

Energy and Economic Feasibility Analysis of a Passive Solar Greenhouse Dryer for Poultry Manure in Southeastern Nigeria

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Abstract

This study evaluates the performance and conducts an energy-economic analysis of a passive solar greenhouse manure dryer in Southeastern Nigeria, providing an affordable and sustainable alternative to grid-powered dryers and open-air sun-drying methods. Drying tests were conducted under varying environmental conditions over a specified period, utilizing automated data loggers to monitor temperature, humidity, and manure moisture content. Results show that the greenhouse achieved an average drying time of one week for a 150 kg batch of manure, reaching equilibrium moisture content. An energy and cost analysis was performed using the life cycle cost (LCC) method, factoring in Nigeria's prevailing energy price, inflation, and interest rates. Key parameters, including initial investment, embodied energy, carbon offset, energy payback, and cost payback period, were calculated. The findings revealed an energy payback period of 209 days and a cost payback period of 80 months. The annual energy output cost was approximately N 182,495.36, with a carbon offset of 4,305.75 kg CO₂ per year. The study demonstrates that passive solar greenhouse dryers are an effective and economically viable solution for poultry manure drying in Southeastern Nigeria, promoting sustainable agricultural practices.

KEYWORDS: Solar greenhouse, manure drying, energy-economic analysis, Southeastern Nigeria, agricultural sustainability

1. INTRODUCTION

Nigeria's poultry production is projected to reach 263,410 metric tons by 2026, with a steady annual growth rate of 0.8% (Report Linker, 2023). This rapid expansion has led to increased poultry waste, including manure, which poses significant environmental challenges due to its decomposition (Ford & Flemming, 2002; Burton, 2007). Drying is a common practice for mitigating these issues, preventing the proliferation of pests and pathogens (Ghaly & MacDonald, 2012). Solar drying, specifically, has been shown to reduce deterioration from biological and chemical processes (Ghaly & MacDonald, 2012).

Traditional open-air drying remains the most prevalent method for poultry manure drying in rural Nigeria, favored for its low cost despite its labor intensity (Tyona & Ojiya, 2022). However, this method's reliance on unpredictable ambient conditions makes it prone to contamination by dust, rain, pests, and rodents, often leading to poor-quality products and financial losses (Singh et al., 2018). In contrast, grid-powered belt dryers are another drying option but are constrained by Nigeria's unreliable electricity supply, particularly in rural and semi-urban areas, making them

economically unfeasible for commercial poultry farms (Chai, 2022).

Greenhouse dryers, a promising alternative, have been identified as an effective solution for poultry manure drying (Janjai *et al.*, 2007; Azaizia *et al.*, 2017; Hamdi *et al.*, 2018). The versatility of greenhouses extends beyond drying agricultural products, offering additional uses such as aquaculture, soil solarization, and crop cultivation (Chauhan *et al.*, 2016; Prakash & Kumar, 2014). Greenhouses are increasingly recognized for drying non-agricultural products, such as rubber and surgical cotton (Sevda & Rathore, 2010; Panwar *et al.*, 2013; Jitjack *et al.*, 2016; Belloulid *et al.*, 2017).

Previous research in Southeastern Nigeria on solar dryers primarily focused on comparing solar dryers to open-air methods (Anyanwu & Okonkwo, 2008; Eze & Chibuzor, 2008; Oparaku, 2008; Okonkwo & Nwoke, 2008; Okonkwo & Okoye, 2005; Eze & Ekechukwu, 1999), with limited attention given to the economic analysis of greenhouse dryer systems. This study seeks to fill this gap by conducting an energy-economic evaluation of a passive solar greenhouse dryer, utilizing life cycle cost (LCC) analysis to assess the economic viability of this drying technology in Southeastern Nigeria.

1.1 Literature Review

Solar drying is one of the oldest and most sustainable methods for preserving agricultural and animal products. The process harnesses solar energy to reduce the moisture content of agricultural products, which in turn extends shelf life, reduces transport weight, and minimizes the risk of microbial contamination (Fudholi *et al.*, 2020). Passive solar dryers, in particular, are low-cost and do not require external power sources, making them ideal for rural and off-grid applications (El-Sebaili & Shalaby, 2017).

