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Development of Centrifugal Dewatering Machine for High Moisture Layer Chicken Manure

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Abstract
The chicken industry holds significant importance within the agricultural sector of the Philippines, primarily driven by the substantial demand for both eggs and meat. However, it produces a significant quantity of manure each year that is left untreated. Excess moisture in chicken manure results in increased transportation cost, accelerated pathogen proliferation and the production of unpleasant odors. The lack of technology for managing chicken manure in the country presents significant health hazards for both humans and the environment. This research investigates the potential for creating a centrifugal dewatering machine designed for processing high moisture layer manure, as well as determining the optimal water to chicken manure ratio for effective treatment of chicken manure. The analysis indicates that the optimal ratio of chicken manure to water is 1kg:3L, based on the three treatments evaluated (1kg:1L, 1kg:2L, and 1kg:3L). The results indicate an average moisture content (wet basis) of 70.06%, 73.06%, and 73.80% achieved through the oven drying method. In summary, the research demonstrates the viability of creating a centrifugal dewatering machine for processing chicken manure, allowing owners to utilize the resulting products as an additional source of income rather than disposing of them in the field.

Index Terms: Chicken manure, Centrifugal separation, Dewatering machine, Waste management.
Pyrolysis presents three distinct variations: slow, fast, and flash. Each variation corresponds to specific operating

I. Introduction

One of the main agricultural sectors in the Philippines is the chicken industry. The overall chicken inventory in the country as of January to March 2023 was 195.48 million birds where 43.3% came from native chicken, 33.5% from broiler, and 23.1% is from layer chicken [1]. These numbers of chickens produce a significant amount of heat, unconsumed feed, feathers, and other related agricultural waste but most especially its manure. In the Philippines, there are approximately 2.46 million metric tons of manure released yearly from the poultry business [2]. The use of untreated raw manure can lead to significant environmental issues. For instance, applying it directly as fertilizer serves as a means for the spread of pathogens, draws in flies and pests, and exacerbates odor problems. [3]. Treatment methods using pesticides, effective microorganisms and daily collection and disposal have been adopted by farmers, but these techniques are relatively costly and associated with potential environmental threats [4]. These waste materials not only cause harmful effects to humans but also to the environment due to its stench and its ability to ruin sources of water. There are several treatment processes that have been utilized to lessen the toxic waste produced by the poultry industry such as composting, pyrolysis, gasification, and drying.

Composting, which yields compost, is favorable to be utilized as a form of organic fertilizer. Nonetheless, there are several disadvantages. For example, the process of composting can be quite prolonged and presents a notable biohazard risk if the compost lacks stability and maturity. [4].

conditions, resulting in unique products that are either abundant in bio-oil, biochar, or pyrolytic gaseous species. [5]. Gasification serves as an effective treatment option for chicken manure, offering environmental sustainability benefits when compared to traditional treatment methods. However, the principal drawback of both aforementioned approaches is that their energy efficiency diminish considerably when there is a substantial amount of water in the feedstock, namely chicken dung. Consequently, applying these treatment strategies requires pre-drying stage [4].

A typical layer house contains around 100,000 hens, which collectively generate between 1,500 and 2,000 tons of manure annually. Fresh layer manure has a moisture content of approximately 75%, which needs to be decreased before it can be stored or applied to the land. Manure with high moisture content can result in increased transportation expenses, quicker growth of pathogens and bacteria, as well as flies, and the creation of unpleasant odors [6], [7]. Moreover, wet manure tends to lead to a higher loss of nitrogen (N) since moisture plays a crucial role in the formation and release of ammonia (NH_3) from chicken manure. [8]. At present, the main methods for drying fresh manure on commercial laying hen farms involve using manure belt systems equipped with exhaust fans and drying tunnels specifically designed for manure. However, manure belt drying methods take about 3 to 4 days to dry depending on the weather which can prolong the drying conditions of the manure in rainy season [9]. It also produces uneven drying conditions and requires supervision when the manure tends to clump in the belt. Manure drying tunnel on the othe hand, requires a lot of space investment which can be very expensive[10].

Spin dryers have been widely used in homes for drying household clothes; they have also been introduced in agricultural applications for many years for drying shredded and leafy vegetables. A spin dryer is a small, energy-saving device that employs centrifugal force to remove moisture from the items being dried. It has the ability to function non-stop, both day and night, regardless of whether the skies are overcast or it's raining. It's incredibly quick and simple to use. [10], [11]. This study will modify the spin dryer technology into a spin manure dryer to solve problems that other dryers had in drying manure, such as longer drying times, complexity of operation, environmental factors, and preservation of nutritive values.

In the Philippines, there is no commercial manure drying system that entirely uses a centrifugal dryer (spin dryer) for chicken manure. Such a system could potentially result in a more compact design and help eliminate the high-moisture chicken manure that is both harmful to humans and to the environment.

