ARTICLE

Design and fabrication of chicken manure dewatering machine

Amor M. Vendiola Jr.[1], Elmar M. Villota*[2], Jeffrey A. Lavarias[2], and Theody B. Sayco[2]

[1]College of Engineering, Central Luzon State University, Nueva Ecija, Philippines
[2]Department of Agricultural and Biosystems Engineering, Central Luzon State University, Nueva Ecija, Philippines

ABSTRACT

Screw press conveyors are widely used in a wide range of industrial applications, particularly for managing substances such as pig slurry and cattle slurry (sludge). However, adapting a screw press conveyor to handle fresh chicken waste presents significant challenges. In the field of poultry farming, the development of a specific dewatering machine modified to chicken manure is critical. Our principal focus is on the development of such equipment, specifically designed to handle the high moisture content of chicken manure. Our primary goal is to effectively handle the daily waste output of a poultry house with 40,000 chickens. This study assesses the performance of a recently developed Chicken Manure Dewatering Machine by examining its capacity and effectiveness. We carefully assessed the machine's capabilities, utilizing experimental methods with three different treatments (17 rpm, 22 rpm, and 29 rpm). The results show significant actual capacities of 351.40 kg/h, 443.60 kg/h, and 619.40 kg/h, machine efficiency of 86.9%, 90.9% and 96.3%, and separation efficiencies of 17.2%, 13.1%, and 9.7%, respectively. These results confirm the machine's efficacy in efficiently dewatering chicken manure, making it a feasible solution for poultry waste management. The conclusion emphasizes the practical implications of these findings and advocates for further exploration and enhancement of sustainable agricultural practices.

INTRODUCTION

The chicken (Gallus gallus domesticus), a domesticated species originating in Southeast Asia, plays a crucial role in the global poultry farming industry, encompassing broiler and layer breeding, egg production, feed manufacturing, hatchery operations, and processing. This industry employs strict management methods to maximize production efficiency and significantly impacts national development goals, poverty reduction, and job creation. For instance, the Philippines saw its chicken population surge to an estimated 185 million in 2022, reflecting the nation's growing demand for poultry products (Statista Research Department 2023).

Chicken farming, deeply embedded in global cultures and diets as a crucial protein source, poses unique manure management challenges due to the high volume and nutrient density of waste produced by poultry. A single broiler chicken generates about 0.3 kg of manure daily, resulting in substantial waste in large-scale operations. This manure, rich in nitrogen, phosphorus, and potassium, can cause significant environmental harm if not

KEYWORDS

Moisture content, poultry, farming, efficiency, capacity, processing

---

*Corresponding author
Email Address: elmar.villota@clsu2.edu.ph
Date received: March 14, 2024
Date revised: May 27, 2024
Date accepted: May 27, 2024
DOI: https://doi.org/10.54645/2024171DAL-61

properly managed. Excessive application or improper timing of manure can lead to nutrient runoff into water bodies, causing eutrophication, depleting oxygen, and damaging aquatic ecosystems. Additionally, pathogens like Salmonella, E. coli, and Campylobacter, along with pharmaceuticals in the manure, can leach into water supplies, posing health risks. Air pollution from ammonia emissions can cause respiratory problems and further environmental degradation through acidification and nutrient enrichment. Improper manure management also produces greenhouse gases like methane and nitrous oxide, contributing to climate change.

As the business continues to grow to meet the increasing global demand for nutritional proteins, the growth of organic waste generated by industrial farming presents a serious environmental concern. Improper waste management procedures can have negative implications, such as increased ammonia gas and odor emissions, disease transmission among animal populations, and negative impacts on aquatic environments (Petersen et al. 2007). Excessive use of animal manure has a variety of negative consequences, ranging from increased heavy metal toxicity and reduced soil aeration to salinization in dry locations (Bernal et al. 1992). Furthermore, nutrient leaching and runoff increase surface and groundwater contamination, requiring additional water treatment techniques to provide safe drinking water (Burton and Turner 2003).