Greenhouse-type solar dryers utilize the greenhouse effect to trap heat and enhance the drying process. They are often built with transparent materials like polyethylene to allow solar radiation in while minimizing convective heat losses (Chikukwa *et al.*, 2022). These systems have been successfully deployed in drying fruits, vegetables, grains, and increasingly, animal waste such as poultry manure (Gomez-de la Cruz *et al.*, 2021). The efficiency of these dryers can be influenced by factors such as climatic conditions, orientation, and ventilation design.

Poultry manure is a rich source of nutrients such as nitrogen, phosphorus, and potassium. However, its high moisture content (often over 70%) poses challenges for transportation, storage, and use as an organic fertilizer (Akinbile & Yusoff, 2020). Drying poultry manure not only reduces its weight and odor but also enhances its suitability for use as a soil amendment and even as a biofuel (Zhang *et al.*, 2023). Traditional sun drying is still common in many regions, but it is weather-dependent and can lead to inconsistent drying quality and contamination risks.

The performance of solar dryers is commonly evaluated through parameters such as drying efficiency, drying rate, moisture removal rate, and temperature profiles (Tiwari *et al.*, 2021). Thermal efficiency, which compares the energy used in moisture removal to the total solar energy incident on the dryer, is a critical measure of performance (Janjai *et al.*, 2018). Recent studies have shown that greenhouse dryers can maintain internal temperatures 10–20°C higher than ambient, enabling faster drying with better microbial control.

Economic viability is a vital consideration in the adoption of solar dryers, particularly in developing regions. Key indicators include net present value (NPV), benefit-cost ratio (BCR), payback period, and internal rate of return (IRR) (Okonkwo *et al.*, 2022). While the initial investment in greenhouse dryers may be higher than traditional open sun methods, the long-term savings in operational costs and gains in product quality often result in favorable economic outcomes. Moreover, government and NGO interventions promoting renewable energy solutions can further reduce capital cost barriers.

In the Nigerian context, the application of solar dryers in poultry farming is gaining traction due to the growing poultry industry and environmental concerns related to waste management (Ezeano *et al.*, 2019). Southeastern Nigeria, with its humid tropical climate, poses specific challenges to open drying, making greenhouse solar dryers an attractive alternative. Locally available materials and labor can be used to construct these systems, thus ensuring sustainability and community acceptance.



2. THEORETICAL ANALYSIS

2.1 Thermal and Energy Balance in Greenhouse

The energy input in a passive solar greenhouse comes primarily from solar radiation. The total solar radiation entering the dryer Q_{in} is given as

$$Q_{in} = I_t \times A \times \tau \quad (1)$$

Where I_t is the total solar irradiance in (W/m^2), A is the surface area of the greenhouse exposed to sunlight and τ is the transmissivity of the glaze material (glass). The drying process is governed by both external conditions (temperature, relative humidity, airflow) and internal properties of the material being dried (moisture content, diffusion coefficients).

The heat energy required to evaporate moisture from manure Q_{evap} is given by (Ghaly and MacDonald, 2012) as

$$Q_{evap} = W_i \left[cp_d \left(1 - \frac{M_i}{100} \right) + cp_w \frac{M_i}{100} \right] (T_i - T_f) + L_v \left(\frac{M_i - M_f}{100} \right) W_i \quad (2)$$

Where W_i is the quantity of manure being dried

cp_d and cp_w is the specific heat capacity of dry manure and water respectively

T_i and T_f are initial and final temperatures respectively

M_i and M_f are the initial and final moisture ratio of the manure respectively in wet bases

L_v is the latent heat of vaporization.

Considering the temperature profile of non-heat storage solar greenhouse dryers where the inside temperature is higher than ambient during the sunshine period and equals the ambient in the absence of sunlight during night hours and also accepting that such cooling is associated with evaporation. The initial and final temperature will be assumed to be the same

$$\text{Hence, } T_i = T_f$$

for simplicity of analysis. Equation (2) now becomes simplified to represent the quantity of energy utilized in drying the manure sample from M_f to M_d . This energy used by the dryer is given as Equation .3

$$Q_{evap} = L_v \left(\frac{M_f - M_d}{100} \right) W_i \quad (3)$$

2.2 Moisture Content of Poultry Manure Before and After Drying

The moisture content can either be expressed on dry or wet basis.

On dry basis (%) it can be calculated as (Haque and Langrish, 2005; Saeed et al., 2006; Upadhyay et al., 2008):

$$\%MC_{db} = \frac{100(M_f - M_d)}{M_d} \quad (4)$$

where

$\%MC_{db}$ = Moisture content of sample, percent dry basis.

