COMPOST MAKING SYSTEM

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Abstract— ***In order to improve sustainable farming methods, this study proposes the design and development of a Smart Compost and Fertilizer Mixing System that combines mechanical automation, sensor-based monitoring, and renewable energy. Through the use of a chain-sprocket mechanism and a 12V DC motor driven by a solar-charged battery, the system allows for the uniform mixing of inorganic and organic materials. The composting environment is continuously monitored by the system, which is outfitted with temperature and moisture sensors. Real-time data is shown on an LCD interface for accurate process control. Improved compost homogeneity, shorter mixing times, and efficient temperature and moisture control within ideal biological activity ranges were all shown by experimental evaluation. Compared to traditional manual techniques, the combination of mechanical design and biological composting principles guarantees effective aeration and quicker stabilization.The system is ideal for small and medium-sized farmers, agricultural institutions, and rural sustainability initiatives due to its affordability, portability, and off-grid capability. All things considered, this study shows how the integration of automation, composting science, and renewable energy can greatly enhance the use of organic waste, increase soil fertility, and support climate-resilient farming systems***.

KEYWORDS: -

Vermicomposting; composting system; fertilizer mixer; solar-powered automation; organic waste management; sustainable agriculture; renewable energy; monitoring of temperature and moisture; Innovation in rural areas and smart farming technologies.

INTRODUCTION

Most developing economies still rely heavily on agriculture to supply food, jobs, and income for a sizable section of the populace. However, there is a growing need to implement sustainable agricultural practices that improve productivity while maintaining environmental health due to the growing global demand for food and the corresponding decline in soil fertility. Utilizing organic compost and nutrient-enriched fertilizer blends made from municipal and agricultural waste is one of the best ways to increase soil fertility and lessen reliance on chemical fertilizers. In addition to aiding in waste management, composting promotes carbon sequestration, nutrient recycling, and long-term soil health enhancement.Due to uneven aeration and moisture distribution, traditional composting techniques like windrow, pit, and heap composting are time-consuming, labor-intensive, and frequently produce compost of variable quality. Mengistu et al. (2017) showed that temperature, aeration, and moisture control have a significant impact on composting efficiency because they have a direct impact on microbial activity and the breakdown of organic matter. Conventional methods don't have the means to keep an eye on or regulate these factors, which causes compost to decompose more slowly and mature below par. Therefore, mechanized, controlled, and environmentally friendly composting systems that can speed up the process while guaranteeing product safety and uniformity are desperately needed.Automation and renewable energy integration into agricultural machinery have become more popular in recent years. For small and medium-sized farmers in rural areas with limited access to electricity, solar-powered systems have shown themselves to be a sustainable alternative. In order to improve process control and compost quality, Manea et al. (2024) highlighted that contemporary composting systems should integrate technological advancements like in-vessel composting, microbial inoculants, and sensor-based environmental monitoring.

In a similar vein, Seyedbagheri (2010) emphasized that in order to maintain microbial growth and avoid anaerobic conditions, effective composting necessitates an ideal carbon and nitrogen balance (C:N ratio between 25:1 and 30:1), sufficient moisture (50–60%), and appropriate aeration.In order to overcome these obstacles, the Smart Compost and Fertilizer Mixing Machine was created as an automated, low-cost, and sustainable system that integrates solar energy use, mechanical mixing, and real-time environmental monitoring. The system is energy-efficient and appropriate for off-grid locations because it uses a 12V DC motor that is powered by a solar-charged battery. A chain-sprocket mechanism powers a revolving drum set atop a sturdy iron frame, guaranteeing even rotation and efficient material blending. Temperature and moisture sensors, which are essential for keeping an eye on composting conditions, are built into the machine. Users can maintain ideal composting or fertilizer mixing parameters by making educated adjustments based on sensor readings that are shown on an LCD screen.This system is innovative because it can be used to mix organic and inorganic fertilizers and prepare compost.

