ORIGINAL ARTICLE

DEVELOPMENT OF A SPRING-LOADED PRESSING SYSTEM AND HUSK DISPOSAL SYSTEM FOR A COCONUT DEHUSKING MACHINE

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ABSTRACT
The previously developed coconut dehusking machine showed operational limitations because the pressing mechanism required operator assistance and the removed husk was not continuously discharged. This study developed and functionally validated an integrated spring-loaded pressing mechanism and belt conveyor-based husk disposal system intended to stabilize coconut movement and maintain a clear dehusking area. The engineering-development process comprised problem identification, computer-aided design, fabrication and assembly, machine testing, and descriptive data analysis. The pressing subsystem used a tension spring, rollers, a belt, and bolt-type lugs to maintain contact with the coconut, whereas the disposal subsystem used a belt conveyor positioned below the dehusking zone. Functional testing was conducted with ten mature coconuts with circumferences of 54.5–57.0 cm. The mean dehusking time was 8.85 s (SD = 0.80 s; range = 7.71–10.27 s). During the reported trials, the pressing mechanism maintained contact and guided coconut rotation, while the conveyor transported the removed husk to the collection area without reported manual clearing during the dehusking cycle. These findings demonstrate successful integration and proof-of-function under the tested conditions; they do not establish comparative performance improvement because no baseline machine was tested concurrently. Further work should quantify capacity, durability, energy use, safety, and performance across a wider range of coconut characteristics and operating conditions.

Keywords: Belt conveyor, Coconut dehusking machine, Functional validation, Spring-loaded pressing system, Tension spring

INTRODUCTION

Indonesia is one of the largest coconut-producing countries and has great potential to support the coconut processing industry. Almost every part of the coconut can be processed into products with economic value, including coconut meat, coconut water, shell, and husk. Therefore, the development of coconut processing technology is important to increase the added value of coconut products and improve the productivity of the processing industry (Alouw & Wulandari, 2020).

Coconut husk is the outermost part of the coconut and accounts for about 35% of the total fruit weight. Although it is available in large quantities, its utilization is still limited. In fact, coconut husk can be processed into various value-added products such as cocopeat, coconut fiber, planting media, and raw materials for different industries. Before it can be processed further, the husk must first be separated from the shell through a dehusking process. Therefore, dehusking is an important step because it affects the efficiency of the following processing stages (Nontji et al., 2022).

In many coconut-processing activities, coconut dehusking is still carried out manually using simple tools. This method requires substantial physical effort, depends on operator skill, and can constrain processing capacity. The need for safer and more productive mechanized alternatives has therefore been recognized for several decades. Early engineering work developed dedicated coconut dehuskers and evaluated dehusking forces, throughput, field operation, and safety considerations (Nijaguna, 1988). Subsequent studies introduced lower-cost mechanical dehusking arrangements and showed that operator configuration can materially affect capacity and machine efficiency (Piyathissa & Kahandage, 2016). Related coconut-processing research has likewise demonstrated the importance of controlled fruit holding, rotational speed, cutting geometry, and repeatable machine settings in achieving consistent operation (Jarimopas & Ruttanadat, 2007).

These findings reinforce that dehusking performance is governed not only by the cutting or peeling element but also by how the fruit is restrained, guided, driven, and cleared from the working zone.

Previous research has addressed coconut dehusking through several mechanical approaches. Widananto and Purnomo (2013) emphasized participatory ergonomic design; Putera et al. (2019) developed a twin-cylinder mechanical dehusking machine; Bahsoan et al. (2020) examined blade modification; Naimuddin et al. (2021) compared machine and manual dehusking; and Bukhari et al. (2022) reported a gasoline-powered modification. Other designs have explored manually assisted lever mechanisms (Silaban, 2021), gasoline-engine configurations (Sahab, 2024), ripping-gear arrangements (Hakim et al., 2023), engineering analysis for low-cost coconut peeling equipment intended for small and medium enterprises (Yusofe et al., 2023), and comparative performance testing of coconut coir peeling tools (Tooy et al., 2024). Collectively, these studies show continuing efforts to increase capacity and reduce operator burden, but they also reveal considerable variation in machine architecture, sample condition, evaluation criteria, and the extent to which fruit restraint and waste removal are explicitly treated as integrated design functions.

