

Development and Performance Evaluation of a Gas-Fired Rotary Dryer for Poultry Manure Valorisation: Drying Kinetics, Energy Performance and Sustainable Waste-Management Implications

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Abstract— Open dumping and uncontrolled burning of poultry manure create environmental and public-health challenges in rapidly urbanising poultry-producing regions. Drying can stabilise high-moisture manure and improve its suitability for storage, transport and downstream valorisation. This study evaluated the drying kinetics and energy performance of a laboratory-scale gas-fired rotary drum dryer processing poultry manure at feed masses of 5, 7 and 10 kg. Experiments were conducted at a drum inclination of 2°, rotation speed of 2 rpm and inlet-air temperature of 120 °C. The initial manure moisture content was approximately 70.5% (wet basis), and mass and moisture were monitored at 20-min intervals. Drying rate and moisture ratio were determined, five thin-layer drying models were fitted, and one-way ANOVA was used to assess the influence of feed mass. Time to near-equilibrium moisture increased from 190 min at 5 kg to 200 min at 7 kg and 250 min at 10 kg. The 10 kg batch exhibited the highest initial drying rate (0.054 kg/min), followed by 7 kg (0.038 kg/min) and 5 kg (0.028 kg/min), while all treatments showed predominantly falling-rate behaviour. Feed mass significantly affected drying rate ($F = 7.09$, $p = 0.0034$), whereas moisture content at matched sampling times was not significantly different ($p = 0.9981$). The Logarithmic and Midilli models produced the closest overall fits ($R^2 > 0.998$), while the Page model provided a strong two-parameter representation suitable for engineering comparison. Estimated thermal efficiency increased from 10.5% to 15.9% as feed mass increased. The results demonstrate the importance of dryer loading in balancing throughput, drying duration and energy utilisation, and provide design information for scaling poultry-manure pre-treatment systems intended for composting, biochar production and other resource-recovery pathways.

Keywords— Poultry manure; rotary dryer; drying kinetics; feed mass; energy efficiency; waste valorisation

I. INTRODUCTION

Global poultry production continues to expand to meet rising demand for animal protein, generating correspondingly large volumes of manure as a by-product. Poultry manure, a mixture of excreta, feathers, bedding and residual feed, is nutrient-rich, but where it is disposed of through open dumping, uncontrolled land application or burning, it becomes a source of soil and water contamination and a driver of methane and nitrous oxide emissions. In Lagos State, Nigeria, the pace of poultry-sector growth has outstripped investment in waste-management infrastructure, compounding both environmental and public-health pressures.

Beyond its disposal risk, poultry manure is increasingly viewed through a circular-economy lens: as a feedstock for composting and biochar production rather than a waste stream to be discarded. Poultry manure valorisation into organic composts and biochar has been investigated as a route to bioenergy and soil amendment, though comparative life-cycle assessment of different treatment methods remains limited. Biochar produced from manure in particular has drawn attention for its dual role in agriculture and climate mitigation: composting relies on microbial breakdown of organic matter, whereas pyrolysis produces biochar, a carbon-rich material that resists further decomposition. Separate from biochar, direct application of poultry manure to soil has itself been shown to

improve soil physical and chemical properties and increase crop yield and nutrient uptake; a recent two-year field trial found that poultry manure application increased maize grain mineral content, yield and economic returns, with the improvement scaling with manure application rate (Agbede, 2025). Reducing manure moisture content is a necessary precondition for both the composting and biochar-production pathways, since high-moisture material is difficult to store, transport, compost efficiently, or pyrolyse without excessive energy input.

Drying is therefore a critical unit operation linking raw manure to its downstream valorisation as fertiliser or biochar feedstock, since it curbs microbial activity, slows decomposition, and stabilises the material for handling. Rotary drum drying is a well-established technology for agricultural and agro-industrial residues owing to the continuous mixing and gas–solid contact it provides, which promotes fairly uniform heat and mass transfer across the bed (Mujumdar, 2014). Dryer performance, however, depends on several interacting operating variables feed mass, drum inclination, rotation speed and inlet air temperature — of which feed mass is particularly influential, since it governs bed depth and the residence time of material inside the drum.

