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Solar-Powered Mechanical Composting Bins: A Review of System Integration, Process Monitoring, and Power Feasibility

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Abstract: *Organic waste from households, canteens and small institutions requires handling methods that reduce nuisance, support biological decomposition and limit dependence on grid electricity. This review examines research and technical documents relevant to a proposed solar-operated compost bin, focusing on mechanical size reduction and mixing, temperature and moisture monitoring, low-power control, and solar-powered waste-bin subsystems. Eleven sources published between 2019 and 2026 were selected from the supplied material. The sources include conceptual composter design, fabricated waste-treatment and shredding machines, automated composting concepts, and solar-powered smart bins. The review finds that mechanical agitation and pre-processing can support material handling, while sensors and controllers can improve observation and automate selected actions. However, a solar-powered waste bin or compactor is not evidence of composting performance, and several compost-machine papers report operating claims without enough independent validation to establish compost maturity, throughput or product quality. A preliminary system concept is therefore outlined using a solar photovoltaic panel, battery, charge controller, geared mixing motor, compost chamber and temperature/moisture sensing. A basic energy check shows that the proposed 150 W panel and 12 V, 40 Ah battery require a carefully controlled motor duty cycle; the 250 W motor cannot be assumed to run continuously from the panel. The paper concludes with a test plan covering energy balance, mixing performance, temperature, moisture, odor, mass reduction and compost maturity. The proposed configuration is a design basis for prototype development, not a claim of experimentally verified performance.*

Key *Words*: *organic waste; composting; solar photovoltaic system; mechanical mixing; shredding; moisture monitoring; temperature sensing; energy balance*

I.INTRODUCTION

Organic waste is biodegradable material that can be biologically converted into a more stable product when moisture, oxygen, particle size and other process conditions are managed. Composting is not simply drying or heating waste: it is a biological process whose rate and outcome depend on the feedstock and operating conditions. A mechanical unit can help with containment, mixing, aeration, monitoring and handling, but its mechanical functions do not by themselves prove that the output is mature compost.

The supplied literature covers several adjacent technology groups. Some papers directly discuss composting machines or composters; others focus on shredding; and a third group describes solar-powered bins that automate lid opening, fill detection, compaction or segregation. These technologies can inform component selection, but they serve different purposes. This review keeps that distinction explicit and treats reported performance as the claim of the cited authors unless the source provides a clear test method and measurements.

The project considered here proposes a solar-operated compost bin for small-scale organic waste management. The engineering challenge is to integrate a mechanically robust chamber and mixing mechanism with a solar-battery supply while preserving conditions needed for biological decomposition. The review therefore considers mechanical design and process control together, rather than treating solar power as the only design objective.

II. OBJECTIVES AND SCOPE

- Review relevant literature on composting machines, household composters, shredders and sensor-based monitoring.
- Compare the functions and limitations of the selected systems without treating smart bins or compactors as composters.
- Identify gaps in validation, energy sizing, process monitoring and output-quality assessment.
- Develop a preliminary design basis and energy calculation for the proposed solar-operated compost bin.
- Recommend measurable prototype tests needed before claiming capacity, composting time, power autonomy or product quality.

III. REVIEW METHODOLOGY

The review is based on the papers, project reports and technical learning documents supplied for this assignment. Eleven sources were selected for relevance to one or more of the following themes: (i) composter concept and design methodology, (ii) mechanical chopping/shredding and mixing, (iii) automated sensing and control, and (iv) solar-powered waste-bin electronics. Duplicate uploads of the same student project report and repeated copies of the same article were counted once. A broad thesis on organic-waste technologies and general composting notes were used as contextual material but were not counted among the eleven core studies.

The selection is a focused narrative review, not a systematic review. No claim is made that every publication on solar composting has been found. For each source, the review records its main function, relevance to the proposed project and limitations visible from the supplied document. Where a source presents a proposed design or author-reported result without a fully described validation protocol, the finding is described as a proposal or reported claim rather than an independently confirmed result.

IV. LITERATURE REVIEW

4.1 Ng et al. (2021): Conceptual design of a household food-waste composter

Ng et al. (2021) present a preliminary conceptual design approach for a household food-waste composter. Their emphasis is on design methodology: translating user needs into design requirements, generating concepts, comparing alternatives and selecting materials. The study is useful because it treats composter development as a structured engineering decision rather than selecting a mechanism without justification. Its principal limitation for the present project is that a conceptual design and CAD-based selection do not, by themselves, establish real operating performance. A solar-operated version would need additional work on power demand, battery sizing, sealing, cleaning, safe access and validation with actual feedstock.