Related agricultural-machinery research also highlights the importance of compliant contact, belt guidance, and controlled conveying. Nie et al. (2023) combined spring-based profiling with a flexible belt conveyor in a soybean header and linked component behavior to contact following and material transfer. Jin et al. (2024) designed a flexible spring-tensioned clamping and conveying device and showed that spring stiffness and conveying conditions are central to balancing retention and mechanical damage. Yang et al. (2025) similarly optimized flexible clamping parameters for safflower harvesting, while Wang et al. (2025) used force analysis and experimental optimization for a digging-and-pulling system that incorporated a clamping conveyor belt. For conveying performance, Li et al. (2024) demonstrated that belt geometry and operating parameters materially affect controlled material transfer, and Issa et al. (2025) showed the value of explicit conveyor configuration and operating-factor evaluation in a multi-stage agricultural separation system. Gu et al. (2022) further demonstrated that conveying-device performance depends on defined geometry, speed, material behavior, and validation conditions. Although these applications differ from coconut dehusking, they provide an engineering basis for treating spring compliance, normal contact, frictional guidance, and continuous material removal as interacting functions rather than isolated components.

The mechanical response of coconut husk also supports the need for compliant rather than purely rigid restraint. Coconut husk contains heterogeneous fibre and pith fractions whose morphology, maturity, and physical properties can vary among samples (van Dam et al., 2006). Coir fibres exhibit substantial variability in tensile behavior as a function of fibre diameter and test conditions (Tomczak et al., 2007), and experimental tensile data also confirm their deformable, load-bearing character (Widnyana et al., 2020). For machine design, this variability implies that a pressing mechanism should accommodate modest changes in coconut geometry and husk response while maintaining sufficient normal force and frictional engagement. This consideration provides a material-mechanics rationale for using a spring-loaded belt instead of a fixed rigid pressing gap.

Although these studies have contributed to the development of coconut dehusking machines, several problems are still found in the machine used in this study. The pressing system still depends on the operator, resulting in inconsistent pressing force during the dehusking process. In addition, the coconut tends to shift when it comes into contact with the peeling element, requiring the operator to repeatedly adjust its position. Another limitation is the absence of an automatic husk disposal system, causing the peeled husk to accumulate around the working area and interrupt the next dehusking process. These conditions indicate that the dehusking process has not yet operated efficiently.

Ideally, a coconut dehusking machine should be able to maintain the coconut in a stable position throughout the dehusking process and continuously remove the peeled husk to keep the working area clean. However, the existing machine has not been able to meet these requirements because the pressing system still relies on operator assistance and no husk disposal system is available. This difference between the expected condition and the actual condition indicates the need to improve the machine mechanism so that the dehusking process can operate more stably and continuously.

The research gap addressed here is therefore more specific than the general need for another coconut dehusking machine. The existing prototype used in this study still required operator-dependent pressing, allowing the coconut to shift during contact with the dehusking element, and it lacked continuous husk removal. The specific novelty of the present development is the integration of two complementary subsystems in one working sequence: a compliant spring-loaded belt pressing mechanism intended to maintain fruit contact and alignment, and a belt conveyor positioned to remove detached husk continuously. The contribution is consequently framed as an integrated operational solution and an initial functional validation, rather than as proof that the prototype outperforms all previous machines.

Accordingly, this study aims to develop and functionally validate an integrated spring-loaded pressing mechanism and belt conveyor-based husk disposal system for a coconut dehusking machine. The validation focuses on whether the two subsystems can operate together under the reported test conditions, maintain the coconut on the intended dehusking path, remove detached husk from the working area, and produce a transparent descriptive record of dehusking time.