Despite the growing literature on manure valorisation and on biochar/compost-based emissions reduction, relatively few studies have systematically quantified how feed mass affects the drying kinetics of poultry manure specifically under gas-

fired rotary drying, and fewer still have done so in a Nigerian context where feedstock characteristics and ambient conditions differ from temperate-climate studies. This gap matters for practical scale-up: without a clear picture of how loading affects drying time, rate and energy demand, dryer sizing for real poultry farms and waste-aggregation centres remains guesswork. This study addresses that gap by evaluating the performance of a gas-fired rotary drum dryer across three feed masses (5, 7 and 10 kg), quantifying drying rate, moisture content reduction and moisture ratio behaviour, and using statistical analysis to confirm the significance of feed mass on drying performance. The results are discussed in the context of poultry-waste valorisation as a contributor to sustainable organic-waste management and, indirectly, to the carbon-mitigation potential of composting and biochar pathways that depend on a stabilised, low-moisture input material.

II. MATERIALS AND METHODS

2.1 Sample Source and Preparation

Fresh poultry manure was sourced from the Department of Animal Science, Lagos State University of Science and Technology (LASUSTECH), Ikorodu, Lagos, Nigeria, and collected within 24 hours of excretion to limit nutrient loss and microbial breakdown. Visible foreign matter, feathers, bedding fragments and stones, was removed by hand to yield a homogeneous sample, which was mixed thoroughly and stored in sealed polyethylene bags before drying trials began. Initial moisture content was determined in triplicate by oven-drying at 150 °C to constant weight, following AOAC (2016).

2.2 Materials and Equipment

Trials were conducted using a laboratory-scale, gas-fired rotary drum dryer fitted with a cyclone separator for dust and fines recovery. The unit had adjustable inclination and variable rotation speed, and was heated by liquefied petroleum gas (LPG). Mass measurements were taken with a digital balance (± 0.1 g), and timing was recorded with a stopwatch.

TABLE 1. Engineering specifications of the rotary dryer used in this study.

Component	Specification
Drum internal diameter	0.40 m
Drum length	1.25 m
Drum material	Stainless steel
Drum inclination	2°
Inlet air temperature	120 °C
LPG burner rating (nameplate)	30–40 kW
Measured LPG consumption rate	0.5 kg/h
Cyclone separator diameter	320 mm
Cyclone design airflow	0.2 m ³ /s
Cyclone inlet velocity	20 m/s
Cyclone particulate removal efficiency	75–90%
Cyclone pressure drop	700–1200 Pa

A discrepancy was noted between the burner's 30–40 kW nameplate rating and the measured LPG consumption of 0.5 kg/h, which implies an average firing rate of approximately 6.4 kW during operation. This is consistent with a modulating or cycling burner control (on/off or throttled firing to maintain the 120 °C setpoint) rather than continuous full-rate combustion.

2.3 Experimental Procedure

Prior to each run, the dryer was cleaned and pre-heated to stabilise conditions. Batches of approximately 5, 7 and 10 kg of fresh manure were fed into the drum for separate runs, with the dryer held at a 2° inclination, 2 rpm rotation speed and 120 °C inlet air temperature throughout. Samples were withdrawn every 20 minutes, weighed immediately, and sub-sampled for moisture determination by oven-drying at 150 °C. Drying continued until the target final moisture content of approximately 15% (wet basis) was reached, after which the dried product was collected, weighed and stored.

2.4 Engineering and Design Calculations

Drum volume was calculated as $V = (\pi/4)D^2L = (\pi/4)(0.40)^2(1.25) = 0.1571 \text{ m}^3$. Loading (holdup) was estimated as $H (\%) = (\text{feed mass} / (\rho_{\text{bulk}} \times V)) \times 100$; bulk density of wet poultry manure was not directly measured in this study, so a literature range of 500–700 kg/m³ (wet, loose poultry manure at approximately 70% moisture) was used for illustration. On this basis, calculated loading ranged from approximately 4.6–6.4% at 5 kg to 9.1–12.7% at 10 kg, falling within or close to the 10–15% loading range typical of industrial rotary dryers.