The machine helps to achieve better stabilization of organic waste, faster biodegradation, and uniform aeration in composting applications. It enables farmers to create specialized formulations based on particular crop and soil requirements by consistently blending various nutrient sources in fertilizer preparation. The solar-powered operation lowers the carbon footprint of agricultural operations by supporting clean energy utilization and lowering energy costs. constraints.In order to improve process efficiency, decrease manual labor, and promote sustainable agriculture, the goal of this study is to design, develop, and evaluate the performance of a smart compost and fertilizer mixing system. The system's energy consumption, sensor responsiveness, mixing efficiency, and suitability for use in rural areas are all taken into consideration when assessing its performance. In addition to advancing agricultural mechanization, this study shows how engineering design concepts can be integrated with biological composting techniques to produce sustainable farming methods.

ISSN NO: 1434-9728/2191-0073

LITERATURE REVIEW

Composting has long been acknowledged as an economical and environmentally friendly way to manage organic waste and improve soil fertility. Numerous studies have been conducted over the years with the goal of enhancing composting systems' effectiveness, quality, and environmental performance through both biological and technological advancements. This section examines pertinent literature with a focus on composting mechanisms, comparing different composting techniques, using sensors to control processes, and integrating renewable energy technologies into agricultural waste management.

2.1 Composting Principles and Biological Mechanisms

Composting is a complicated biochemical process that uses the activity of microorganisms in regulated aerobic conditions to transform organic materials like food waste, animal dung, and crop residues into stable, humus-like materials.outlined the three main stages of the process, which are mesophilic, thermophilic, and curing. Each stage has its own unique microbial populations and temperature ranges. The breakdown of readily degradable organic compounds releases heat during the mesophilic phase, raising the temperature of the compost pile.

While the curing phase guarantees humus formation and stabilization, the thermophilic phase (45–65°C) is essential for eliminating parasites, weed seeds, and pathogens. Seyedbagheri (2010) asserts that the carbon-to-nitrogen (C:N) ratio (25–30:1), moisture content (50–60%), and maintaining adequate aeration are crucial elements that impact the effectiveness of microbial activity. Inadequate aeration can result in anaerobic conditions, which can cause unpleasant odors and incomplete decomposition, the author stressed. Therefore, to ensure uniform oxygen distribution, frequent turning or mechanical mixing is required

2.2 Comparative Research on Composting Techniques

Mengistu et al. (2017) used dried fecal sludge and municipal organic waste to perform a thorough comparative analysis of four composting techniques: windrow composting, pit composting, vermicomposting, and combined windrow–vermicomposting (WVC). According to the study, the combined WVC approach performed better in terms of sanitization, maturation, and stabilization. Pit composting took more than 90 days to partially stabilize, whereas the WVC system reached optimal decomposition in 60 days.

The combined effects of vermicomposting and aerobic microbial activity, which promoted humic substance formation and nutrient mineralization, were responsible for the increased efficiency in WVC.In order to guarantee efficient pathogen removal and compost maturity, Mengistu et al. (2017) also underlined the significance of keeping temperature and moisture levels within ideal ranges. Their results highlight the potential benefits of using sensor-based monitoring and mechanized mixing to produce consistent compost quality, which serves as the study's technological basis.

2.3Composting Technological Advancements

Automation, process monitoring, and system optimization have been the main focuses of recent developments in composting technology. In their thorough analysis of sustainable composting techniques and advancements, Manea et al. (2024) noted the rise of in-vessel composting systems, bio-inoculants, and real-time data monitoring tools as significant developments in contemporary composting. These technologies reduce environmental effects like leachate formation and odor emission while also improving process control.Additionally, Manea et al. (2024) pointed out that the incorporation of sensors for oxygen, moisture, and temperature monitoring enables accurate control of the composting environment, lowering the need for human intervention and enhancing reproducibility.