In addition to environmental factors, chicken farming needs dedication to animal health, welfare, and waste management regulations (Alders et al. 2018). Effective waste management is critical for promoting sustainability, minimizing environmental risks, and protecting human health (Jayawardhana et al. 2016). Given that poultry farms produce millions of tons of waste annually, proper management solutions are essential. A single laying hen weighing about four pounds produces approximately 75 pounds of feces per year, resulting in an estimated 13.9 billion pounds of chicken waste in a country with 185 million hens (Newsome 2022).

The poultry industry faces numerous sustainability challenges, particularly in waste management (Soisontes 2015). Poultry farmers must develop and oversee various waste management methods, from biogas digesters to mechanized systems for separating, dewatering, drying, and pelletizing chicken manure into fertilizer. Chicken manure, known for its nutrient-rich composition, has emerged as a preferred feedstock for biogas production, with nitrogen and phosphorus levels double those of other farm manures (Chai et al. 2019). However, the composition of chicken manure varies significantly in terms of nitrogen, phosphorus, and potassium (NPK) ratio, as it includes components such as urine, feathers, and bedding materials (Chai et al. 2019). Composted material can be utilized as bedding in free-stall barns, while the separated liquid portion might be recycled as flush water or stored and applied to soil (Ford and Fleming 2002).

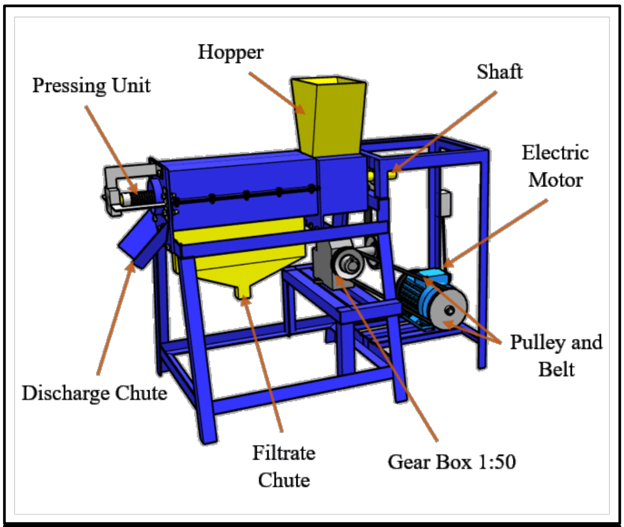
Valentin et al. (2021) examined experiments concerning the mechanical extraction of water from manure using both a press and a centrifuge. Their findings indicated that between 2.5 and 3.5 tons of liquid could be extracted from 10 tons of manure containing 70% moisture. Hjorth et al. (2010) reviewed that animal slurry contains vital plant nutrients necessary for crop growth. However, the intensive production of livestock can result in an excess of these nutrients on farms, leading to their discharge or emission into the environment.

Embracing innovative waste management strategies is critical for the poultry industry to address various challenges while remaining environmentally and socially responsible. Proper disposal reduces disease outbreaks and contamination while recycling waste into valuable resources like renewable energy and fertilizer is essential. Dewatering, although challenging, is crucial for optimal waste utilization, requiring further research into dewatering machines for effective farm waste management. These machines not only increase revenue but also reduce pollution and health problems associated with inadequate waste management.

MATERIALS AND METHODS

Description of the Machine

The machine is built with a strong main frame made of an angle bar with an appropriate thickness for stability, an electric motor and a 1:50 gear driving box to drive the machine, a hopper for receiving fresh manure, a shaft, belt and pulley to control speed, a pressing unit, a filtrate, and discharge chute, and a screw conveyor covered by a cylindrical perforated sieve with 1.2mm hole to separate the sludge and filtrate, as shown in Figure 1 and 2.