The nitrogen and phosphorus concentration of chicken excrement, or chicken manure, is at least double that of other agricultural manures, including cow manure. Consequently, chicken feces serves as an excellent nutritional source [12], [13]. Cleaning out a poultry house involves gathering various materials like urine, feathers, leftover feed, and bedding items from the coop. These can include straw, grass clippings, cedar shavings, shredded leaves, and recycled paper, all of which are collectively known as chicken excrement. The NPK ratio in chicken dung can differ significantly from one location to another [14].

The moisture level of fresh chicken manure, which is typically about 75%, has to be decreased before it can be stored or used for land application. In the past, applying poultry manure to land has been the primary method for harnessing its potential as a valuable source of essential plant nutrients and a soil conditioner, helping to enhance soil structure and alleviate issues related to soil compaction [15]. Furthermore, when manure contains a lot of moisture, it can lead to higher transportation costs, faster growth of harmful bacteria and flies, and more unpleasant odors. Moreover, wet manure tends to lose a higher percentage of nitrogen (N) because moisture plays a vital role in the formation of ammonia ($NH3$) from chicken waste and the release of this gas into the atmosphere. Emissions of ammonia contribute to higher acid depositions and an overload of nutrients in our soil, rivers, and lakes. This can harm aquatic ecosystems and negatively affect forests, crops, and other plants. [16]

Drying helps to eliminate moisture from the manure, which in turn slows down the deterioration caused by chemical and biological processes. The lack of technology for reducing chicken manure moisture hinders efficient drying, collection and transportation, posing health risks to poultry and humans.

This study aimed to develop a pilot-scale centrifugal dewatering machine specifically designed to process high-moisture layer manure. It involved designing an engineering model for the centrifugal dewatering system, fabricating a functional prototype suited for high-moisture manure, and determining the ideal water-to-manure ratio of sludge by using different amounts of water.

II. Materials And Methods

A. Description of the Centrifugal Dewatering Machine

The proposed design was implemented to construct the centrifugal dewatering machine. The main component consists of a cylindrical drum crafted from a galvanized iron sheet that is 2 mm thick, featuring holes with a diameter of 1
mm. The dimensions of the drum are a diameter of 48 cm and a height of 26.8 cm. A central shaft is secured by pillow block bearings, allowing for smooth rotation.

The system is powered by a 3-horsepower electric motor that utilizes a belt-and-pulley arrangement, enabling the drum to run consistently at a speed of 1,500 rpm. The design of the machine intentionally excludes internal blades, allowing for the ease of discharging the dewatered manure through a simple and effective centrifugal dewatering process. The whole unit is securely attached to a steel frame, which not only minimizes vibration but also ensures stability while it operates.

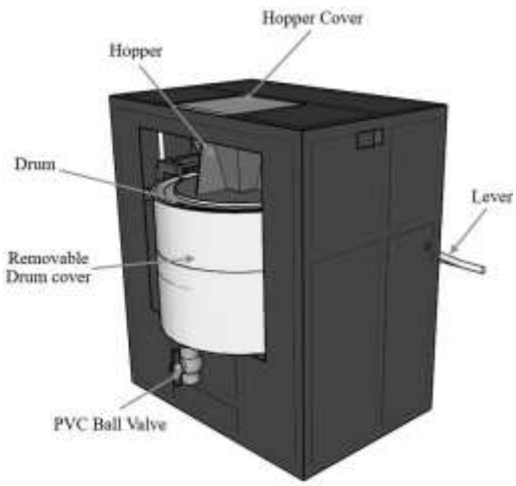

Figure 1. Isometric View of Dewatering Machine

B. Principle of Operation

The centrifugal dewatering machine operates based on the principle of centrifugal force. The machine can be operated by two people. Initially, the pretreated chicken manure sludge will be placed into the hopper. Once the sludge is placed, the excess water will be drained, leaving only the solid part of the sludge, initiating the dewatering process. The wet materials inside get pushed towards the wall of the drum due to centrifugal forces, causing them to be compressed against the wall. Solid particles with higher density experience a greater centrifugal force. As a result, the moisture content is effectively removed as the drying container spins. Centrifugal force is a force that acts in the opposite direction of the center of rotation [17]. Once the dewatering is done, the dewatered chicken manure can be collected through pulling the lever down to discharge as the lever is pushed down, the drum is pulled up, causing the hopper to push the manure to the floor of the drum.

C. Sample Preparation

Fresh high-moisture-layer chicken manure was collected from Central Luzon State University Poultry Module 1. The manure was manually mixed at 3 different mixing ratios (i.e., 1kg:1L, 1kg:2L, and 1kg:3L) as a pretreatment for 5 minutes to achieve uniform consistency. The homogenized mixture was then loaded into the dewatering machine through the hopper.