This is in good agreement with the current study, which uses temperature and moisture sensors to monitor the internal conditions of the composting drum in real time. The system maintains the biological conditions within the optimal range for microbial activity and compost maturation by continuously providing feedback via an LCD display.

2.4 Agricultural Systems' Integration of Renewable Energy

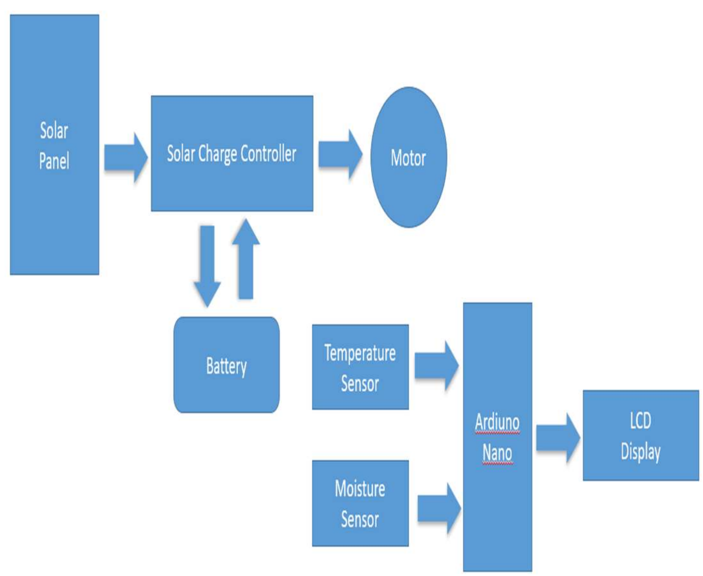
Sustainability and energy access continue to be major obstacles for small and medium-sized farmers, especially those in rural regions. A plentiful and renewable resource, solar energy is being used more and more in irrigation, agricultural automation,

2.5 Research Direction and Existing Systems Gaps

Even though current composting technologies have shown notable advancements in nutrient recovery and waste stabilization, a number of drawbacks still exist. Numerous systems are unsuitable for small-scale applications, require a significant amount of energy input, or are expensive to maintain. Additionally, conventional composting systems don't have built-in monitoring capabilities, which makes it difficult to regulate process variables like moisture and temperature. Adoption of fully automated systems is also impractical due to the unreliable electricity supply in many rural areas

The literature review indicates that low-cost, solar-powered, decentralized composting systems that blend engineering simplicity and biological efficiency are needed. Farmers with little technical knowledge may be able to monitor and modify composting parameters with the help of smart sensors and intuitive user interfaces.

BLOCK DIAGRAM



METHODOLOGY

In order to create a sustainable and automated compost-making and fertilizer-mixing system, the research methodology combines biological composting process control with engineering design principles. A solar-powered mechanical mixer with environmental sensors integrated for real-time temperature and moisture monitoring—two crucial factors that affect composting efficiency—makes up the experimental setup.With a focus on energy efficiency, mixing uniformity, sensor functionality, and system suitability for small-scale agricultural use, the study focuses on the system's design, construction, and performance evaluation. Three stages can be used to broadly categorize the methodology

Design of the System

The Smart Compost and Fertilizer Mixing Machine's design unifies control, electrical, and mechanical subsystems into a single structure. Every subsystem is designed with dependability, affordability, and usability in mind, especially for off-grid or rural settings.

Design of Mechanical Systems

The mechanical subsystem's design ensures durability and low maintenance while achieving effective mixing of organic and inorganic materials. The primary elements consist of:

Frame Structure: The frame supports the revolving drum, motor, and electronic units and is made of mild steel (iron) for strength and stability. During operation, the frame is made to resist rotational stress and vibrations.Rotating Drum: The compost or fertilizer materials are mixed in the drum. It has internal baffles to increase mixing efficiency, is cylindrical in shape, and is constructed of sheet metal. A hinged loading/unloading door on the drum makes it simple to insert materials and release the finished mixture.