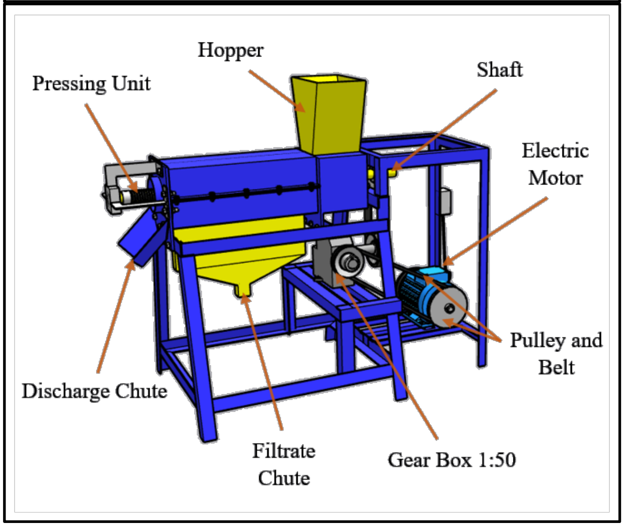


Figure 1: Isometric view of the dewatering machine and components

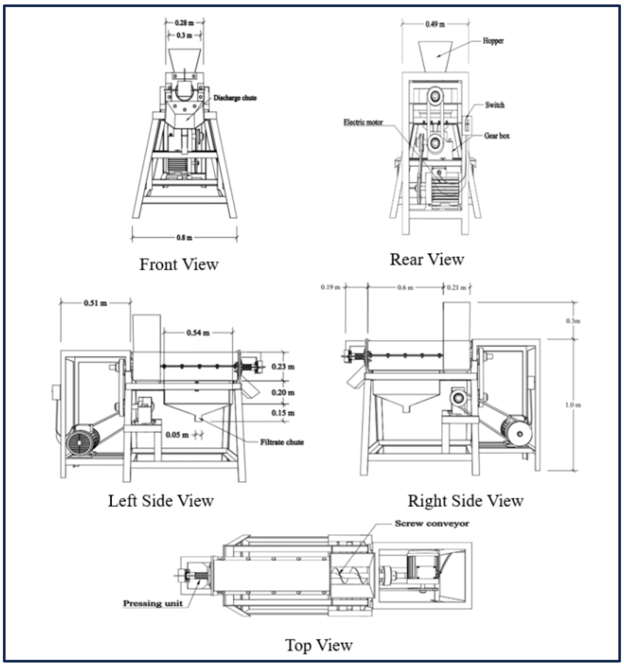


Figure 2: Orthographic view of the dewatering machine

Principles of Operation

The machine aims to remove water from chicken excrement/manure. 20 kg of fresh chicken manure will be fed into the machine hopper. When it is fed, it is transported to the screw conveyor or auger, where the manure is continually forced to the pressing machine through this component. The auger will be provided with a cylindrical perforated sieve covering to filter the sludge. Filtrates will be collected below the machine through a filtrate chute during the dewatering process, while sludge or dewatered manure will be compacted and fall into the discharge chute.

Design and Consideration

The dewatering machine will be specifically designed to remove water from chicken dung entirely in line with the unit's established operational capabilities. This fabrication process will prioritize the use of locally available resources, with an electric motor serving as the power source for efficiency. Its design prioritizes ease of operation and mobility, as well as the ease of simple repairs and component replacements. Furthermore, the machine aims to surpass traditional dewatering machines in terms of moisture content efficiency, with a target capacity of 3,500 kg to 4,000 kg of manure processed in an eight to ten-hour daily operation. Lastly, it will be built according to high safety standards while maintaining great proficiency.

Design of Machine Components

The essential elements of the machine are to determine the power requirement and identify the size of the screw conveyor or auger, belts and pulleys combinations, gearbox ratio, and the corresponding speed that will be provided in the different component parts/units to be used in the power transmission.

Driving Pulley

The driving pulley sizes vary depending on the treatment applied: Treatment 1 utilizes a 6-inch driving pulley, Treatment 2 employs a small 5-inch driving pulley, and Treatment 3 utilizes a 3.5-inch driving pulley. These different sizes are likely selected based on specific operational requirements or experimental considerations, aiming to assess the impact of pulley size variation on the performance or behavior of the system. Such experimentation allows for a comprehensive understanding of how different pulley sizes affect the overall functioning and efficiency of the machinery.