METHOD

This study used an engineering development approach followed by preliminary functional validation. The development responded to two operational limitations of the existing machine: operator-dependent pressing that allowed coconut displacement during dehusking and the absence of a dedicated husk-removal mechanism. The work was organized into five stages: problem identification, computer-aided design (CAD), fabrication and assembly, machine testing, and descriptive data analysis. The workflow shown in Figure 1 was used to move from identification of the mechanical problems to construction and proof-of-function testing of the integrated prototype.

The first stage identified the components that required improvement. The redesigned subsystems were then modeled using CATIA and AutoCAD to prepare three-dimensional representations and engineering drawings for fabrication. The design logic was to provide a compliant pressing path above the coconut and a gravity-assisted disposal path below the dehusking zone. The available manuscript records document the component configuration but do not report several numerical parameters needed for full replication, including spring stiffness and preload, belt material and thickness, roller and pulley dimensions, bolt/lug spacing, conveyor speed, and the transmission ratio at the test condition. These values are therefore not inferred or reconstructed in this revision. Their absence is treated as a reproducibility limitation and a priority for the next design-validation stage.

The fabrication and assembly stage involved manufacturing the machine frame, pressing mechanism, conveyor frame, rollers, shafts, blade holder, and other supporting components based on the engineering drawings. Conventional workshop processes such as cutting, turning, drilling, grinding, and welding were used during fabrication. After all components had been manufactured, they were assembled into one machine unit. The assembled machine was then inspected to ensure that every component had been installed properly before testing. The developed coconut dehusking machine is shown in Figure 2.

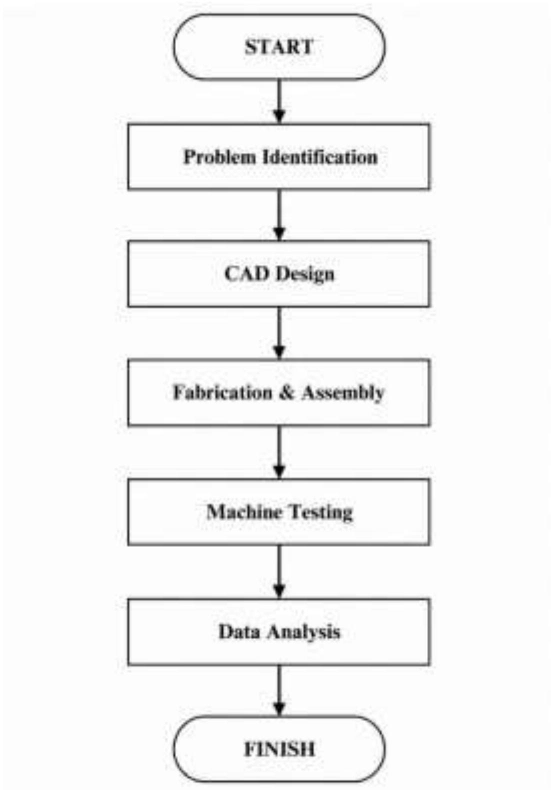

Figure 1. Research procedure for development and functional validation.

Figure 2. Developed coconut dehusking machine.

After fabrication, the completed machine consisted of a gasoline engine, gearbox, belt transmission, spring-loaded pressing mechanism, belt conveyor, and coconut dehusking unit. Before functional testing, the assembled prototype was inspected to confirm that the subsystems were installed and mechanically connected as designed. Because the present study evaluates integration and functional behavior rather than structural certification, it does not report a finiteelement strength analysis, long-duration reliability test, or formal guarding assessment. The machine configuration presented in the figures should therefore be interpreted as a development prototype.