4.2 Gunasegaran et al. (2019): Economical smart composting machines

Gunasegaran et al. (2019) discuss an economical smart food-waste composting machine in the context of waste management at Penang Hill. The described approach combines a contained composting unit with mechanical mixing and operational features intended to make handling more practical. Its value for this project lies in the integration perspective: a composting appliance has to be convenient to operate and maintain as well as mechanically functional. The context and study approach are not equivalent to a controlled performance trial for the proposed 500 L design, so the article should not be used to infer the proposed unit's throughput or composting duration.

4.3 Pandey et al. (2019): Mechanically assisted organic-waste processing

Pandey et al. (2019) describe an organic-waste composting machine using a motor-driven blade arrangement and a sequence involving size reduction and heat treatment. The paper gives a mechanical basis for considering rotating blades and powered processing, but its described heat-based treatment should not be conflated with biological compost maturation. Heating or reducing moisture can change the material quickly, while mature compost requires evidence of stability and suitability for use. For the proposed system, mechanical mixing should be evaluated as a support to decomposition, and any heater should be justified separately through an energy budget and biological rationale.

4.4 Mane et al. (2020): Portable waste-treatment bin

Mane et al. (2020) describe a portable waste-treatment bin with an upper chopping/storage section and a lower treatment chamber, including a powered heating element and manual stirring. The paper reports a temperature range and a short processing period. These are the authors' reported operating claims; the supplied description does not establish that a short heated cycle is equivalent to mature, stable compost under a standardized test. The design is relevant for chamber layout and material transfer, but it also highlights the need to separate waste-treatment time from verified compost maturity.

4.5 Resmi and Vinod (2022): Portable organic-waste shredding machine

Resmi and Vinod (2022) report the development of a portable shredding machine intended to prepare organic waste for rapid composting. Their paper reports a processing rate of 360 kg/h for vegetable waste and fuel use of 1 L/h. Those figures belong to the specific shredder and operating conditions reported by the authors; they should not be transferred to the proposed compost bin, whose feed rate and energy source are different. The broader design implication is that particle-size reduction may improve handling and create a more uniform feed, but blade safety, blockage, cleaning, power consumption and the balance between particle size and aeration require assessment.

4.6 Karawade et al. (2024): Organic-waste shredding system

Karawade et al. (2024) also focus on an organic-waste shredding system. The work supports the distinction between pre-processing and composting: a shredder can reduce particle size, but it does not demonstrate decomposition or compost quality. In the proposed system, shredding could be a separate upstream module or a manually controlled pre-processing step. Adding it inside the solar-powered bin would increase peak power, guarding requirements and maintenance complexity, so its inclusion should follow a measured need rather than be assumed.

4.7 Kakade et al. (2022–2023): Automatic composting machine project

Kakade et al. (2022–2023), in a student project report, propose an automatic composting machine using a shaft-and-blade mechanism and electronic control based on temperature and moisture sensing. This provides a practical reference for combining a mechanical agitator with a microcontroller and simple sensors. As a project report, it is best used as an implementation reference rather than as a peer-reviewed benchmark. Sensor placement, calibration, protection from wet and corrosive material, and the logic used to trigger mixing or watering would need to be specified and tested in a new prototype.

4.8 Dinesh Kumar et al. (2024): Organic-waste composting machine

Dinesh Kumar et al. (2024) describe an organic-waste composting machine with automation and monitoring elements, including temperature and moisture sensing and a heater-related arrangement. The article illustrates the common design objective of reducing manual supervision. However, its framing of aerobic/anaerobic operation and aeration-related mechanisms is not entirely consistent throughout the supplied text. For that reason, it is more reliable to cite it as evidence of a proposed sensor-enabled machine than to use it to make a definitive claim about the best biological process. The present project should explicitly select its process mode and document how oxygen, moisture and temperature are managed.

4.9 Añonuevo et al. (2026): Smart organic-waste composter

Añonuevo et al. (2026) present a smart organic-waste composter using an ESP32, environmental sensors, actuators, a display and Blynk connectivity. The architecture is relevant to monitoring and user feedback. The article mentions short correction or response cycles; these should be understood as control-system response intervals, not the total time required for compost to mature. For the proposed bin, a controller can record conditions and activate mixing or alerts, but automated actuation should be bounded by safety interlocks, motor-current limits and battery state.