The Shaft Design

The shaft is essential in the dewatering machine because it serves as a platform for attaching the gear, speed reducer, and bearings. The shaft diameter was calculated as 40mm using Equations (1) and (2) for shaft design,

$$T=\frac{60}{2\pi}\left(\frac{Pmax}{n}\right) \qquad (1)$$

Where T = the twisting moment or torque, P_{max} = the power of electric motor, watts, n = the screw speed in rpm

$$d_s^{\,3}=\frac{16}{\pi}\left(\frac{\sqrt{My^2+T^2}}{\sigma}\right) \qquad (2)$$

Where d_s = the diameter of the shaft, σ = the allowable shear stress of the steel consider the maximum bending moment My and maximum twisting moment or torque.

Power Requirements of the Machine

The power required to drive the screw press was calculated using the equation,

$$P_r=4.5\ QvL\rho gd \qquad (3)$$

Where P_r is the power required to drive the screw press, Qv is the volumetric capacity of the material, L is the length of the shaft, f is coefficient of friction.

$$P_m=\frac{P_r}{\eta} \qquad (4)$$

Where P_m is the power of the electric motor and η is the drive efficiency, 75% or 0.75.

Experimental Design

The chicken manure dewatering machine has undergone three (3) treatments using twenty kilograms (20 kg) of samples fed into the machine per treatment, and prepared and tested at a different level of speeds (revolution per minute) of the screw conveyor where manure samples were conveyed to the pressing unit. The experimental set-up was composed of nine (9) experimental units consisting of three (3) replications.

The study will use a Completely Randomized Design and a One Factor Experimental Design. The data will be subjected to analysis using one-way ANOVA to determine significant differences among the treatment groups. Comparison among means was done using the Least Significant Differences (LSD).

Treatment, T, (Screw Conveyor or Auger shafting Speed, rpm)
T_1 = 29 rpm T_2 = 22 rpm T_3 = 17 rpm
R_n = Replicate n for 20 kg fresh chicken manure samples
The experimental layout showing treatment combinations, sequence of testing, and the number of experimental units is shown in the Table below.

Table 1: Experimental layout.

Experimental Layout		
T_1R_3	T_3R_3	T_2R_1
T_3R_1	T_2R_3	T_2R_2
T_3R_2	T_1R_2	T_1R_1

RESULT

Performance Evaluation]

Theoretical Capacity of the Machine

The theoretical capacity of the Screw Press Conveyor was determined using a modified form of the equation given by:

$$Ct=A \times P \times n \times \psi \times \rho \times c \qquad (5)$$

Where Ct = the theoretical capacity, A = the cross-sectional area, P is the pitch of the screw, n is the speed of the screw, Ψ is the loading efficiency, ρ is the density of the material, and c is the factor of inclination / horizontal,

Table 2: Theoretical capacity of the machine (kg/h).

Treatment	Theoretical Capacity, kg/h
T1 (17 rpm)	404.10
T2 (22 rpm)	488.10
T3 (29 rpm)	642.50

The theoretical capacity of the chicken manure dewatering machine is a crucial measure indicating the highest possible output achievable by the machine under ideal circumstances. It is typically determined by considering the machine's design specifications and operational parameters. In this instance, theoretical capacities are provided for three different treatments (Table 2). The capacity tends to be lower with slower speeds, whereas higher speeds lead to higher capacity. These figures represent the maximum potential output of the machine across varying operation speeds. The theoretical capacity is influenced by factors such as the machine's design, mechanical efficiency, and its ability to effectively process chicken manure. Generally, higher speeds result in increased throughput, as evidenced by Treatment 3 having the highest theoretical capacity compared to Treatments 1 and 2.