Machine testing was conducted after assembly using ten coconuts identified in the available records as mature. Their circumferences ranged from 54.5 to 57.0 cm and were recorded before testing. All ten samples were operated under the same reported machine condition. The available test record does not specify the instrument used for circumference measurement, the formal maturity criterion, or numerical rotational-speed settings; these details are therefore acknowledged as unavailable rather than assumed. The functional test evaluated the spring-loaded pressing mechanism and the belt conveyor while the total dehusking time for each coconut was recorded.
Functional success was assessed using observable operational criteria derived from the development objectives: (a) the pressing belt remained in contact with the coconut during the dehusking cycle; (b) the coconut remained on the intended dehusking path without a reported need for repeated manual repositioning; (c) detached husk reached the conveyor and was transported toward the collection area; and (d) the available record showed no reported conveyor jam or manual husk clearing during the recorded dehusking cycle. These criteria are qualitative and are used only to support proof-of-function, not to quantify comparative improvement.

Figure 3. Functional testing of the developed coconut dehusking machine.

No human participants were enrolled and no human-subject outcomes were analyzed; accordingly, human-subject ethics approval and participant informed consent were not applicable to this mechanical functional test. Machine safety remains a separate engineering requirement. Agricultural machinery studies have shown that safety-oriented design changes, guarding, and ergonomic configuration can materially reduce exposure to hazardous moving components (Kumar et al., 2002), while farm-level evidence also associates the availability of machinery safety devices with injury risk (Narasimhan et al., 2010). Formal safety performance of the present prototype—including guarding effectiveness, emergency stopping, operator exposure, and personal protective equipment compliance—was not evaluated as an outcome. These aspects require a dedicated risk assessment and safety-validation stage before the prototype can be considered ready for routine or unrestricted operational deployment.

The ten individual dehusking times and coconut circumferences were analyzed descriptively. In addition to presenting each trial, the analysis reports the mean, sample standard deviation, and range to characterize the observed test set. No inferential statistical test was applied because the study did not include a control machine, randomized treatment groups, or repeated operating conditions designed for hypothesis testing. The analysis is therefore intentionally limited to functional behavior and descriptive performance under the single reported test condition.

RESULTS AND DISCUSSION

Development of the Machine Systems

The machine developed in this study focuses on two main systems: a spring-loaded pressing mechanism and a belt conveyor-based husk disposal system. These systems were developed to overcome several limitations found in the previous machine. During operation, the coconut was not always held firmly because the pressing force depended on the operator. As a result, the coconut often shifted when it came into contact with the dehusking blade. In addition, the peeled husk accumulated around the dehusking area because there was no automatic disposal system. These conditions interrupted the dehusking process and increased the operator's workload.

To address the two identified operational problems, the prototype was redesigned by integrating a spring-loaded pressing mechanism with a belt conveyor for husk removal. The pressing mechanism provides a compliant contact path that follows the coconut as it rotates against the dehusking element, while the conveyor provides a separate material-flow path for the detached husk. The purpose of the integration is not to alter the basic dehusking principle but to reduce dependence on repeated operator correction and to keep the dehusking zone clear during the recorded cycle.