D. Statistical Analysis

This research used an experimental methodology using a Completely Randomized Design (CRD) to determine the ideal water-to-chicken manure ratio for maximum dewatering efficacy. The study examined three alternative water-to-manure ratios, each with three replications, to ensure that the data was correct and to determine how well the fabricated centrifugal dewatering machine operated to reduce moisture.

Data was analyzed using ANOVA under CRD framework. Pairwise comparisons were conducted to determine the significant differences between treatments at 5% significance level. Analyses were performed using the Statistical Tool for Agricultural Research (STAR) software.

Three water-to-manure ratios were investigated using a Completely Randomized Design (CRD):

T1: 1 liter of water for every 1 kilogram of chicken dung T2: 2 liters of water for every 1 kilogram of chicken dung T3: 3 liters of water for every 1 kilogram of chicken dung

E. Moisture Content Determination

The moisture content (wet basis) of the samples was determined using the oven-drying method at 105°C for 24 hours, following standards procedure. Moisture Content (MC) was calculated as:

$$MCwb = (W2-W3)/(W2-W1) \qquad (1)$$

Where MC_{wb} is the moisture content wet basis in percentage, W_1 is the weight of the empty container in grams, W_2 is the weight of the container with wet sample, and W_3 is the weight of the container with dried sample.

F. Efficiency

Efficiency points out how best the machine can carry out the drying of the sample. It is expressed as the ratio of output to the input. The machine dewatering efficiency was determined using equation (2).

$D_e = (M_i - M_d)/M_i$ (2)

Where D_e is the dewatering efficiency in percentage, M_i is the initial mass of sludge in kg, and M_d is the mass of dewatered sludge in kg.

G. Capacity

The capacity is the machine's capability to produce output over a specific period, capacity.

$D_c = M_a/t$ (3)

Where D_c is the capacity in kg/hr, M_a is the actual amount of dewatered chicken manure and t is the operating time in hr.

III. Results And Discussion

A. Moisture Content of Dewatered Sludge

Table 1 shows the moisture content of the material which varied significantly across the three treatment ratios evaluated in the Completely Randomized Design (CRD). ANOVA revealed that the different treatment ratios had a highly significant effect on the moisture content (MC) of the samples ($F = 63.22$; $p < 0.01$).

Table 1. Moisture Content of Dewatered Sludge, % MC_{wb}

Treatments	Rep1	Rep2	Rep3	Mean
T1(1:1)	80.82	82.11	81.29	81.41^a
T2(1:2)	74.56	77.20	77.38	76.38^b
T3(1:3)	70.05	73.06	73.80	72.30^c

Means followed by different superscript letters differ significantly at $p \leq 0.05$ based on the Least Significant Difference (LSD) test.

The mean comparison using LSD ($\alpha = 0.05$) indicated that all treatment means exhibited significant differences from each other. The 1kg:1L treatment yielded the maximum moisture content (81.41%), followed by 1kg:2L (76.38%), whereas 1kg:3L exhibited the lowest moisture content (72.30%). Increasing the solid-to-liquid ratio continuously decreased the moisture content, signifying that an increased liquid volume enhances dewatering efficiency. This pattern suggests that moisture retention is significantly affected by the solid-to-liquid ratio, probably due to enhanced dilution and more free-water release at higher liquid levels.

The observed reduction in moisture content with increasing liquid ratio is consistent with previous reports that the solid-to-liquid ratio can substantially alter dewatering outcomes. A recent study found that solid-to-liquid ratio to be among the most influential process variables for final water content in metal-sludge dewatering, which supports the interpretation that changing the treatment ratio was the dominant factor driving MC differences in the study[18]. Optimization studies and polymer-assisted separation of animal manures have shown that improved polymer/flocculant distribution and floc structure often aided by reduced slurry viscosity after dilution can increase filterability and produce drier solids despite a higher feed water content [19]

B. Efficiency

Table 2. Efficiency, %

Treatments	Initial wt (L)	Final wt. (L)	Time (min)	D_e
T_1(1:1)	4	1.230	2	69.25
T_2(1:2)	6	0.883	2	85.28

T_3(1:3)	8	0.289	2	96.39

Table 2 shows that across all treatments the final weight is substantially lower compared to its initial weight. Treatment 3 exhibited more pronounce water loss due to its ratio. The highest efficiency was observed in the highest mixing ratio. This demonstrates that T_3 was the most effective, removing nearly all removable moisture content from materials. This suggests that increasing the ratio of material significantly improves the overall dewatering process, like due to enhance permeability and more efficient separation of free water.