Actual Capacity, Ca

The capacity is the machine's capability to produce output over a specific period, actual capacity (Ca), kg/h (PAES 205:2015)

$$C_a = \frac{DM_a}{T_o} \qquad (6)$$

Where $\mathbf{C_a}$ is the actual capacity, kg/h, DM_a is the actual amount of chicken manure, kg, and T_o is the operating time, hr.

Table 3: Evaluation of actual capacity of the dewatering machine.

Treatment	Sludge		Time (S)	Time (min)	Actual Capacity (Kg/h)
	Initial wt.	Final wt.			
T1 (17 rpm)	20.0	16.8	205.0	3.4	351.4^{a}
T2 (22 rpm)	20.0	17.2	162.3	2.7	443.6^{b}
T3 (29 rpm)	20.0	18.1	116.3	1.9	619.0^{c}

* - a, b, c – means with different letters are significantly different at 1% level

The treatment means indicate that Treatment 3 exhibits the highest average output of 619.4 kilograms per hour (kg/h), it signifies a set of parameters or conditions that optimize the machine's efficiency in processing chicken manure. Following closely behind, Treatment 2 demonstrates an average output of 443.6 kg/h, indicating its effectiveness but slightly inferior to Treatment 1. In contrast, Treatment 1 displays the lowest average output at 351.4 kg/h, suggesting less favorable conditions or suboptimal parameters for the machine's operation as shown in Table 3.

The analysis of variance (ANOVA) results at the 1% level revealed that there are significant differences in the actual capacity of the chicken manure dewatering machine across the different treatments (Table 3). This indicates that the variation in output volumes observed among treatments is not due to random chance but rather due to the treatments themselves.

Efficiency of the Machine (%)

The ratio of actual capacity and theoretical capacity (PAES 172:2015).

$$E_{ff} = \frac{C_a}{C_t} \text{ x } 100 \qquad (7)$$

Where C_a is the actual capacity of the dewatering machine, kg/h, and C_t is the theoretical capacity of the dewatering machine, kg/hr.

Table 4: Efficiency of the machine.

Treatment	Actual Capacity (Kg/h)	Theoretical Capacity (Kg)	Efficiency (%)
1	351.4	404.1	86.9%^{a}
2	443.6	488.1	90.9%^{b}
3	619.0	642.5	96.3%^{c}

*- a, b, c – means with different letters are significantly different at 1% level

The efficiency of the chicken manure dewatering machine is a critical factor in assessing its performance and sustainability. Efficiency measures how effectively the machine extracts moisture from the manure, minimizing waste and maximizing resource utilization. The data of the three treatments with varying speeds of operation are evaluated for their efficiency. The treatment means indicate that Treatment 1 has an average output of 86.9%, Treatment 2 has an average output of 90.9%, and Treatment 3 has an average output of 96.3%, as shown in Table 4.

The analysis of variance (ANOVA) results indicating high significance for the efficiency of the chicken manure dewatering machine, underscores the importance of understanding the factors influencing the machine's performance. Like actual capacity, the comparison of means revealed that all the treatments are significantly different from each other.

Separation Efficiency, SE

The separation efficiency of solid particles is an important measure of separator performance. There are multiple methods to express a separator's performance, including percent removal, total solid (TS%) content of separated solids, and percentage of solids directed into the fiber stream. These methods provide information into the separator's operational performance and manure management effectiveness (Ford and Fleming 2002).

$$SE = \frac{\text{Initial MC} - \text{Final MC}}{\text{Initial MC}} \text{ X } 100 \qquad (8)$$

where SE - Separation Efficiency

Table 5: Evaluation of Initial, Final moisture content and separation efficiency of chicken manure

Treatment	Initial			Final				Separation Efficiency
	Weight	MC % (Average)	Weight of Aluminum foil	Sample for Oven dry (g)	Weight after drying	Final Weight of sample	MC %	
T1 (17 rpm)	20.0	74.1	14.1	100.0	52.7	38.6	61.4	17.2^{a}
T2 (22 rpm)	20.0	74.1	14.0	100.0	49.6	35.6	64.4	13.1^{ab}
T3 (29 rpm)	20.0	74.1	14.1	100.0	47.3	33.1	66.9	9.7^{b}