4.10 Adeduntan et al. (2025): Solar-powered smart waste bin

Adeduntan et al. (2025) develop a solar-powered smart waste bin with automated lid opening and fill-level detection. Its solar supply, actuator control and fill-detection arrangement are relevant to low-power electronics and user interaction. However, a smart collection bin is not a composting reactor: its performance cannot validate decomposition rate, compost maturity or biological process control.

4.11 Ajayi et al. (2025): Intelligent solar-powered waste bin

Ajayi et al. (2025) describe an intelligent solar-powered waste-bin prototype using sensing and control elements such as fill-level detection, motion-related input, a controller, a display and a solar-battery supply. The authors report battery endurance for their prototype. That result is system-specific and should not be assumed for a bin with a geared mixing motor, because a mixing motor can dominate the energy budget.

V. RESEARCH GAP

The reviewed sources show that the individual building blocks of a composting appliance—mixing mechanisms, shredding, sensing, microcontroller-based automation and solar-powered electronics—have been explored separately or in partially integrated systems. The supplied literature provides less direct evidence for a small-scale solar-operated compost bin in which the solar-battery subsystem, geared mixing motor and biological process are validated together under a stated feedstock and operating schedule.

- Energy-performance gap: solar-bin autonomy figures cannot be transferred to a system with a higher-power mixing motor without measuring the complete duty cycle.
- Process-validation gap: several papers report rapid treatment or heating, but do not provide sufficient evidence in the supplied documents to confirm stable, mature compost at the stated time.
- Integrated-control gap: sensor values, calibration, thresholds, actuator logic and fault handling are not consistently documented across the selected studies.
- Mechanical-performance gap: shaft torque, blade loads, blockage behaviour, corrosion, cleaning and guarding need to be evaluated for the proposed waste mixture.
- Reporting gap: the proposed design needs a consistent stated capacity and test protocol; inconsistent batch and daily-feed estimates should not be presented as established values.

The project can address these gaps through prototype testing rather than by claiming novelty solely from combining known components. Its contribution should be framed as the design, integration and measured evaluation of a solar-powered mechanical composting unit.

VI. PROPOSED SYSTEM AND PRELIMINARY DESIGN BASIS

The following values are the project's preliminary design inputs, not validated results: nominal chamber volume 500 L; approximate external dimensions 1800 mm × 1200 mm × 1000 mm; 150 W photovoltaic panel; 12 V, 40 Ah battery; 20 A charge controller; 250 W geared motor; vertical shaft approximately 40 mm diameter and 1600 mm long; 18 curved mixing blades made from 5 mm mild-steel plate; UCP208 bearing units; coupling; feed hopper; compost discharge outlet; perforated stainless-steel screens; HDPE leachate tank; sprinkler arrangement; inspection door; base frame and wheels; and temperature/moisture sensors. Final dimensions, shaft sizing, blade geometry, material grades and frame sections must be confirmed by engineering calculations and fabrication constraints.

6.1 Functional arrangement

- Feed and chamber: biodegradable feedstock enters through a guarded hopper and is retained in a chamber that allows inspection and cleaning.
- Mixing mechanism: a geared motor drives the shaft and blades intermittently to turn the material. The gear ratio and blade geometry should be chosen from measured torque requirements, not motor wattage alone.
- Monitoring: temperature and moisture sensors provide observations at representative positions. Readings should be calibrated and logged; one sensor at a single point may not describe the entire mass.
- Moisture management: any sprinkler should operate only when readings and inspection indicate a need. Excess water can restrict air spaces and increase leachate.
- Power system: the PV module charges the battery through a charge controller. The controller should prevent deep discharge and inhibit mixing when voltage is too low.
- Safety and maintenance: guards, an emergency stop, motor overload protection, safe access to the inspection door, drainage, and isolation before cleaning are required.

6.2 Preliminary electrical energy check

The nominal energy stored in a 12 V, 40 Ah battery is:

$E = V \times Ah = 12 \times 40 = 480$ Wh (nominal)

This is a nameplate calculation, not the usable energy available at the motor. Battery chemistry, allowable depth of discharge, inverter or controller losses, wiring losses, battery age and temperature reduce usable energy. At a nominal 250 W motor input, ideal continuous runtime would be 480 Wh ÷ 250 W = 1.92 hours, before those losses. The motor's actual electrical input and starting current may differ from its rating.

A 150 W panel is rated under standard test conditions and will not deliver 150 W throughout the day. Even at its rating, it is below the motor's 250 W nominal power, so the motor cannot be assumed to run continuously directly from the panel. The battery must buffer motor-starting and operating loads, while daily PV generation must replenish both motor use and control-system consumption.