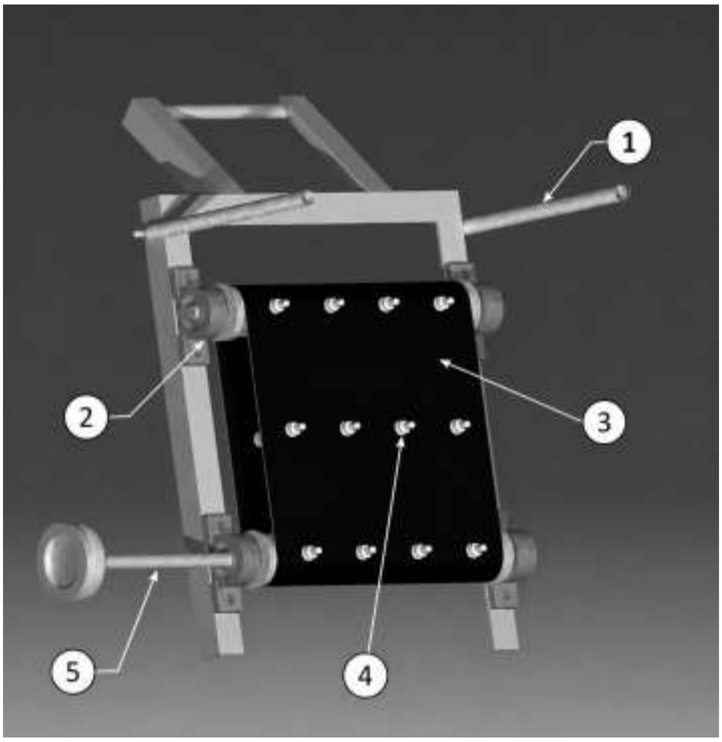

Figure 4. Spring-loaded pressing mechanism.

Legend:

1. Tension spring
2. Roller
3. Belt
4. Bolt
5. Shaft

The pressing mechanism consists of a tension spring, rollers, a belt, bolts that act as lugs, and a shaft. From an engineering perspective, the tension spring introduces compliance into the pressing path. As the coconut geometry changes during rotation, spring extension allows the roller-belt assembly to follow the surface instead of relying on a fixed rigid gap. The resulting spring action provides a normal contact force that helps maintain belt-to-coconut contact. Because spring stiffness and preload were not documented in the available design record, the present study cannot quantify the resulting normal force; however, the functional test can establish whether the selected arrangement maintained contact under the reported condition.

The belt acts simultaneously as a pressing and guiding element. Distributed belt contact can reduce reliance on a single restraint point, while roller motion allows the belt to travel with the coconut surface. This arrangement is mechanically consistent with flexible belt-contact systems used in agricultural machinery where controlled following, clamping, and material transfer are required (Jin et al., 2024; Nie et al., 2023; Yang et al., 2025). In this prototype, the intended effect is more stable guidance along the dehusking path rather than a direct increase in blade cutting capability. Because the husk is fibrous and mechanically variable (Tomczak et al., 2007; van Dam et al., 2006), future optimization should determine the spring stiffness, preload, belt compliance, and lug geometry required to maintain contact without excessive local loading.

Figure 5. Belt conveyor-based husk disposal system.

Bolts attached to the belt surface function as lugs that increase mechanical engagement with the fibrous husk. Their purpose is to reduce relative slipping and improve rotational coupling between the moving belt and the coconut. This design choice also introduces a trade-off: insufficient lug engagement may allow slip, whereas excessive protrusion or pressure could increase local husk damage or transmit undesirable loads toward the shell. The present functional test observed guidance behavior but did not quantify slip ratio, contact force, husk damage, or shell damage. Those measures should be included in subsequent optimization.

The second system developed in this study is the belt conveyor-based husk disposal system, as shown in Figure 5.

Legend:
1. Pulley
2. Roller
3. Pillow block
4. Belt
5. Frame
6. Shaft
7. Roller cover

The belt conveyor consists of a pulley, rollers, pillow blocks, a belt, a frame, a shaft, and a roller cover. The conveyor is installed directly below the dehusking area so that the peeled husk falls onto the moving belt immediately after it is separated from the coconut. The belt then transports the husk to the collection area located at the rear of the machine.

The conveyor was selected because a belt system can receive detached husk directly below the dehusking zone and move it away in a continuous path without requiring a complex secondary transfer mechanism. This placement takes advantage of gravity for initial husk transfer and separates the waste-flow function from the pressing function. Agricultural conveying studies consistently show that transfer reliability depends on parameters such as belt speed, geometry, inclination, material properties, and interaction with the conveyed material (Gu et al., 2022; Issa et al., 2025; Li et al., 2024). In the present prototype, conveyor speed and capacity were not instrumented, so the evaluation is limited to whether the husk was successfully carried away during the ten functional trials.