M_f = Mass of fresh sample (grams).

M_d = Mass of dried sample (grams)

And on wet basis (%) by the formula (Rodrigues and Fernandes, 2007; Simpson, 1991): for calculating.

$$\%MC_{wb} = \frac{100(M_f - M_d)}{M_f} \quad (5)$$

where

M_f = Mass of fresh sample (grams).

M_d = Mass of dried sample (grams)

$\%MC_{wb}$ = Moisture content of sample, percent wet basis.

Substituting and eliminating $(M_f - M_d)$ in equation (4) and (5) shows the relationship between the moisture content dry bases and wet bases as

$$\frac{MC_{wb}}{M_d} = \frac{MC_{db}}{M_f} \quad (6)$$

Samples of greenhouse dried manure is being oven dried in other to obtain the weight of the dry matter and overall



moisture content. The overall moisture content (W) is given by Liška, and Kic (2011) as

$$W = 1 - \left(\frac{W_{M1} \times W_{DM}}{W_{M0} \times W_{M2}} \right) \quad (7)$$

Where W is the moisture content of the material (%)

W_{M0} is a sample mass of manure being dried in the greenhouse dryer (g)

W_{M1} is the mass of the sample after drying in the greenhouse (g)

W_{M2} is a sample mass of manure being dry (g)

W_{DM} is a sample manure mass of dry matter (g)

2.3 Energy Payback Time of the Passive Greenhouse Dryer

Energy payback time (EPBT) is the period required to pay back the embodied energy of the components of the dryer.

The EPBT is obtained in Equation 8

$$\text{EPBT} = \frac{\text{Embodied Energy}}{\text{Annual Energy Output}} \quad (8)$$

The annual energy output could be obtained by multiplying the average daily energy output by the number of days operated per year. The average daily energy output obtained in Equation (3) will be multiplied by the total number of working days per annum.

2.3.1 Dryer daily energy output

The dryer's daily energy output is obtained from the difference in the moisture ratio of the manure after daily drying.

The dryer's daily energy output (E_{output}) is given as Equation 9

$$E_{\text{daily output}} = L_v \left(\frac{M_i - M_f}{100} \right) W_i \quad (9)$$

Where L_v is the latent heat of vaporization, M_i and M_f are the initial and final moisture content wet basis respectively.

2.3.2 Weekly energy output

The weekly energy output is obtained by multiplying the average daily energy output by the number of days operated per week using deductions from the average daily energy output from equation (9) and using drying days of approximately 6 days per week leaving one day or loading and offloading the manure and dryer cleaning and maintenance. The weekly energy output is given as equation (10)

$$\text{Weekly energy output: } E_{\text{output}} = L_v \left(\frac{M_i - M_f}{100} \right) W_i \times 6 \quad (10)$$

2.3.3 Annual energy output

The annual energy output is obtained by multiplying the average daily energy output by the number of days operated per year using deductions from the average daily energy output from equation (9) and assuming drying days of 312 days per year. (6 days per week and 52 weeks in a year). The annual energy output is given as equation (11)

$$\text{Annual energy output: } E_{\text{output}} = L_v \left(\frac{M_i - M_f}{100} \right) W_i \times 312 \quad (11)$$

2.4 CO₂ Emissions from Embodied and Thermal Energy Output of the Dryer

The standard emission factor is the total quantity of carbon emissions from the generation of energy equivalent to 1kwh of electricity by a coal plant. This emission factor depends on the quality of coal and efficiency of the coal powered generating plant (www.reddit.com). The overall emission factor also increases with losses in electricity transmission and distribution of the region or location (Samaila *et al.*, 2022)

However, the amount of CO₂ emission per kilowatt-hour from coal-powered generators varies from 8 -1.2 kg/kwh depending on factors like the efficiency of the plant/generator and the quality of coal used (www.reddit.com). Using James Watt's energy conversion, the emission factor for coal in Nigeria is equivalent to 0.98kg of CO₂/KWh (Houghton,1996)



2.4.1 CO₂ emission from embodied energy per year

Using James Watt’s energy conversion, 1kwh equals 0.98kg to CO₂/KWh. (Watt *et al.*,1998). Considering a dryer lifetime of 35 years as proposed by Prakash and Kumar (2014) on the assumption of regular maintenance and painting of the iron parts. The CO₂ emission per year from the embodied energy is given by (Vipin and Anil, 2015)

$$\text{CO}_2 \text{ emission per year from embodied energy} = \frac{\text{Embodied energy} \times 0.98}{\text{lifetime of dryer}} \tag{12}$$