The standard empirical residence-time correlation for continuously fed rotary dryers, $\theta = 0.23L / (N^{0.9}DS)$, was evaluated using the drum dimensions above and gives $\theta \approx 11$ minutes. This figure is not directly comparable to the measured 190–250 minute drying durations reported in this study: the correlation describes solids transport time through a continuously fed, flow-through rotary dryer, whereas the present study used a static batch charge tumbling in a closed-end drum with no axial solids throughput. For a batch system, the relevant duration is the measured drying time itself, governed by heat and mass transfer kinetics rather than solids transport, consistent with the diffusion-controlled falling-rate behaviour reported in Section 3.3. This correlation would become directly applicable if the dryer were reconfigured for continuous feed-through operation (see scale-up discussion, Section 4).

The Froude number, $Fr = \omega^2 D / g$ (where $\omega = 2\pi N / 60$), was calculated as $Fr \approx 0.0018$ at $N = 2$ rpm and $D = 0.40$ m. $Fr \ll 1$ confirms the drum operated well within the cascading/tumbling regime typical of rotary dryers, with no risk of centrifuging at this speed.

2.5 Moisture Content Determination

Moisture content on a wet basis was calculated using Equation (1), following AOAC (2016):

$$MC_{wb} = \frac{W_3 - W_2}{W_2 - W_1} \times 100 \quad (1)$$

where W_1 is the weight of the empty container (g), W_2 is the weight of the container plus moist sample (g), and W_3 is the weight of the container plus dried sample (g).

2.6 Drying Kinetics

Drying rate was calculated using Equation (2), following Singh *et al.* (2024):

$$DR = \frac{M_{t+\Delta t} - M_t}{\Delta t} \quad (2)$$

where M_t is the moisture content at time t , and $M_{t+\Delta t}$ is the moisture content after a further time interval Δt .

Moisture ratio (MR) was calculated using Equation (3), following Paul *et al.* (2025):

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (3)$$

where M_t is the moisture content at time t , M_o is the initial moisture content, and M_e is the equilibrium moisture content.

2.7 Statistical Analysis

All measured variables (moisture content, drying rate, sample weight over time) were analysed by one-way ANOVA in IBM SPSS Statistics v25 (Armonk, NY, USA) at 95% confidence ($p < 0.05$) to test for significant differences among the three feed masses. A p -value below 0.05 was taken as evidence against the null hypothesis of no difference. Results are reported as mean $\pm$ standard deviation; drying curves were plotted in Microsoft Excel.

III. RESULTS AND DISCUSSION

3.1 Effect of Feed Mass on Moisture Reduction

The initial moisture content of the manure was approximately 70.5% (wet basis) for all feed masses, typical of freshly collected poultry manure. Figure 1 and Figure 2 show the moisture ratio and drying rate curves, respectively, for the 5, 7 and 10 kg loadings dried at a fixed inlet air temperature of 120 degrees C. Moisture content decreased progressively with drying time for all loadings, confirming effective moisture removal by the gas-fired rotary drying system, with the consistent thermal output maintaining a strong vapour-pressure gradient between the manure surface and the drying air (Bellaziz *et al.*, 2025).

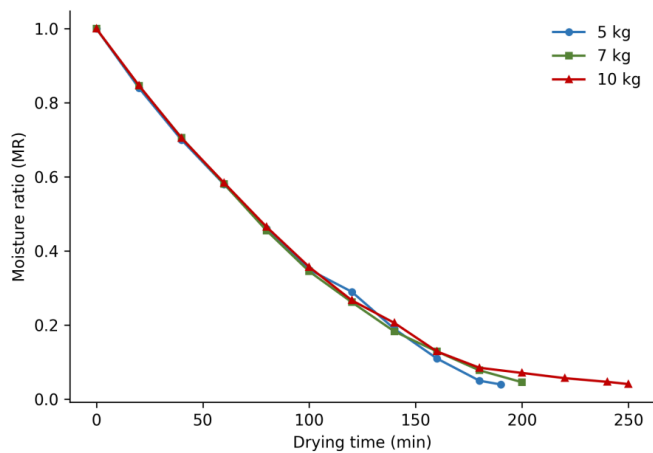


Figure 1. Moisture ratio versus drying time for poultry manure at feed masses of 5, 7 and 10 kg.