For illustration only, if the motor is operated for 10 minutes per day at 250 W, its nominal energy use is about 41.7 Wh/day (250 W × 10/60 h), excluding starting peaks and losses. At 30 minutes per day, it is 125 Wh/day. These examples show why a timed duty cycle and measured motor load are essential; they are not a recommendation that a particular mixing duration is biologically sufficient.

6.3 Capacity and throughput must be measured

A 500 L geometric volume does not directly establish the mass capacity because bulk density varies with feedstock, moisture and particle size, and the chamber should not be filled completely if mixing and aeration are required. Earlier draft estimates of batch mass, daily feed rate, compost yield and processing duration are not supported by a completed prototype test and are therefore not reported here as established performance. The project should measure actual feed mass, occupied volume, moisture and final mass over multiple batches.

VII. PROPOSED PROTOTYPE EVALUATION PLAN

A useful evaluation should compare operation with the motor disabled and with controlled mixing, while keeping feedstock composition and environmental conditions as consistent as practical. The protocol should be documented before collecting data.

Parameter	Suggested measurement	Why it matters
Electrical energy	Battery voltage/current and motor runtime; PV output where possible	Checks energy autonomy and duty-cycle feasibility
Mixing performance	Motor current, shaft speed, observed mixing uniformity and blockage events	Checks motor/shaft/blade suitability
Process temperature	Repeated readings at multiple locations over time	Tracks process trend and temperature uniformity
Moisture	Calibrated sensor readings plus periodic gravimetric checks	Checks sensor reliability and moisture control
Mass and volume	Weigh and record feedstock, additions, leachate and output	Establishes mass balance and practical capacity
Odor and leachate	Structured observation log and leachate volume	Identifies moisture/aeration issues and nuisance
Compost maturity	Use a suitable maturity/stability assessment and document method	Avoids equating drying or heating with mature compost
Reliability and safety	Record faults, overheating, guarding issues, cleaning time	Evaluates usability and safe maintenance

At least several repeated batches are needed to determine whether results are repeatable. Report the feedstock recipe, ambient conditions, initial mass, mixing schedule, sensor calibration, battery state, panel exposure, and the method used to assess compost maturity. Any final numerical performance claim should be traceable to these measurements.

VIII. DISCUSSION

The literature supports a modular design strategy. Mechanical processing can improve the handling of fibrous or bulky feedstock, but shredding increases power demand and introduces a separate safety risk. A mixing shaft is mechanically simpler than an integrated shredder, although its required torque can rise sharply when the chamber contains wet, compacted material. The shaft, blades, coupling and bearings should therefore be designed around realistic loading, with a conservative motor protection strategy.

Monitoring is valuable only when it leads to an interpretable action. Temperature and moisture readings should be logged, checked against independent measurements and used with explicit thresholds. A sensor reading should not automatically trigger watering or mixing unless the control logic accounts for sensor error, battery condition and the possibility of local variation inside the chamber. Connected dashboards may improve visibility, but connectivity is secondary to dependable local operation.

Solar power can reduce grid dependence, but the panel, battery and load must be sized as one system. Solar-bin studies provide useful reference architectures for charging, fill sensing and actuator control, yet their endurance figures do not demonstrate that a motor-driven composter will be energy self-sufficient. A measured energy budget is necessary before deciding whether 150 W of PV and a 12 V, 40 Ah battery are adequate.

Finally, the term ‘composting’ should be reserved for a process whose output has been assessed for stability or maturity. Short thermal cycles, chopping and moisture loss may change waste appearance, but they are not sufficient evidence of finished compost. This distinction is central to a credible review and to the project's final evaluation.

IX. LIMITATIONS OF THIS REVIEW

- This is a narrative review of the supplied source set, not a systematic search of all available publications.
- The sources differ in type and strength, including journal articles, a student project report and design-focused papers.
- Several sources concern waste collection, compaction or shredding rather than biological composting; these are included only for relevant subsystems.
- The proposed dimensions and component ratings are preliminary project inputs. No completed prototype measurements were supplied for this review.
- Reported results from individual papers are not independently reproduced here, and the review does not claim that all author-reported performance has been externally validated.

X. FUTURE SCOPE

- Perform torque and current measurements with representative dry, wet and mixed feedstocks before finalizing the motor and shaft.
- Evaluate different mixing schedules and determine the lowest duty cycle that maintains acceptable process conditions.
- Compare the actual daily PV energy yield with the measured energy use of the motor, sensors and controller across different weather conditions.
- Add data logging for temperature, moisture, battery voltage and motor current; validate each sensor against a reference method.
- Assess output stability and maturity using a documented test method before stating a composting duration or end-use recommendation.
- Conduct a cost and life-cycle comparison with manual composting and grid-powered alternatives after the prototype's performance is measured.