When considering electricity transmission, distribution, and domestic losses of 53.83% in Nigeria Samaila *et al.*, 2022, the emission factor increases from 0.98 to 1.51, and the carbon emission per year is obtained as equation 13

$$\text{CO}_2 \text{ emission per year from embodied energy in Nigeria} = \frac{\text{Embodied energy} \times 1.51}{\text{lifetime of dryer}} \tag{13}$$

2.4.2 Daily CO₂ emission mitigation from drying

The daily CO₂ emission mitigation is taken as the mass of CO₂ emitted from the dryer's daily energy output. The daily CO₂ emission from the dryer energy output in Nigeria is given as Equation 14

$$\text{Daily CO}_2 \text{ emissions} = E_{\text{daily output}} \times 1.51 \tag{14}$$

2.4.3 Weekly and annual CO₂ emission mitigation

The weekly or annual CO₂ mitigation is the corresponding CO₂ emission from electricity when delivering the same quantity of energy output as the greenhouse. Since the dryer is assumed to work for 6 days a week and 312 days a year with a projected lifespan of 35 years (Prakash and Kumar, 2014), the weekly, annual, and lifetime emission offset is obtained from equations 15,16, and 17 respectively

$$\text{Weekly CO}_2 \text{ emission offset} = \text{Daily CO}_2 \text{ emission} \times 6 \tag{15}$$

$$\text{Annual CO}_2 \text{ emission offset} = \text{Daily CO}_2 \text{ emission} \times 312 \tag{16}$$

$$\text{Lifespan CO}_2 \text{ emission offset} = \text{Annual emission offset} \times 35 \tag{17}$$

2.4.4 Resultant CO₂ emission offset

The resultant emission offset during the lifetime of the dryer is the difference between the CO₂ emission from the embodied energy of the dryer and the total lifetime emission offset of the dryer. This is given by (Vipin and Anil, 2015) as

$$\text{Resultant CO}_2 \text{ offset} = \text{Lifespan CO}_2 \text{ emission offset} - \text{CO}_2 \text{ emission from embodied energy} \tag{18}$$

Table 2.1: Table of technical parameters

S/N	Parameters	Value	Nomenclature/comment
1	cp_w	4.19KJ/kg°C	Specific heat capacity of water
2	cp_s	4.19KJ/kg°C	Specific heat capacity of manure
3	L_v	2260.KJ/kg	Latent heat of vaporization
4	M_i	84.79%	Initial moisture content (%WB) obtained
5	M_f	16.7%	Final moisture content @EMC (%WB) obtained
6	G	4.92KWh/m ² /d	Incident radiation at the location Ani (2014)
7	τ	0.86	Transmissivity of glass
8	I	--	Intensity of solar radiation falling on greenhouse (W/m ²)
9	f	32.15%	Inflation rate as at September 2024
10	i	26.25%	Interest rate as at September 2024
11	Dryer lifespan	35 yrs	Using life time of 35 years as proposed by Prakash and Kumar (2014)



12	CO ₂ emission factor	1.51	
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2.5 Economic Analysis

2.5.1 Life cycle cost analysis

Life cycle costing (LCC) is the accumulated worth of all the costs that are both recurring and non-recurring during the life period of the system and the different components considered when calculating LCC are capital cost, replacement cost, maintenance cost, and salvage value (Paul *et al.*,1997), The Capital cost is the initial cost that is spent for the purchase. Replacement cost is the cost incurred for replacement within the lifetime of the dryer. Maintenance cost is the cost incurred every year as annual maintenance cost. Salvage value is the money that is obtained while disposing the greenhouse dryer at the end of its life cycle period. For calculating LCC, each of the costs is converted to its present worth (Paul *et al.*, 1997). Even the salvage amount is converted to its present worth for calculating LCC. Assuming the maximum life of solar dryer is 35 years as proposed by Prakash and Kumar (2014) it means the replacement of the setup should be done after 35 years, further calculations are to be carried out putting into consideration Interest rate and Inflation rate in Nigeria (i and f respectively)

The present worth (PW) of the dryer is its capital cost. Let the replacement cost of the unit be taken as *U*, then

$$PW1 = U \tag{19}$$

Since there are no moving parts, assume the dryer should be replaced after 35 years, (Prakash and Kumar, 2014) then the present worth of replacement cost in 35 years is calculated as

$$PW2 = U((1+f)/(1+i))^{35} \tag{20}$$

Where I = Interest rate and f = Inflation.