By removing the husk continuously, the conveyor prevents husk accumulation around the dehusking unit. This keeps the working area clean and allows the dehusking process to continue without frequent interruptions. As a result, the operator no longer needs to stop the machine repeatedly to remove the accumulated husk.

The two subsystems are complementary during operation: the spring-loaded belt guides the coconut while the conveyor removes the detached husk from below the dehusking zone. This coordinated sequence is the principal design contribution of the study. The observed operation supports successful integration under the tested condition, but the study does not include a concurrent test of the previous machine. Statements of superiority or improved efficiency relative to the earlier design are therefore avoided.

Functional Testing

After assembly, the prototype was subjected to functional testing with ten mature coconuts. The evaluation focused on the operational criteria defined in the Method: continuity of belt contact, maintenance of the coconut on the intended dehusking path, transfer of detached husk to the conveyor, and absence of reported interruption for manual husk clearing during the recorded cycle. Dehusking time was recorded for each sample to provide a quantitative descriptor of the test set rather than to demonstrate a statistically significant performance advantage.

Across the reported trials, the spring-loaded pressing mechanism maintained belt contact with the coconut and supported rotation along the dehusking path. The available observation record did not indicate repeated manual repositioning during the recorded cycles. This outcome is consistent with the intended role of spring compliance and belt guidance, although the absence of displacement sensors or force measurements means that positional stability is demonstrated qualitatively rather than quantified.

The belt conveyor also performed its intended disposal function during the reported trials. Detached husk fell onto the moving belt and was transported toward the collection area without reported manual clearing during the recorded dehusking cycles. No conveyor jam is reported in the available test record. These observations establish proof-of-function for husk transfer, but they do not establish maximum conveyor capacity, long-duration resistance to clogging, or performance under a sustained production load.

Figure 6. Testing process of the developed machine.

Table 1. Coconut Circumference and Dehusking Time During Functional Testing

No	Coconut Circumference (cm)	Dehusking Time (s)
1	57	8.4
2	57	7.71
3	57	9.19
4	56.5	10.27
5	56	8.79
6	56	10.12
7	56	8.57
8	55	8.6
9	55	8.43
10	54.5	8.43

The dehusking time recorded during functional testing is presented in Table 1. The ten coconuts had a mean circumference of 56.0 cm (SD = 0.91 cm; range = 54.5–57.0 cm). Mean dehusking time was 8.85 s (SD = 0.80 s), with individual values ranging from 7.71 to 10.27 s. The relatively narrow spread of the recorded times provides a concise description of the prototype under this single test condition, but it should not be interpreted as evidence of general performance across coconut varieties, moisture levels, sizes, operators, or machine settings.

Taken together, the observation record and timing data support the conclusion that the two developed subsystems were successfully integrated and functioned during the ten tests. The evidence supports proof-of-function: the pressing mechanism maintained contact and guidance, and the conveyor transferred detached husk. It does not, however, establish that the system is faster, safer, more energy efficient, or more durable than the previous machine because no concurrent baseline or control test was performed.

Interpretation, Practical Significance, and Limitations

The recorded dehusking time can be positioned cautiously within the existing literature. Nijaguna (1988) demonstrated that dedicated mechanical design could substantially increase coconut dehusking throughput relative to manual spike dehusking, whereas Piyathissa and Kahandage (2016) showed that capacity and efficiency changed with operator configuration. More recent Indonesian prototypes have likewise reported faster mechanical operation than conventional manual work (Bukhari et al., 2022; Naimuddin et al., 2021). Tooy et al. (2024) reported an average of 7.454 s per coconut for a modern peeling machine in a larger comparative test, while Putera et al. (2019) reported a capacity of 100 coconuts per hour for a twin-cylinder design. The present mean of 8.85 s lies within a broadly comparable operational range to several powered-machine reports, but direct ranking is not scientifically justified because the studies differ in machine architecture, coconut condition, definition of completed dehusking, operator involvement, sample size, and timing protocol. The main value of the present result is therefore internal: it provides a transparent baseline for subsequent controlled testing of this specific integrated prototype.