* - a, b – means with different letters are significantly different at 5% level

Evaluating the efficiency of a chicken manure dewatering machine's separation process under various revolutions per minute (rpm) treatments offers important information about its operational performance. As shown in Table 5, Treatment 1 consistently had the highest efficiency across all replications, indicating that operating the machine at 17 rpm results in a 17.2% more successful separation of particles and liquids than higher rpm settings. Treatments 2 at 22 rpm had a 13.1% efficiency, whereas 29 rpm had a 9.7% efficiency, indicating lesser separation efficiencies. However, data analysis revealed that their efficiencies were reasonably comparable.

The analysis of variance underscores the significance of rpm in influencing separation efficiency, with the treatments demonstrating statistically significant differences at a 5% level of significance. Interestingly, while Treatments 2 and 3 are significantly different from Treatment 3, they are not significantly different from each other, indicating a potential threshold effect in their operational range as shown in Table 4.

Economic Analysis

The estimated processing cost of ₱2.27 per kg of chicken manure is derived from an economic analysis that leverages economies of scale and accounts for specific fixed costs, including a machine priced at ₱79,960. By processing the manure produced by 40,000 chickens, the farm can spread both its fixed and variable costs over a large production volume, totaling 137,000 kg annually. The initial investment in machinery is a significant fixed cost that, when amortized over the total yearly production, contributes to a lower average cost per kilogram. This large-scale operation allows for a more efficient distribution of costs, reducing the per-unit cost. Consequently, the farm can achieve a processing cost of ₱2.27 per kg, ensuring that the processing remains economically viable. This enables the farm to set competitive market prices while covering all production costs and achieving profitability. The inclusion of the machine price highlights the impact of capital investments on cost efficiency, showcasing the benefits of large-scale agricultural practices.

DISCUSSION

Analysis of the results reveals crucial insights into the machine's performance at different rotational speeds. At 17 rpm, the machine achieved an actual capacity of 351.7 kg/h, with a machine efficiency of 86.9%, and it boasted the highest separation efficiency of 17.2%. Moving to 22 rpm, the machine demonstrated an average production of 443.3 kg/h, with a machine efficiency of 90.9% and a separation efficiency of 13.1%. Notably, at 29 rpm, it showcased the highest actual capacity of 619.4 kg/h, with a machine efficiency of 96.3%, but it had the lowest separation efficiency among the treatments at 9.7%. The results suggest that treatment 2, set at 22 RPM, emerged as the optimal choice among the three treatments. It proved to be the most effective and successful, capable of processing the daily manure output of one poultry house, while achieving a separation efficiency of 13.2%. Additionally, Treatment 3, operating at 17 RPM, though exhibiting lower machine efficiency, achieved a high separation efficiency of 17.2%, aligning with one of the primary objectives of the machine. Higher capacity results in lower separation efficiency because increasing the throughput reduces the contact time between the manure and the separation mechanisms. At higher speeds, the material moves through the machine more quickly, which can lead to less thorough separation of the solids from the liquids. This reduced interaction time means that the machine has less opportunity to effectively extract water from the manure, resulting in lower separation efficiency.

These findings underscore the significant role of rotational speed in enhancing the dewatering performance of the machine. Poultry farmers need to consider the trade-offs between capacity and separation efficiency when integrating such a machine into their operations. The choice of operational speed will depend on whether the priority is to maximize the volume of manure processed or to achieve higher separation efficiency. Igbozulike and Bill (2015) designed a similar dewatering machine with a capacity of 472.9 kg/h, which is comparable, and achieved a separation efficiency of 9%. However, the present study had a higher separation efficiency (Table 4), allowing for the removal of much more water in the dewatering process. Gusev et al. (2021) also studied a dewatering machine, obtaining a separation efficiency of 16.1%, which is comparable to the result of the present study in treatment 3. Therefore, the chicken manure dewatering machine is more effective and efficient based on the results.