Chain-Sprocket Mechanism: A chain drive made up of two sprockets, one attached to the motor shaft and the other to the axle of the drum, transfers the rotational motion from the DC motor to the drum. This configuration ensures steady drum speed and effective mixing by transferring torque in a smooth and controlled manner. Solar and Electrical Power The system's main power source is renewable solar energy to guarantee sustainable operation. The electrical design is made up of:

12V DC Motor: The motor drives the drum via the chain-sprocket mechanism by converting electrical energy into mechanical motion. For reasons of safety, portability, and solar system compatibility, a 12V setup was selected.

Rechargeable Battery: The energy gathered from the solar panel is stored in a 12V lead-acid or lithium-ion battery, which powers the motor and sensors continuously.

Solar Panel: The charge controller uses the solar panel's ability to transform sunlight into electrical energy to charge the battery. Based on projected power consumption and anticipated sunlight availability in rural areas, the panel capacity (e.g., 20–40W) was chosen. A solar charge controller prevents deep discharge or overcharging of batteries by controlling the charging and discharging process. In addition, it controls the motor and sensor circuitry and acts as a power distribution node.

Switching Circuit: During operation, users can quickly start or stop drum rotation by pressing the ON/OFF control button built into the controller.

This configuration guarantees a completely independent, off-grid power source, which makes the system perfect for remote farming uses. The results of Manea et al. (2024), who highlighted renewable integration as a crucial step toward sustainable composting technologies, are directly supported by the use of solar energy. System of Sensors and Monitoring process optimization, precise composting condition monitoring is essential. Thus, two essential sensors are included in the system: A temperature sensor (such as the DHT22 or LM35) keeps track of the drum's internal temperature. Compost maturity and microbial activity are both influenced by temperature. Effective thermophilic activity and pathogen removal are ensured by maintaining temperatures between 45 and 65°C (Seyedbagheri, 2010).

Moisture Sensor: Determines how much water is in the compost. For the best microbial growth, composting needs a moisture content of 50–60%. While low moisture slows decomposition, excessive moisture can result in anaerobic conditions.

LCD Display: A 16x2 or 20x4 character LCD screen shows the sensor readings in real time, enabling users to manually monitor and modify composting conditions as needed. Principle of The following steps are used by the Smart Compost and Fertilizer Mixing System to function:

Through the hinged door, fertilizer ingredients or organic waste materials (such as manure, crop residues, and food waste) are loaded into the drum. Drum rotation is started by the chain-sprocket system being driven by a solar-powered motor. The materials are constantly mixed as the drum rotates, guaranteeing uniform aeration and homogenization.

Real-time internal temperature and moisture levels are measured by the sensors. By giving users access to environmental readings via the LCD display, users can manually modify the composting conditions by adding water or stopping the rotation. The motor is switched off following a predetermined mixing time (for example, 10 to 15 minutes for blending or 2-3 hours for compost aeration). In a single sustainable composting unit, the suggested methodology shows how mechanical engineering design, sensor technology, and renewable energy systems can be practically integrated. The Smart Compost and Fertilizer Mixing System provides small-scale farmers and agricultural researchers with an affordable, energy-efficient, and ecologically friendly alternative by utilizing biological composting principles from earlier studies and fusing them with solar-powered automation. The system's performance metrics and the observed improvements in compost quality are examined in the results and discussion section that follows, which is made possible by this methodological framework.