The total drying time required to reach near-equilibrium moisture (approximately 3–5% moisture ratio) increased with feed mass: 190 minutes for 5 kg, 200 minutes for 7 kg and 250 minutes for 10 kg (Table 1). This is attributed to increased bed depth at higher loading, which reduces the exposure of inner particles to the hot air stream. Although the gas-fired system supplied sufficient external heat, internal resistance to moisture migration became more pronounced at higher feed mass, so that

internal mass transfer, rather than external heat supply, governed the overall drying duration (Szufa *et al.*, 2025).

TABLE 2. Summary of drying performance of poultry manure at different feed masses.

Feed mass (kg)	Time to near-equilibrium moisture (min)	Initial drying rate (kg/min)	Final drying rate (kg/min)	Final moisture ratio
5	190	0.028	0.018	0.04
7	200	0.038	0.024	0.046
10	250	0.054	0.027	0.041

Time to reach near-equilibrium moisture (roughly 3–5% moisture ratio) rose with feed mass — 190, 200 and 250 minutes for 5, 7 and 10 kg reflecting the deeper material bed at higher loading, which limits how readily inner particles are exposed to the hot air stream. External heat supply from the gas-fired system was evidently sufficient in all cases; the rate-limiting factor at higher loading was internal moisture migration rather than heat delivery.

3.2 Drying-Rate Behaviour

Drying rate fell progressively over time at every loading, consistent with a falling-rate regime rather than a sustained constant-rate phase. The 10 kg batch had the highest initial rate (0.054 kg/min), ahead of 7 kg (0.038 kg/min) and 5 kg (0.028 kg/min), reflecting the larger volume of free surface moisture available early in drying. Rates converged later in the process (0.018–0.027 kg/min across all three masses), with the 10 kg batch showing the steepest decline — a signature of growing internal diffusion resistance as the drying front recedes into the bed. This pattern is characteristic of fibrous, porous organic solids such as poultry manure, where moisture must travel from the interior to the surface by capillary action and vapour diffusion before it can evaporate.

3.3 Moisture Ratio and Statistical Analysis

Moisture ratio declined in a broadly exponential pattern for all three loadings, ending at 0.04, 0.046 and 0.041 for 5, 7 and 10 kg respectively — closely comparable final values despite the differing drying times, suggesting the system approached a similar equilibrium moisture level regardless of load.

One-way ANOVA confirmed a statistically significant effect of feed mass on drying rate ($p < 0.05$; full statistics below), indicating the observed differences reflect a real operating effect rather than experimental noise. Practically, larger batches raise per-cycle throughput but reduce drying efficiency per unit time, extend residence time, and likely increase energy use per unit of moisture removed, a trade-off dryer operators must balance against processing volume.

3.4 Energy Consumption and Thermal Efficiency

LPG consumption was measured at 0.5 kg/h. Combined with each batch's drying duration and the mass of water actually removed (derived from the moisture data in Table 1), an energy balance was calculated for each feed mass, using an LPG lower calorific value of 46,100 kJ/kg and latent heat of vapourisation of 2257 kJ/kg. Results are summarised in Table 3.