The poultry farmers can integrate this machine, not their operations, by assessing the volume of manure produced daily to determine the optimal speed setting. If processing large volumes quickly is a priority, higher speeds may be preferred despite the lower separation efficiency. Farmers who prioritize thorough separation might opt for lower speeds even if it means processing smaller volumes per hour for balance efficiency and effectiveness. Furthermore, integrating this machine may require adjustments in existing waste management infrastructure, such as allocating space for the machine, storage facilities for separated solids and liquids, and systems for handling the byproducts.

These findings indicate significant potential cost savings and environmental benefits from using the dewatering machine. Improved manure management can reduce costs associated with manure disposal, lower labor costs, and enable the conversion of separated solids into marketable fertilizer products. Efficient manure processing can also minimize the need for expensive waste treatment facilities. By effectively separating solids from liquids, the machine helps in reducing nutrient runoff and water pollution, mitigating the impact on local water bodies, and reducing the risk of eutrophication. Additionally, better manure management can reduce greenhouse gas emissions, particularly methane and nitrous oxide, contributing to climate change mitigation efforts. This discussion emphasizes the practical implications of the study's findings in improving poultry waste management practices. However, it's important to note that the efficiency of solid-liquid separation treatment of livestock waste can be further improved using flocculants (ASAE 1998, Garcia et al. 2009, Gonzales 2008, and Vanotti and Hunt 1999).

CONCLUSION

The development, construction, and evaluation of a chicken manure dewatering machine aimed to mitigate the environmental impact of chicken waste. This locally produced machine, priced at approximately ₱79,960, was designed to be affordable for local farmers. The evaluation demonstrated its effectiveness, significantly reducing moisture content during waste processing and achieving its intended objective. Treatments 2 and 3, set at 22 and 29 rpm, have actual capacities of 443.6 kg/h and 619.4 kg/h, respectively. These rates are sufficient to process the daily manure production of a poultry house with 40,000 chickens in 8 to 9 hours continuously. The separated material exhibited semi-solid properties, with separation efficiencies ranging from 9.7% to 17.2%.

To enhance the separation process, it is recommended to explore the use of thicker screens in the dewatering machine to increase pressure during operation, thereby improving moisture reduction. Further research should also be conducted to assess the performance of different screw conveyor designs. By experimenting with alternative configurations, optimal design parameters can be identified to enhance dewatering performance. Maintaining a uniform clearance of 1 millimeter between the screen and screw conveyor is crucial to prevent the backflow of saturated manure.

Additionally, to prevent slippage and ensure consistent operation, replacing the belt and pulley system with a sprocket and chain mechanism should be considered. This modification can minimize downtime associated with belt slippage and enhance overall system reliability. The use of coagulants to facilitate particle aggregation is another area for further optimization. These findings underscore the machine's potential to address environmental concerns associated with chicken waste management, while emphasizing the importance of ongoing optimization efforts.

ACKNOWLEDGMENT

The authors would like to extend their special thanks to the Engineering Research and Development for Technology (ERDT) at the Department of Science and Technology (DOST) for the financial support for the completion of this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

All authors contributed to the study’s conception and design, materials preparation, data collection, and analysis were perform by Amor M. Vendiola Jr. Elmar M. Villota, Jeffrey A. Lavarias, and Theody B. Sayco. The first draft of the manuscript was written by Amor M. Vendiola Jr. and all authors on previous versions of this study. All authors read and approved this study.

REFERENCES

Alders R, Dumas S, Rukambile E, Magoke G, Maulaga W, Jong J, Costa R. Family Poultry: Multiple roles, systems, challenges, and options for sustainable contributions to household nutrition security through a planetary health lens. Maternal & Child Nutrition 2018. 14, e12668. https://doi.org/10.1111/mcn.12668.