RESULT AND DISCUSSION

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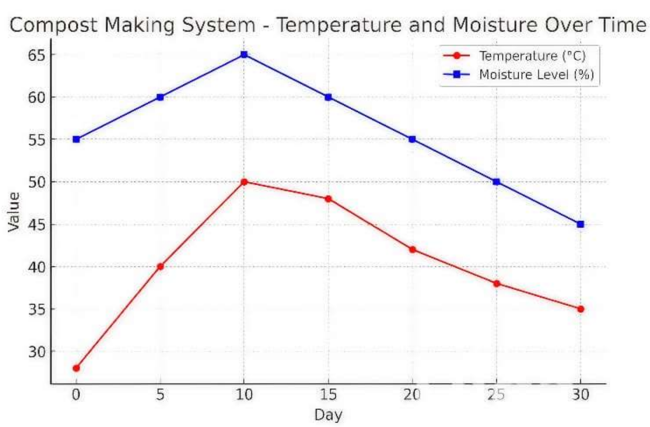
Day	Temperature (°C)	Moisture Level (%)
0	28	55
5	40	60
10	50	65
15	48	60
20	42	55
25	38	50
30	35	45

The given graph shows how temperature and moisture content interact dynamically over the course of a 30-day composting period. The y-axis shows the measured values for temperature (in °C) and moisture content (in %), while the x-axis shows time (in days). A direct examination of the two parameters' correlated behavior across the various stages of the composting process is made possible by their plotting on the same timeline



Mesophilic and Thermophilic Phase (Days 0–10):

At room temperature (28°C, 55% moisture), the process starts. The temperature rises significantly and quickly, reaching a peak of 50°C on Day 10. At the same time, the moisture content increases from 55% to 65%. Because mesophilic microorganisms quickly give way to thermophilic populations, this steep temperature incline indicates intense microbial activity. This high metabolic activity and the initial breakdown of organic matter, which releases water, are the direct causes of the rising moisture.

Cooling Phase (Days 10–25): The

system moves into the cooling phase after the peak. By Day 25, the temperature has gradually dropped from 50°C to 38°C. This decrease indicates the exhaustion of easily biodegradable substances, which lowers the amount of heat produced by metabolism. As a result, the moisture content starts to gradually drop from its peak of 65% to 50%. The ongoing evaporation caused by the residual heat and the increased aeration as the pile structure changes are to blame for this moisture loss.

Phase of Maturation/Curing (Days 25–30):

Temperature and moisture levels stabilize in the last stage. The temperature drops to 35°C, which is close to room temperature, and the moisture content drops to 45%. The compost is approaching the maturation stage, as evidenced by this stabilization. The lower moisture content is ideal for avoiding anaerobic conditions and finishing the stabilization process, and the microbial activity returns to mesophilic organisms that aid in the formation of stable humus.

Conclusion and Correlation

During the active thermophilic phase, the graph shows a strong positive correlation between temperature and moisture; however, during the cooling and maturation phases, there is a subsequent negative correlation. This pattern demonstrates a properly controlled composting process in which high microbial activity initially produces heat and moisture on its own before naturally stabilizing. A stable, mature compost product by Day 30 is suggested by the temperature curve's obvious rise, peak, and fall, which show that these phases have been successfully completed.

In order to ensure effective decomposition while reducing moisture loss in the later stages, this data is essential for validating composting models and optimizing operational parameters, such as aeration and turning schedules.

CONCLUSION

The Fertilizer Mixing Machine project successfully demonstrates an efficient, eco-friendly, and cost-effective solution for mixing fertilizers in agricultural applications. By integrating a 12V DC motor powered through a solar charging system, the machine ensures reliable operation even in areas with limited or no access to electricity. The use of a chain-sprocket mechanism for drum rotation provides consistent mixing performance with minimal mechanical complexity. Additionally, the incorporation of moisture and temperature sensors, along with an LCD display, enhances the usability of the machine by allowing real-time monitoring of internal conditions.

The machine not only reduces manual effort and time but also offers a sustainable approach to fertilizer preparation. Overall, the project serves as a practical and innovative tool for small-scale farmers and agricultural students, promoting both energy conservation and productivity.

ISSN NO: 1434-9728/2191-0073

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 ISSN NO: 1434-9728/2191-0073