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DEVELOPING A SIMULATION MODEL FOR ENERGY CONSUMPTION IN MUSHROOM SUBSTRATE COMPOSTING

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ABSTRACT

Energy-efficient production and processing of agricultural products have become a top priority to reduce fossil fuel use, which contributes to global warming and climate change. Computer simulations can determine energy consumption for stochastic processes. This manuscript presents the development of a simulation model for a large-scale mushroom farm to audit energy expenditure and improve process efficiency in the substrate processing facility. The mushroom substrate composting involves steps like bale transportation, crushing, watering, nutrient supply, turning, and compost transport. The model analyzes energy requirements for each stage using industry equipment and vehicle specifications collected from literature. The simulation integrates these parameters to measure stochastic energy consumption during composting. We estimated the energy requirement for producing mushroom substrate compost and compared it with available data. This information aids in evaluating the lifecycle and techno-economic analysis and suggests improvements to reduce energy and resource requirements, enhancing process efficiency.

1 INTRODUCTION

Simulation software models and analyzes complex systems by incorporating variability, randomness, and uncertainty (Hendrawan et al. 2019). These models can track production performance, resource requirements, and manpower needs, often with animated visualizations. In mushroom production, the process includes substrate preparation, pasteurization, mycelium inoculation, spawning, casing, growing, harvesting, packaging, and substrate disposal.

Simulation models exist for some steps, like environmental control (Hendrawan et al. 2019; Najmurrokhman et al. 2019) and greenhouse parameter analysis (Li et al. 2022). Other studies (Qasemi-Kordkheili et al. 2013; Salehi et al. 2014; Beghi et al. 2020) focus on the environmental impact and energy consumption using data-driven approaches. However, a comprehensive simulation model for all steps of mushroom substrate composting is still lacking.

2 METHODS

2.1 Large-scale Mushroom Production Steps

Button mushrooms are cultivated using composted and pasteurized substrates (Figure 1). The process involves organizing wheat straw bales, mixing them with chicken litter and urea, and maintaining moisture content with water sprinkling. Aerobic bacteria break down the biomass in a composting shed, with cotton seed hulls and gypsum added to balance the carbon-to-nitrogen ratio and maintain pH levels. After 20 days, the substrate is transferred to a pasteurization tunnel.

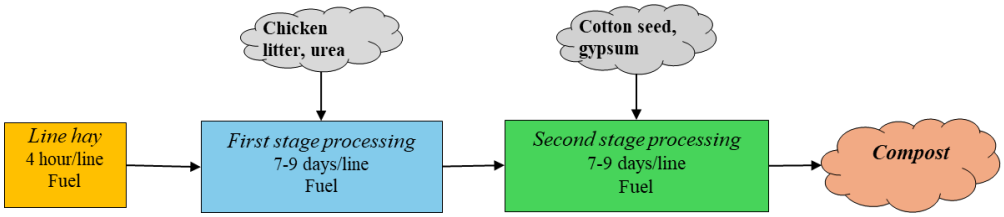

Figure 1: Composting process with time and consumed energy type.

2.2 Simulation Model

The Simio (Simio LLC) software model includes entities, modules, definitions, transporters, and animations to emulate the compost production process. The model shows bales transported by forklifts, mixed with additives, and periodically watered and turned. The process is divided into two stages, with loaders carrying partially composted substrate to racks in the second stage, where further decomposition occurs.

3 RESULTS AND DISCUSSION

The simulation modeled energy consumption based on equipment and vehicle usage rates. The average energy consumption rates for forklifts, loaders, bale crushers, turners, and labor were calculated. Initial results showed a transient response period, after which the system stabilized, allowing for accurate energy consumption recording. The model ran multiple replications to ensure statistical significance.

Energy consumption for different resources was calculated, showing the highest consumption by loaders and bale crushers. The energy required per rack of compost, bale, and pound of dry substrate was determined, with results compared to existing literature. The average total energy requirement to produce 1lb. of compost is determined to be 0.88 MJ/ lb, whereas Qasemi-Kordkheili et al. (2013) calculated this value to be 1.56 MJ/lb. Discrepancies were noted, likely due to assumptions and omitted factors like electricity usage (e.g. pump water for watering the bales).

4 CONCLUSION

The study successfully developed a Simio model to audit energy consumption in mushroom compost production, highlighting the complexities and stochastic nature of the process. The results provide insights into energy usage, aiding in optimizing production steps and improving efficiency. Future work will focus on enhancing the model's robustness and exploring resource utilization, staffing, and cost optimization.

REFERENCES

Beghi, R., V. Giovenzana, A. Tugnolo, D. Pessina, and R. Guidetti. 2020. "Evaluation of Energy Requirements of an Industrial Scale Plant for the Cultivation of White Button Mushroom (Agaricus Bisporus)." *Journal of Agricultural Engineering* 51(2): 57-63.

Hendrawan, Y., D. K. Anta, A. M. Ahmad, and S. M. Sutan. 2019. "Development of Fuzzy Control Systems in Portable Cultivation Chambers to Improve the quality of oyster mushrooms." *IOP Conference Series: Materials Science and Engineering.* Wuhan: IOP Publishing. 032013.

Li, Y., F. Sun, W. Shi, X. Liu, and T. Li. 2022. "Numerical Simulation of Ventilation Performance in Mushroom Solar Greenhouse Design." *Energies* 5899.

LLC, Simio. Simio Simulation Software. Accessed Feburary 2023. https://www.simio.com/.

Najmurrokhman, A., U. Komarudin, A. Daelami, and F. Adiputra. 2019. "Design and Implementation of Temperature and Humidity Control System in Oyster Mushroom Cultivation Using Fuzzy Logic Controller." *International Conference on Computer, Control, Informatics and its Applications (IC3INA)* . Serpong, Indonesia.

Qasemi-Kordkheili, P., M. A. Asoodar, M. Taki, and M. S. Keramati-E-Asl. 2013. "Energy Consumption Pattern and Optimization of Energy Inputs Usage for Button Mushroom Production." *International Journal of Agriculture* 3(2): 361.

Salehi, M., R. Ebrahimi, A. Maleki, and H. G. Mobtaker. 2014. "An Assessment of Energy Modeling and Input Costs for Greenhouse Button Mushroom Production in Iran." *Journal of Cleaner Production* 64: 377-383.