American Society of Agricultural Engineers (ASAE). Moisture measurement – unground seeds S352.2. American Society of Agricultural Engineers 1998. 2950 Niles Road, St. Joseph MI 49085-9659, Michigan, USA.

Bernal MP, Roig A, Madrid R, Navarro AF. Salinity risks on calcareous soils following pig slurry application. Soil use management 1992. 1992; 8:125-130.

Burton CH, Turner C. Manure Management: Treatment strategies for sustainable agriculture, 2nd ed., Silsoe Research Institute 2003. UK

Chai L., Xin H., Wang Y., Oliveira J., Wang K., Zhao Y. Mitigating particulate matter generation in a commercial cage-free hen house. ASABE 2019. 62(4): 877-886. (doi: 10.13031/trans.12982).

Ford M, Fleming R. Mechanical solid-liquid separation of livestock manure. Literature review 2002. Ridgetown College–University of Guelph

Garcia MC, Szogi AA, Vanotti MB, Chastain JP, Millner PD. Enhanced solid–liquid separation of dairy manure with natural flocculants. Bioresource Technology 2009. 2009;100(22):5417-5423.

González-Fernández C, Nieto-Diez PP, León-Cofreces C, García-Encina PA. Solids and nutrients removals from the liquid fraction of swine slurry through screening and flocculation treatment and influence of these processes on anaerobic biodegradability. Bioresource Technology 2008. 2008;99(14):6233-6239.

Gusev V, Zazykina L, Sysoeva I, Lukashenko V. Advantages and disadvantages of mechanical manure dewatering. E3S Conference Proceedings 2021. Volume 285. E3S Web Conference., 285 04004. International Conference on Advances in Agrobusiness and Biotechnology. Russia.

Hjorth, M., Christensen, K.V., Christensen, M.L. and Sommer, S.G. Solid–liquid separation of animal slurry in theory and practice: a review. Agronomy Sustainable Development 2010., 30, 153–180.DOI: 10.1051/agro/2009010. www.agronomy-journal.org

Igbozulike A, Bill U. Design and Evaluation of Livestock Dewatering Machine. British Journal of Applied Science & Technology 10(6): 1-6, 2015, Article no. BJAST.17858

Jayawardhana, Y., Kumarathilaka, P., Herath, I., & Vithanage, M. Municipal solid waste biochar for prevention of pollution from landfill leachate. Environmental Materials and Waste 2016. 117-148. https://doi.org/10.1016/b978-0-12-803837-6.00006-8.

Newsome, M. Chicken Frenzy: A state awash in hog farms faces a poultry boom. Yale School of the Environment 2022. https://e360.yale.edu/features/chicken-frenzy-a-state-awash-in-hog-farms-faces-a-poultry-boom

Philippine Agricultural Engineering Standards (PAES). (2015). Agricultural machinery – rice precision seeder – method of test. PAES published in 2015. PAES 172:2015. ICS 65.060.30.

Philippine Agricultural Engineering Standards (PAES). (2015). Agricultural machinery – mechanical rice thresher – methods of test. PAES published in 2015. PAES 205:2015. ICS 65.060.50.

Petersen SO, Sommer SG, Béline F, Burton C, Dach J, Dourmad JY, et al. Recycling of livestock manure in a whole farm perspective. Livestock science 2007. 2007; 112:180-191

Soisontes, S. Sustainability in poultry production: a comparative study between Germany and Thailand. 2015. https://www.researchgate.net/profile/Sakson- Soisontes /publication /307925209_Sustainability_in_Poultry_Production_A_Comparative_Study_between_Germany_and_Thailand/links/57d1dc9008ae6399a38b88c8/Sustainability-in-oultry-Production-A-Comparative-Study-between-Germany-and-Thailand.pdf.

Statista Research Department. Chicken inventory Philippines 2012 - 2023. 2024. https://www.statista.com/statistics/661211/philippines-chicken-production.

Vanotti MB, Hunt PG. Solids and nutrients removal from flushed swine manure using polyacrylamides. Trans. ASAE 1999. 1999; 42:1833-1840.