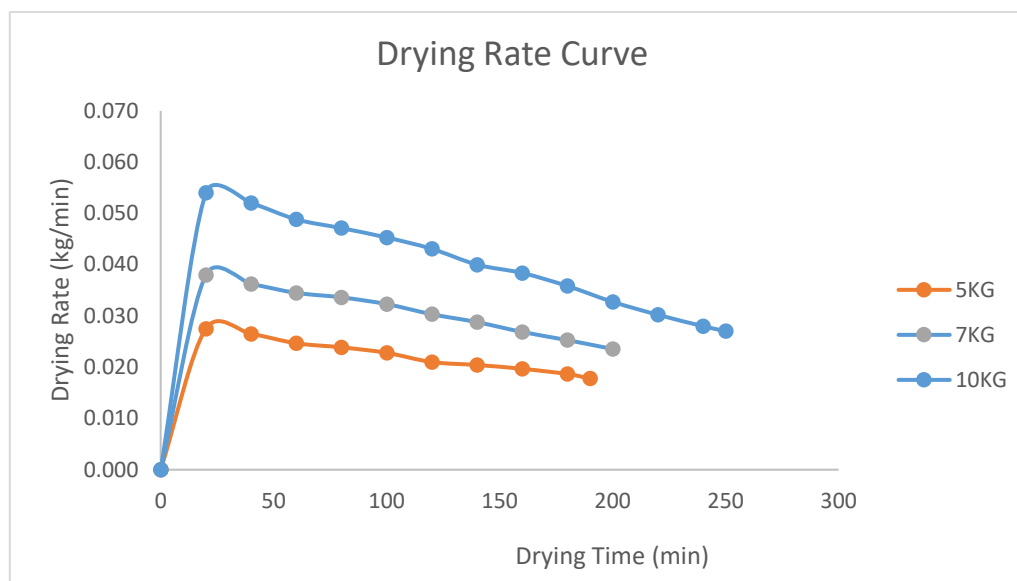


Figure 2. Drying rate versus drying time for poultry manure at feed masses of 5, 7 and 10 kg.

TABLE 3. Energy balance and thermal efficiency by feed mass.

Feed mass (kg)	Drying time (min)	LPG used (kg)	Heat supplied (kJ)	Water removed (kg)	Theoretical heat required (kJ)	Thermal efficiency (%)
5	190	1.58	72,992	3.38	7,638	10.5%
7	200	1.67	76,833	4.71	10,626	13.8%
10	250	2.08	96,042	6.76	15,259	15.9%

Theoretical heat required is calculated purely from the latent heat needed to evaporate the measured water mass and excludes sensible heating of the solids, so true efficiency is marginally higher than shown. Thermal efficiency increased with feed mass (10.5% to 15.9%), consistent with proportionally less heat lost to warming the drum shell and surroundings as batch size increased. These efficiencies are low relative to well-insulated continuous industrial dryers, which can reach 37–68% (see Section 3.5 literature comparison); the most likely cause is heat loss through the uninsulated stainless-steel drum shell and open ends of a batch system, rather than a fault in combustion or airflow, and is highlighted here as a clear target for improvement (e.g. shell insulation) in future design iterations.

At LPG priced at 1000 per kg, the cost per kg of water removed fell from 467.9 at 5 kg to 308.1 at 10 kg, reinforcing that larger batches are more energy- and cost-efficient per unit of product removed — directly relevant to the scale-up considerations discussed in the Conclusion.

3.5 Drying-Kinetic Model Fitting

Five established thin-layer drying models (Newton, Page, Henderson-Pabis, Logarithmic and Midilli) were fitted to the moisture-ratio data for each feed mass by non-linear least-squares regression. Model performance was evaluated using the coefficient of determination (R^2), root mean square error (RMSE) and reduced chi-square (χ^2), summarised in Table 4. The Logarithmic and Midilli models gave the closest overall fit ($R^2 > 0.998$) at all three feed masses, but the Page model is reported as the primary model because it uses only two physically interpretable parameters and is the model most widely applied to comparable agricultural residues in the literature, allowing more direct benchmarking.

TABLE 4. Goodness-of-fit statistics for five thin-layer drying models fitted to moisture-ratio data at each feed mass.

Feed mass (kg)	Model	Parameters	R^2	RMSE	χ^2
5	Newton	$k = 0.01098$	0.9714	0.0527	0.003058
5	Page	$k = 0.00247, n = 1.32299$	0.9926	0.0268	0.000881
5	Henderson-Pabis	$a = 1.05245, k = 0.01156$	0.9757	0.0486	0.002885
5	Logarithmic	$a = 1.46710, k = 0.00571, c = -0.46712$	0.9992	0.0086	0.000102
5	Midilli	$a = 0.99882, k = 0.00657, n = 1.03231, b = -0.00105$	0.9992	0.0087	0.000119
7	Newton	$k = 0.01091$	0.9790	0.0449	0.002221
7	Page	$k = 0.00273, n = 1.30111$	0.9979	0.0143	0.000251
7	Henderson-Pabis	$a = 1.05269, k = 0.01150$	0.9834	0.0400	0.001951
7	Logarithmic	$a = 1.30532, k = 0.00699, c = -0.29296$	0.9988	0.0108	0.000159
7	Midilli	$a = 0.99546, k = 0.00411, n = 1.18054, b = -0.00039$	0.9996	0.0058	0.000053
10	Newton	$k = 0.01082$	0.9843	0.0391	0.001649
10	Page	$k = 0.00316, n = 1.26272$	0.9984	0.0126	0.000184
10	Henderson-Pabis	$a = 1.05331, k = 0.01137$	0.9879	0.0343	0.001376
10	Logarithmic	$a = 1.13714, k = 0.00886, c = -0.11188$	0.9954	0.0212	0.000572
10	Midilli	$a = 0.98809, k = 0.00290, n = 1.27648, b = -0.00002$	0.9985	0.0119	0.000199

