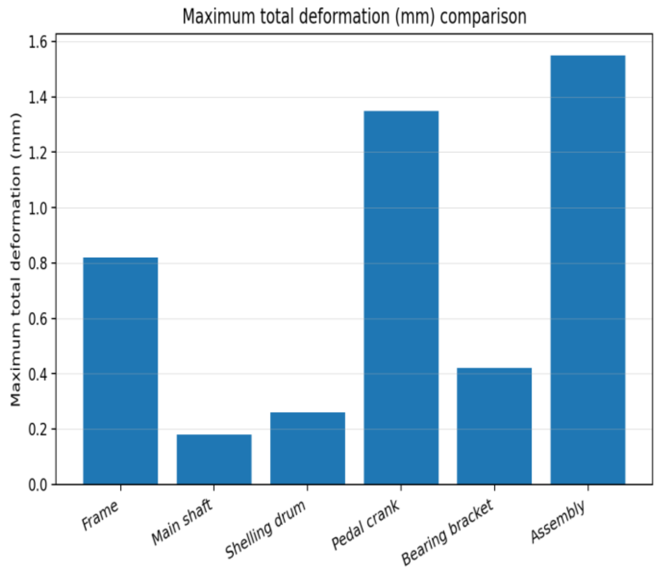

Figure 7. Journal-format comparison of total deformation for analysed components.

VI. FABRICATION AND EXPERIMENTAL TESTING

The prototype was fabricated using standard workshop operations. The frame was cut and welded from mild-steel sections, bearing blocks were drilled and bolted, the 25 mm shaft was aligned through P-205 pedestal bearings, and the shelling drum and concave were assembled to maintain the required working clearance. The hopper was fabricated from sheet metal and positioned above the shelling chamber. The chain drive and sprockets were aligned to prevent derailment and minimize transmission loss. Before testing, the assembly was checked for frame seating, pedal rotation, sprocket alignment, shaft rotation, drum-concave clearance, fan rotation, hopper flow and outlet clearance.

Table 7. ***Component-wise fabrication details.***

Component	Material/part	Fabrication process	Quality check
Base frame	Mild steel section	Cutting and welding	Square frame
Cycle/pedal frame	Cycle crank and support	Mounting and alignment	No pedal wobble
Main shaft	25 mm steel bar	Turning and bearing fitting	Smooth rotation
Shelling drum	Cylindrical drum	Welding of bars/shell	No rubbing
Concave/jali plate	Perforated sheet	Curving and fixing	Suitable hole size
Hopper	Sheet metal	Bending and welding	No sharp edge
Fan/blower	Fan unit	Mounting and outlet fitting	Airflow direction
Chain drive	Chain and sprockets	Chain tension setting	No derailment

Table 8. ***Assembly inspection checklist.***

Inspection point	Acceptance condition	Corrective action
Frame seating	All base points touch floor	Grind or shim base
Pedal rotation	Smooth crank motion	Tighten crank support
Sprocket alignment	Same chain plane	Shift sprocket spacer
Shaft bearing fit	No tight spot	Realign bearing block
Drum-concave gap	No rubbing at rest	Adjust concave bracket
Hopper feed	No sudden choking	Control gate opening
Fan outlet	Shells move outward	Change outlet angle
Trial discharge	Kernels collected below	Recheck clearance

Experimental trials were planned for 1 kg, 3 kg, 5 kg, 7 kg and 10 kg input batches. For each batch, the measured outputs included shelled kernels, shells/chaff, unshelled pods and damaged kernels. Time was recorded using a stopwatch. Performance was then calculated through shelling capacity, shelling efficiency, cleaning efficiency, damaged kernel percentage and unshelled percentage.

VII. RESULTS AND DISCUSSION

7.1 Structural performance

The structural analysis confirms that the proposed machine has adequate strength for the selected pedal force and shelling loads. The frame stress of 62.4 MPa and deformation of 0.82 mm indicate that the support structure can maintain alignment of the bearings, hopper and shelling chamber. The main shaft stress of 74.8 MPa and deformation of 0.18 mm show that the shaft can transmit the required torque without excessive bending. The shelling drum shows the lowest stress among the main working parts, with 48.7 MPa maximum stress and 0.26 mm deformation, which is acceptable for maintaining drum-concave clearance. The complete assembly has a maximum stress of 93.6 MPa and a factor of safety of 2.67, confirming safe operation under the modelled loading condition.