The present worth of the annual maintenance cost (AMC) considered over 35 years is

$$PW3 = AMC ((1+f)/(1+i)) \times [1-((1+f)/(1+i))^{35}] \tag{21}$$

then the present worth of the salvage value obtained after disposing of the unit and mechanical frames at the end of 35 years is given as

$$PW4 = Sal ((1+f)/(1+i))^{35} \tag{22}$$

Therefore, the Life Cycle Cost, LCC is calculated from the following expression given by (Selvi *et al.*, 2017).

$$LCC = PW1 + PW2 + PW3 - PW4 \tag{23}$$

The present value (PV) of the cost of energy generated annually with respect to inflation and interest rate can be obtained using annuity formula

$$PV = \frac{P}{r} (1 - (1 + r)^{-n}) \tag{24}$$

Where

PV is the present value of the annuity,

P is the annual cost of the energy output

r is the effective discount rate per period (adjusted for interest rate and inflation),

n is the number of periods (35 years).

The effective discount rate (r) is given as

$$r = \left(\frac{1+inflation}{1+interest} \right) - 1 \tag{25}$$



This is based on the assumption that both the interest rate and inflation is relatively steady within the period of the lifespan (35 years)

2.5.2 Estimated cost payback period of the dryer

The payback period (PBP) estimates the number of years it takes to recover an investment's initial capital. The actual payback period considering the inflation and interest rate components was obtained by replacing the present value of an annuity with the investment cost in equation (24) while imputing other values except (n) which will be made the subject of the equation. Hence the actual payback time is given by Banout *et al.*, 2011 as

$$n = \frac{\ln \left[1 - \frac{P_v}{s}(i-f) \right]}{\ln \left(\frac{1+f}{1+i} \right)} \quad (26)$$

In a simple payback period the time value of money is not considered (Joseph *et al.*, 2021), the payback period (PBP) is expressed mathematically as

$$\text{PBP} = \frac{C_i}{S} \quad (27)$$

Where;

C_i is the initial investment cost and

S is the value of energy output per year.

In the case of a passive greenhouse, assume the cash inflow to be equivalent to the levelized cost of the quantity of energy being utilized in drying which will be obtained from equation (3).

The daily thermal energy output E_{daily} in KWhr is given as (Jain *et al.*, 2019)

$$E_{\text{daily}} = \frac{(M \times L_v)}{3.6 \times 10^6} \quad (28)$$

Where M and L_v are mass of evaporated water per day and latent heat of vaporization respectively.

Assuming drying days of 330 days per annum,

Annual thermal energy output (KW_{thermal})

$$E_{\text{annual}} = 330 \times E_{\text{daily}} \quad (29)$$

2.5.3 Energy payback time

Energy payback time (EPBT) is the period required to pay back the embodied energy of the components of the dryer.

$$\text{EPBT} = \frac{\text{Embodied Energy}}{\text{Annual Energy Output}} \quad (30)$$

The annual energy output could be obtained by multiplying the average daily energy output by the number of days operated per year using deductions from average daily energy output from equation (3) and assuming drying days of 330 days per year

$$\text{Annual energy output: } E_{\text{output}} = L_v \left(\frac{M_i - M_f}{100} \right) W_i \times 330 \quad (31)$$

The technical parameters used in conducting the techno-economic analysis were as specified in Table 2.2



Table 2.2: Table of technical parameters used for techno-economic analysis

S/N	Parameters	Value	Nomenclature/comment
1	cp_w	4.19KJ/kg°C	Specific heat capacity of water
2	cp_s	4.19KJ/kg°C	Specific heat capacity of manure
3	L_v	2260.KJ/kg	Latent heat of vaporization
4	M_i	74.9%	Initial moisture content (%WB) obtained
5	M_f	16.7%	Final moisture content @EMC (%WB) obtained
6	G	4.92KWh/m ² /d	Incident radiation at the location Ani (2014)
7	τ	0.86	Transmissivity of glass
8	f	32.15%	Inflation rate as at September 2024
9	i	26.25%	Interest rate as at September 2024

3. MATERIALS AND METHODS

3.1 Experimental Set-Up

In this research, a passive solar greenhouse dryer was developed and used in testing the technical and economic feasibility of using solar greenhouse dryers for commercial poultry manure drying in south-eastern Nigeria. . The drying experiment was conducted in Nsukka longitude 7.390 N and latitude 6.860 E. The internal dimensions of the dryer are 3.08 m x 2.09m x 3.31m in length, width, and height respectively the total drying tray area is about 10m² .