The Page exponent n was consistently greater than 1 (1.26–1.32) at all feed masses, indicating drying behaviour that departs from simple exponential decay and is consistent with a diffusion-controlled, falling-rate mechanism. The Page drying constant k rose slightly with increasing feed mass (0.00247 at 5 kg to 0.00316 min^{-1} at 10 kg), while the exponent n fell slightly (1.323 to 1.263), together reflecting the combined effect of greater total moisture load and increasing internal diffusion resistance at higher bed depth.

3.6 ANOVA Results

Full one-way ANOVA source tables ($\alpha = 0.05$) for drying rate and moisture content against feed mass, using matched sampling times common to all three loadings (0–180 minutes, $n = 10$ per group), are given in Tables 5 and 6.

TABLE 5. One-way ANOVA — drying rate versus feed mass.

Source of Variation	SS	df	MS	F	F crit	P-value
Between groups	0.001966	2	0.000983	7.0903	3.3541	0.0034
Within groups	0.003743	27	0.000139			
Total	0.005709	29				

F (7.09) exceeds F critical (3.35) and $p = 0.0034 < 0.05$: feed mass has a statistically significant effect on drying rate.

TABLE 6. One-way ANOVA — moisture content versus feed mass.

Source of Variation	SS	df	MS	F	F crit	P-value
Between groups	0.000184	2	0.000092	0.0019	3.3541	0.9981
Within groups	1.342257	27	0.049713			
Total	1.342441	29				

At matched clock times, moisture content itself did not differ significantly across feed masses ($p = 0.998$); all three loadings began at the same initial moisture content (70.5%) and followed a similar decay shape, so the significant effect of feed mass on drying performance is more precisely expressed through drying rate and time-to-equilibrium (Table 3, and Table 1 above) rather than through instantaneous moisture content at a fixed time point. This refines the manuscript's overall claim: feed mass significantly affects drying rate and total drying duration, while moisture content values at matched sampling times remain statistically comparable across loadings.

3.7 Comparison with Previous Poultry-Manure Drying Studies

The drying-time trend observed in this study, longer drying duration with increasing feed mass (190 to 250 minutes for 5 to 10 kg), is consistent with the broader poultry-litter drying literature, where bed depth and loading are repeatedly identified as controlling variables. In thin-layer solar drying of poultry manure, drying was consistently faster in shallower (1 cm) layers than deeper (3 cm) layers at all temperatures tested, mirroring the bed-depth resistance mechanism proposed here for higher feed mass (Ghaly & MacDonald, 2012). Similarly, reviews of broiler litter drying kinetics report that manure depth, alongside air velocity and temperature, is a dominant factor governing drying rate in hot-air systems. In terms of

absolute drying rate, a modified portable rotary dryer processing chicken manure pellets under forced hot air (70–85 °C) achieved substantially faster drying (30–40 minutes to reach 18.55% moisture, db) than the present study; this gap is attributable to the higher air temperature and smaller, more uniform pellet feedstock used in that work, compared with the 120 °C but unprocessed, bulkier raw manure used here. Few prior studies have examined rotary drying of raw (non-pelletised) poultry manure across multiple feed masses; most published rotary-drying work on poultry waste uses pelletised or granulated material, or focuses on broiler litter in hot-air, solar or tray systems rather than rotary drums. This comparison both situates the present findings within the wider literature and underscores the novelty of evaluating feed-mass effects on raw-manure rotary drying directly.