Table 9. ***Component-wise structural performance results.***

Component	Maximum stress	Maximum deformation	Factor of	Result status

	(MPa)	(mm)	safety	
Frame	62.40	0.82	4.01	Safe
Main shaft	74.80	0.18	3.34	Safe
Shelling drum	48.70	0.26	5.13	Safe
Pedal crank	86.50	1.35	2.89	Safe
Bearing bracket	58.20	0.42	4.30	Safe
Assembly	93.60	1.55	2.67	Safe

7.2 Shelling time and capacity

The experimental data show that shelling time increases approximately with input mass and also depends on operator age group. The fastest group, 20-25 years, required 40 s for 1 kg and 420 s for 10 kg, while the 35-40 years group required 51 s and 535 s respectively. Corresponding shelling capacity decreased slightly as batch mass increased, indicating that continuous operation introduces fatigue and feed-handling effects. The 20-25 years group produced the highest capacity range of 90.00 to 85.71 kg/h, while the 35-40 years group produced 70.59 to 67.29 kg/h.

Table 10. Time required for shelling different groundnut quantities.

Input mass (kg)	20-25 years	25-30 years	30-35 years	35-40 years
1	40	42	46	51
3	121	128	139	155
5	204	215	233	260
7	289	305	330	368
10	420	445	480	535

*Table 11. **Age-wise calculated shelling capacity.***

Input mass (kg)	20-25 years	25-30 years	30-35 years	35-40 years
1.00	90.00	85.71	78.26	70.59
3.00	89.26	84.38	77.70	69.68
5.00	88.24	83.72	77.25	69.23
7.00	87.20	82.62	76.36	68.48
10.00	85.71	80.90	75.00	67.29

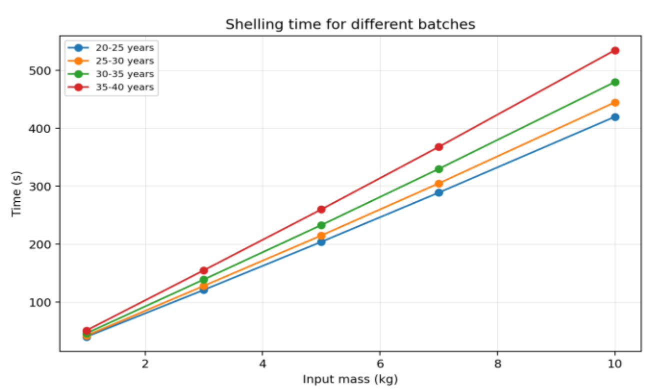

Figure 8. Shelling time for 1-10 kg input batches.

7.3 Energy, calories and operator demand

Useful mechanical energy and metabolic calorie values increase with batch size. The 10 kg batch required approximately 48.30-50.83 kJ of useful mechanical energy and 46.18-51.69 kcal metabolic energy across the tested operator groups. The trend confirms that the machine transfers meaningful human work into shelling while remaining suitable for non-electric operation. However, prolonged use should include ergonomic improvements such as comfortable seat height, guarded chain drive and reduced vibration.

Table 12. Useful mechanical energy generated during shelling.

Input mass (kg)	20-25 years	25-30 years	30-35 years	35-40 years
1.00	4.60	4.62	4.69	4.84
3.00	13.91	14.08	14.18	14.72
5.00	23.46	23.65	23.77	24.70
7.00	33.23	33.55	33.66	34.96
10.00	48.30	48.95	48.96	50.83

*Table 13. **Metabolic calories consumed during shelling.***

Input mass (kg)	20-25 years	25-30 years	30-35 years	35-40 years
1.00	4.40	4.51	4.67	4.93
3.00	13.30	13.74	14.12	14.98
5.00	22.43	23.07	23.67	25.12
7.00	31.77	32.73	33.52	35.56
10.00	46.18	47.75	48.76	51.69

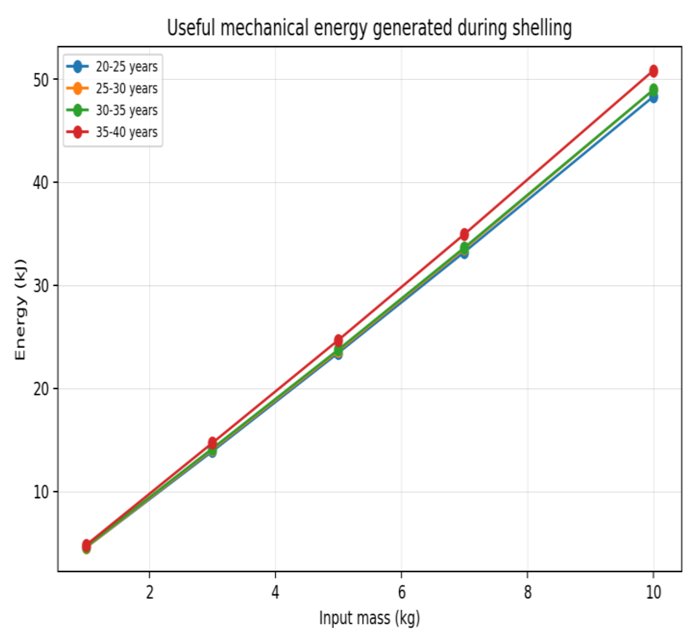

Figure 9. Useful mechanical energy generated during shelling trials.