Fig. 3.1: During drying experiment in the greenhouse manure dryer



3.2 Instrumentation

The physical parameters both inside and outside the dryer. were obtained using. Applent AT4208 Multi Channel temperature meter which is capable of measuring up to 8 distinct temperature values concurrently with an accuracy of 0.2%+1°C. The relative humidity values were obtained using UNI T industrial hygrometer which measures both temperature and relative humidity. Model: UT331. The wind velocity value at the dryer site was obtained using a hot wire anemometer integrated to a personal computer for data logging. The incident solar radiation was measured using Lutron electronic solar power meter model SPM-1116SD with range of 2000 W/m²,

The moisture content was determined using the oven drying method following the procedures defined in the ASABE standards (ASABE, 2009). Samples of approximately 5 g were dried and the moisture contents (MC) were calculated using equations (4) to (7).

4. RESULTS AND DISCUSSIONS

4.1 Results of Drying Experiment

Samples of fresh poultry manure was dried. The performance evaluation of the dryer showed its ability to dry about 150kg of manure per week with moisture reduction of 77.7% (wet basis).

4.2 Results of Dryer Energy Analysis

4.2.1 Estimated embodied energy of the dryer

The embodied energy which is a summation of all the energy in the materials that was used in the fabrication. The embodied energy of the various materials and quantity estimated to be used in the fabrication of the greenhouse dryer is presented in the Table 4.1 below.

Table 4.1: Table of embodied energy

S/N	Construction Material	Quantity (KG)	Embodied Energy (MJ/kg)	Total Embodied Energy (MJ)
1	Angle iron	134	20.1	2693.4
2	Glass	108	15	1620
3	Aluminum profile	11.2	155	1736
4	Ceramic tiles	27.4	12	328.8
5	Matt black paint	3.4	97	329.8
6	Concrete block	86	0.67	57.62
7	Concrete Mortar (1:3)	90	1.33	119.7
	TOTAL ESTIMATED EMBODIED ENERGY			6885.32

Source : https://en.wikipedia.org/wiki/Embodied_energy accessed on 2nd July, 2023.

The total embodied energy of the dryer was estimated to be about 6885.32 MJ

The embodied energy contribution of the various components of the dryer to the overall dryer embodied energy is as represented in a chart in Fig.4.1.



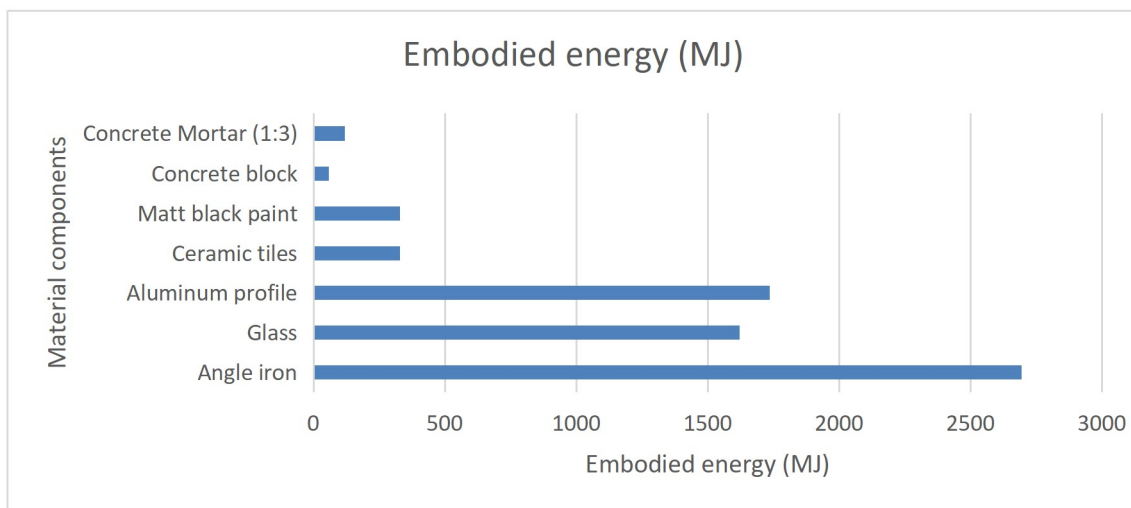


Fig.. 4.1: A chart of the total energy embodied by different materials used in the dryer construction