The functional observations also clarify the design trade-offs that should guide further optimization. A more compliant spring arrangement can accommodate variation in coconut diameter, but insufficient force may permit slipping, whereas excessive force may increase frictional load, power demand, husk damage, or shell damage. Flexible clamping research in other agricultural machines similarly demonstrates that spring settings and contact geometry influence both retention and damage outcomes (Jin et al., 2024; Yang et al., 2025). More aggressive belt lugs can improve rotational engagement but may increase local damage, particularly because coir properties vary with fibre morphology and loading condition (Tomczak et al., 2007; Widnyana et al., 2020). For the disposal subsystem, a simple belt conveyor reduces manual clearing and is easy to integrate, but its practical value ultimately depends on belt speed, load capacity, resistance to fibrous entanglement, cleaning requirements, and power consumption (Gu et al., 2022; Issa et al., 2025). Future optimization should therefore couple complete mechanical specifications with quantitative outcomes such as slip frequency, contact force, dehusking completeness, husk/shell damage, throughput, energy consumption, and stoppage rate.

From a practical perspective, the use of a tension spring, rollers, belt elements, bolts, shafts, and a conventional belt conveyor provides a mechanically understandable configuration that can be fabricated with standard workshop processes. This supports the potential relevance of the design for small- and medium-scale coconut processing, where simpler fabrication and maintainability can be important. Nevertheless, practical suitability has not yet been established through cost analysis, maintenance assessment, sustained-load testing, operator-safety evaluation, or field deployment. Safety is particularly important for machines combining rotating dehusking elements, belts, shafts, and power transmission; prior agricultural-equipment research emphasizes that safe geometry, guarding, and safety-device provision should be treated as explicit design requirements rather than post-development additions (Kumar et al., 2002; Narasimhan et al., 2010). The appropriate interpretation is therefore that the prototype is potentially applicable to small- and medium-scale settings and warrants further performance, durability, and safety validation rather than that it is already validated for commercial use.

Several limitations define the boundary of the findings. First, functional validation used only ten mature coconuts within a narrow circumference range of 54.5–57.0 cm. Second, one prototype and one reported operating condition were evaluated, and key engineering parameters such as spring stiffness/preload, belt specification, conveyor speed, and drive ratio were not preserved in the available records. Third, the study did not include a concurrent baseline machine, repeated operating-speed treatments, long-duration reliability testing, formal throughput testing, energy measurement, cost analysis, or structured safety evaluation. Fourth, the primary functional outcomes were based on direct observation rather than instrumented measurements of force, displacement, slip, or material flow. These limitations mean that the findings should be generalized only to the proof-of-function demonstrated under the reported test condition. A subsequent validation study should use a larger and more diverse sample, document complete engineering specifications, predefine timing and failure criteria, replicate tests across operating settings, and include comparative and safety performance measures.

CONCLUSION

This study developed and functionally validated an integrated spring-loaded pressing mechanism and belt conveyor-based husk disposal system for a coconut dehusking machine. In ten tests using mature coconuts with circumferences of 54.5–57.0 cm, the prototype recorded a mean dehusking time of 8.85 s (SD = 0.80 s; range = 7.71–10.27 s). The reported observations show that the pressing belt maintained contact and guided the coconut along the dehusking path, while the conveyor transported detached husk away from the working area without reported manual clearing during the recorded cycle. These results support successful subsystem integration and initial proof-of-function under the tested condition. Because the study did not include a concurrent baseline, long-duration testing, energy measurement, formal safety evaluation, or a broader range of coconuts, the findings should not be interpreted as definitive evidence of comparative superiority or commercial readiness. Further validation should quantify mechanical parameters, throughput, durability, energy use, safety, and performance across wider operating conditions.

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