B. Capacity

The ANOVA revealed a highly significant effect of treatment ratio on the dewatering capacity ($F = 17.28$; $p = 0.0032$). LSD means separation showed that the 1kg:1L (36.90%) and 1kg:2L (26.50%) treatments were statistically similar ($p > 0.05$), as indicated by their shared grouping letter in Table 3. In contrast, the 1kg:3L treatment (8.68%) was significantly lower and formed a separate group (b). This indicates that higher liquid dilution (3L) greatly reduces the dewatering capacity, while 1L and 2L levels maintain relatively similar performance.

Table 3. Capacity, kg/hr

Treatments	Rep1	Rep2	Rep3	Mean
T_1(1:1)	47.07	33.36	30.27	36.90^a
T_2(1:2)	31.38	25.83	22.29	26.50^a
T_3(1:3)	11.28	7.68	7.08	8.68^b

Means with the same superscript letter are not significantly different at $p \leq 0.05$ using the Least Significant Difference (LSD) test.

The reduction in capacity with higher liquid ratios is likely due to the increased water load in the material, which reduces the amount of solid material that can be handled per cycle. This indicates that lower liquid ratios have higher output than those with high liquid ratio.
Across the three treatments, distinct differences in mixture behavior and machine performance were observed. Treatment 1 produced a thick and highly viscous mixture that was difficult to mix and frequently adhered to the drum surface, resulting in occasional clogging and noticeable vibrations when the manure was unevenly distributed inside the drying unit. In contrast, Treatment 2 exhibited moderate viscosity and good flowability, allowing the material to move uniformly within the drum. Treatment 2 and 3 generated minimal vibration and demonstrated the most stable and balanced performance operational performance. Meanwhile, Treatment 3, however, this increased fluidity also causes small amounts of solids to escape, slightly reducing the recovered yield. These observations highlight how manure-to-water ratio directly influences both process stability and effectiveness.

C. Weight of Dewatered Sludge

Table 4 shows that the mean final weights decreased consistently with increasing liquid content in the treatment mixture. The 1kg:1L treatment resulted in the highest final weight (1.230 kg), followed by 1kg: 2L (0.883 kg), while the 1kg:3L treatment displayed the lowest final weight (0.289 kg). This trend indicates that higher dilution levels enhanced the dewatering efficiency of the machine, producing lighter final outputs.

Table 4. Weight of Dewatered Sludge, kg

Treatments	Rep1	Rep2	Rep3	Average
T_1(1:1)	1.569	1.112	1.009	1.230^a
T_2(1:2)	1.046	0.861	0.743	0.883^a
T_3(1:3)	0.376	0.256	0.236	0.289^b

Means with the same superscript letter are not significantly different at $p \leq 0.05$ using the Least Significant Difference (LSD) test.

The one-way ANOVA revealed a significant treatment effect on the final weight ($F = 17.28$, $p = 0.0032$), indicating that the observed differences among treatment means were not due to random variation but were attributable to the varying manure-to-water ratios. The mean final weights showed a clear decreasing trend with increasing water volume. This pattern suggests that higher water volumes substantially improved moisture removal efficiency, resulting in lower final weights. The results therefore demonstrate that the amount of water incorporated during treatment has a statistically significant impact on dewatering performance, with the 1kg:3L ratio yielding the greatest reduction in final weight. These results can guide operational parameters for improved manure waste management and machine performance optimization. Similar results have been reported that show how moderate dilution can change the rheology of a slurry and make it easier to flow or handle, which may improve mechanical separation in some cases. However, it also said that too much dilution can make solids capture less effective and make dewatering less effective [20].

Conclusion

This study successfully developed and evaluated a centrifugal dewatering machine specifically designed for high-moisture layer chicken manure. The machine demonstrated effective moisture reduction across all treatments, confirming the viability of centrifugal separation as a rapid and practical approach for manure preprocessing. Among the three water-to-manure ratios tested, the 1kg:3L mixture consistently produced the lowest moisture content and final weight, and highest dewatering efficiency indicating improved free-water release at higher dilution levels. Statistical analysis validated the significant influence of the manure-to-water ratio on moisture content, capacity, and efficiency emphasizing the importance of appropriate mixture preparation prior to dewatering.

RECOMMENDATION

Based on the findings of this study, the following recommendations are proposed:

1. Implement additional screening or filtration when using highly diluted mixtures to minimize the escape of fine solids during dewatering.
2. Optimize the machine further for larger-scale applications by exploring variations in drum hole size, rotation speed, and loading capacity to enhance throughput while maintaining effective moisture removal.
3. Evaluate the quality and nutrient profile of the dewatered manure for its potential use as organic fertilizer or soil amendment, ensuring it meets safety and regulatory standards.
4. Perform extended field testing in commercial poultry farms to validate long-term performance, durability, and economic benefits compared to traditional drying methods.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest associated with the conduct, analysis, and publication of this research.

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