7.4 Output quality and shelling performance

The output-composition results show that the machine produced 0.67 kg shelled kernels from a 1 kg batch and 6.78

kg shelled kernels from a 10 kg batch. Unshelled pods remained limited, ranging from 0.04 kg to 0.32 kg. Damaged kernels were also relatively low, ranging from 0.01 kg to 0.08 kg. Shelling efficiency varied from 89.2% to 91.3%, while cleaning efficiency varied from 84.5% to 86.2%. Mechanical damage varied from 4.3% to 5.4%. These values indicate that the revised pedal-operated machine can provide useful kernel recovery and acceptable output quality for small-scale processing. The slight rise in mechanical damage for larger batches suggests that feed rate, drum speed and concave clearance should be monitored during continuous operation.

Table 14. Output composition and performance values.

Input mass (kg)	Shelled kernels (kg)	Shells/ chaff (kg)	Unshelled pods (kg)	Damaged kernels (kg)	Shelling efficiency (%)	Cleaning efficiency (%)	Mechanical damage (%)
1.00	0.67	0.28	0.04	0.01	89.20	84.50	4.30
3.00	2.04	0.83	0.09	0.04	90.50	85.40	4.80
5.00	3.43	1.37	0.14	0.07	91.30	86.20	5.10
7.00	4.78	1.95	0.20	0.07	90.80	85.80	5.00
10.00	6.78	2.82	0.32	0.08	89.70	84.90	5.40

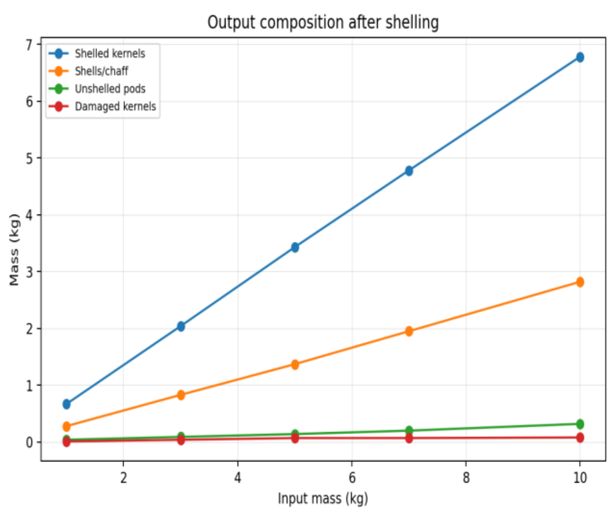

Figure 10. **Output composition of kernels, shells, unshelled pods and damaged kernels.**

VIII. CONCLUSIONS

1. A revised pedal-operated groundnut shelling machine was successfully converted from project concept into a structured journal-style engineering study covering design, analysis, fabrication and testing.
2. The selected drum-concave shelling mechanism is suitable for small-scale use because it is simple, locally fabricable and independent of electricity.
3. The pedal crank and chain drive can provide sufficient torque and drum rotation when moderate sprocket ratios are used. Excessive speed multiplication should be avoided because it may increase kernel breakage.
4. Structural analysis confirmed the adequacy of the frame, shaft, shelling drum, pedal crank, bearing bracket and complete assembly. The highest assembly stress was 93.6 MPa with a factor of safety of 2.67.
5. Testing showed shelling efficiency of 89.2-91.3%, cleaning efficiency of 84.5-86.2% and mechanical damage of 4.3-5.4%, confirming the practical usefulness of the prototype for small users.
6. Future work should focus on adjustable concave clearance, improved fan-outlet geometry, better chain guarding, lightweight frame optimization, multi-size sieves and extended field testing with different groundnut varieties and moisture contents.

DECLARATIONS

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Conflict of interest: The authors should declare that there is no conflict of interest, unless otherwise applicable.

Data availability: The design, analysis and experimental data used for manuscript preparation are included in the tables and figures of this article.

Ethical approval: Not applicable; the work concerns a mechanical agricultural prototype. Human participation was limited to operator-based machine trials and should be reported with institutional consent if required by the target journal.

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