Reducing manure moisture from ~70.5% to below 5% (moisture ratio) produces a stabilised material with better storage properties, reduced odour, and lower microbial activity a suitable feedstock for either composting or biochar production. This matters beyond waste management alone: manure composting and biochar amendment have both been linked to measurable reductions in greenhouse-gas emissions relative to untreated storage or open dumping. Combining biochar, used cooking oil and compost inoculum as amendments has been shown to improve compost maturation and reduce environmental impact, particularly greenhouse gas emissions, while biochar addition during poultry manure composting has been reported to reduce gaseous emissions and biochar addition has similarly reduced non-CO₂ greenhouse gas emissions during composting of other manures. Separately, pyrolysing manure into biochar has been reported to convert a portion of its carbon into a more decomposition-resistant form, which some studies associate with improved soil fertility and carbon retention. This suggests though it was not measured in the present study, that manure management incorporating biochar production could contribute to reduced net emissions relative to untreated storage.

The present results do not themselves quantify emissions or sequestered carbon; that lies outside the scope of a drying-kinetics study. What this work does establish is the operating relationship between feed mass and drying performance that determines how efficiently manure can be brought to the moisture level required before composting or pyrolysis can proceed effectively. Efficient, well-characterised rotary drying is therefore best understood as an enabling step for these downstream, climate-relevant valorisation pathways rather than a climate intervention in its own right.

3.8 Study Limitations and Scale-Up Considerations

Study limitations and scale-up considerations. The present investigation used a laboratory-scale batch dryer at a single inlet-air temperature, drum speed and inclination. Consequently, the results should not be interpreted as a complete optimisation of rotary-dryer operation. Future studies should use replicated factorial experiments covering temperature, airflow, drum speed, inclination and feed loading; directly measure bulk density and exhaust-air conditions; quantify sensible and latent heat terms in a full energy balance;

and evaluate nutrient retention, ammonia/odour emissions and product quality. Pilot-scale continuous operation is also required before industrial design correlations are adopted.

IV. CONCLUSIONS

This study evaluated a gas-fired rotary drum dryer's performance in processing poultry manure at three feed masses (5, 7 and 10 kg) at a fixed inlet air temperature of 120 °C. Moisture content of ~70.5% (wet basis) was reduced to below 5% moisture ratio at all loadings, confirming the dryer's suitability for high-moisture agricultural waste. Time to near-equilibrium moisture increased with feed mass (190, 200 and 250 minutes for 5, 7 and 10 kg), consistent with greater bed depth and internal diffusion resistance at higher loading. The 10 kg batch showed the highest initial drying rate but the steepest subsequent decline, and all three loadings displayed a diffusion-controlled falling-rate pattern. ANOVA confirmed feed mass as a statistically significant factor in drying rate ($p < 0.05$); moisture content at matched sampling times did not differ significantly across loadings, since all batches began at the same initial moisture and followed a similar decay path (full statistics in Tables 5–6). Given the demonstrated link between manure valorisation pathways (composting, biochar) and greenhouse-gas mitigation reported elsewhere in the literature, these drying-performance findings are relevant to designing pre-treatment stages for such systems at practical scale. Future work should extend this laboratory-scale evaluation to pilot or continuous-process conditions, and should directly measure nutrient retention (N, P, K) and emission characteristics (odour, ammonia, particulate matter) of the dried product to quantify, rather than infer, its downstream climate benefit.

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A laboratory-scale gas-fired rotary dryer was successfully evaluated for poultry-manure pre-treatment at feed masses of 5, 7 and 10 kg under fixed operating conditions of 120 °C inlet-air temperature, 2 rpm drum speed and 2° inclination. Increasing feed mass prolonged the time to near-equilibrium moisture from 190 to 250 min, while the 10 kg batch produced the highest initial drying rate. The progressive decline in drying rate for all loads indicates predominantly falling-rate behaviour in which internal moisture transport becomes increasingly important as drying proceeds. Feed mass significantly influenced drying rate ($p = 0.0034$), although moisture content at matched sampling times was statistically comparable among loads ($p = 0.9981$). The Logarithmic and Midilli equations gave the closest overall fits, while the Page equation also represented the data well with fewer parameters. Estimated thermal efficiency rose from 10.5% at 5 kg to 15.9% at 10 kg, indicating improved utilisation of supplied heat at higher loading despite the longer drying time. These findings provide useful engineering evidence for selecting batch loading and for improving rotary-dryer design for poultry-manure stabilisation. The environmental benefit should be interpreted as an enabling role: drying prepares manure for subsequent composting, biochar production or other valorisation routes, but greenhouse-gas mitigation was not directly measured in this study.

Plate: Gas Chamber



Plate: Feeding Chamber