4.2.2 Results of the energy-economic analysis of the drying experiment

Samples of fresh poultry manure whose initial moisture content was 84.79% wet basis were dried in the greenhouse to an equilibrium moisture content level of 16.67% wet basis within 6 days. The initial mass of manure dried was 150kg. The parameters used in the energy economic analysis are shown in Table 4.2.

Table 4.2: Table of values used in the economic analysis

S/N	PARAMETER	VALUE
1	Interest rate	26.25% (CBN monetary policy as of August 2024)
2	Inflation	32.15%(CBN monetary policy as at August 2024)
3	Electricity cost	₦64.07/kwh for band B customers. (NERC August 2024)
4	Present Salvage Value (Sal)	₦300,000 (obtained from similar structures)
5	Initial Cost of Dryer (U)	₦1,896,250

The quantity of manure being dried per week is used to deduce the dryer energy output which was used to calculate other parameters. The calculated parameters were tabulated in Table 4.3.

Table 4.3: Table of results

S/N	CALCULATED PARAMETERS	VALUES
1	Mass of sample dried per week	150kg
2	Mass of water evaporated per week	87.35kg
3	Energy output per week	54.84Kwh/wk
4	Energy output per day	9.13Kwh/day
5	Annual energy output	2,851.49 Kwh/yr
6	Estimated energy output for lifespan (35 yrs)	99,802.22kwh
7	Total estimated embodied energy in kilowatt-hours	1,912.6kwh
8	Estimated energy payback time	0.67yrs (209 days)
9	CO ₂ emission from embodied energy	2888.02kg
10	CO ₂ emission per year from embodied energy	82.51kg/yr
11	CO ₂ emission offset from drying per year	4,305.75kg/yr
12	Resultant carbon offset per year	4,223.24kg/yr
13	Estimated resultant carbon offset for dryer lifespan	147.813.4kg of CO ₂
14	Investment cost	₦ 1,896,250
15	Salvage value after 35 years	₦ 300,000
16	Cost of Energy output per annum	₦ 182,495.36
17	The total life cycle cost (35 years)	₦ 9,599,955
18	Cost of energy output throughout the lifespan(35 years)	₦ 19,641,742.49
19	Investment profit	₦ 10,041,787.49



20	Simple payback time	6.3 years (77 months)
21	Actual payback time	6.65 years (approximately 80 months)

4.3 Discussion of results

The dryer's annual performance was based on 312 days of drying per year. The result of the dryer cost analysis shows an approximately 230 percent return on investment in terms of capital cost, considering the values of investment cost and energy output cost from Table 4.1. The energy payback time of 99 drying days and financial payback time of 55 months as observed from Table 4.3 shows the spontaneous payback period for both the embodied energy and investment. The profit on investment was ten million forty-one thousand seven hundred and eighty-seven naira (₦ 10,041,787.49) with an initial investment cost of one million eight hundred and ninety-six thousand two hundred and fifty naira (₦ 1,896,250).

The carbon emission offset was so intensive that the contributions of such dryers in the greenhouse gas mitigation and the consequent global warming is so commendable with CO₂ emission mitigation throughout the dryer lifetime of 248,179.4kg of CO₂.

5. CONCLUSION AND RECOMMENDATIONS

In conclusion, this work has affirmed that the integration of solar greenhouse dryers into the commercial poultry industry will serve as a vital and energy-efficient step toward combating greenhouse gas emissions and the resultant global warming. The results also proved that the economic viability of using greenhouse dryers will drastically cut down the running costs associated with manure drying among commercial farmers and will also contribute to climate change mitigation.

It is recommended that the government enlighten the farmers on the uses and applications of greenhouse technologies. This could be achieved through a combination of policy measures, financial incentives, technological innovation, and public awareness campaigns using the relevant ministries and agencies. It has been identified that the major challenge deterring the integration of solar dryers into the energy mix is ignorance on the side of poultry farmers. The results of the findings of this research work will serve as a base information to encourage farmers to adopt the use of solar greenhouse dryers in order to minimize operating cost.

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