XI.CONCLUSION

The reviewed sources show that mechanical mixing, waste-size reduction, sensor-based monitoring and solar-powered control are established design directions that can inform a solar-operated compost bin. Conceptual composter studies help structure design decisions; shredding and blade-based machines provide mechanical references; automated composters illustrate sensing and actuation; and solar smart-bin papers offer examples of low-power electronics. These technology groups should not be treated as interchangeable, because a smart collection bin or compactor does not establish composting performance.

For the proposed project, the most important engineering issue is integration: the chamber and agitator must operate reliably, the process sensors must provide useful measurements, and the PV-battery system must support the real motor duty cycle. The nominal 480 Wh battery capacity and 150 W panel rating are insufficient by themselves to prove energy autonomy. Likewise, chamber volume cannot establish feed capacity, and short treatment claims cannot establish compost maturity. A credible project outcome will therefore depend on measured energy consumption, mechanical reliability, process trends, mass balance and a documented compost-maturity assessment. Until these tests are completed, the presented design remains a preliminary design basis rather than a validated performance claim.

References

1. Ng, A., Tokit, E. M., Abd Rahman, N., Mohamad Saat, F. A. Z., Shikh Anuar, F., & Mitan, N. M. M. (2021). A preliminary conceptual design approach of food waste composter design. Evergreen, 8(2), 397–407. https://doi.org/10.5109/4480721
2. Adeduntan, A. S., Oyewo, A. T., Gbopa, R. A., Adeyanju, S. K., Ajao, L. A., & Ajayi, S. A. (2025). Development of a solar-powered smart waste bin with automated lid opening and fill level detection. OAUSTECH Journal of Engineering and Intelligent Technology, 1(1). https://doi.org/10.36108/ojeit/5202.10.0131
3. Ajayi, S. A., Onu, P., Ejiroghene, O., & Orobome, A. L. (2025). Development of an intelligent solar-powered waste bin prototype. NIPES Journal of Science and Technology Research, 7(Special Issue), 859–873. https://doi.org/10.37933/nipes/7.4.2025.SI99
4. Añonuevo, J. K. R., Delima, M. J. A., Jimenez, S. J. S., Morabe, E. Z., Santuyo, I. E. B., & Zoleta, M. C. (2026). Smart organic waste composter (automatic biodegrader). International Journal of Research and Scientific Innovation, 13(1). https://doi.org/10.51244/IJRSI.2026.13010096
5. Dinesh Kumar, V., Anantha Harini, S. K., Anwar, A., & Dakshin, D. S. (2024). Organic waste composting machine. International Research Journal on Advanced Engineering Hub, 2(2), 297–302.
6. Gunasegaran, K., Zulkifli, C. Z., Tan, S. X., Abu Hassan, N. H., Amiruddin, Yapid, B. M., Putri, S. A. K., Burhanuddin, & Nurdini, N. H. (2019). Economical smart composting machines to manage food waste, alleviate environmental degradation and combat climate change on Penang Hill. International Journal of Innovation, Creativity and Change, 9(11).
7. Kakade, P., Mhatre, T., Maji, S., & Boyware, S. (2022–2023). Design and analysis of automatic composting machine for organic waste. Student project report, Bharati Vidyapeeth College of Engineering.
8. Karawade, A., Karalkar, D., Kavitkar, O., Damle, C., & Malusare, S. (2024). Design and fabrication of organic waste shredding system. International Journal of Advanced Research in Science, Communication and Technology, 4(1). https://doi.org/10.48175/IJARSCT-18740
9. Mane, A. R., Saindane, N. P., and co-authors. (2020). Design and fabrication of portable waste treatment bin. International Journal for Research in Applied Science & Engineering Technology, 8(IX). https://doi.org/10.22214/ijraset.2020.31607
10. Pandey, A. M., Bhavani Shankar, C. J. V., Santhosh, N., Subbarao, P. V., & Akhil, K. (2019). Design and fabrication of organic waste composting machine. Journal of Emerging Technologies and Innovative Research, 6(3).
11. Resmi, G., & Vinod, V. (2022). Development and fabrication of a portable shredding machine for rapid composting of organic waste. Nature Environment and Pollution Technology, 21(1), 275–281. https://doi.org/10.46488/NEPT.2022.v21i01.032.