

STUDY OF ENERGY CONSUMPTION FOR OPTIMUM POULTRY YIELD IN NIGERIA: NEFRADAY FARM LTD ILORIN AS A CASE STUDY

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ABSTRACT

The work reported in this paper involves studying the energy consumption for optimizing poultry yield in Nigeria using NEFRADAY farm as case study. The energy consumption of the hatchery section of the farm alongside the environmental temperatures for a period of thirty (30) days were measured. The temperature data were analyzed to determine the heating degree day for the period and this was related to the energy consumption for each day. The linear regression obtained between energy consumption (E_H in kWh) and the heating degree-day (D_H in °C-day) was:
 $E_H = 4.448D_H$. This equation was applied for estimating Energy consumption for all the months of the year using the available calculated degree-days for Ilorin. It was concluded that February is the period that is most suitable for hatchery business in Ilorin since the energy consumption is lowest for that month.

1. INTRODUCTION

Poultry refers to all kind of birds that are of economic value to man, for example chicken, turkey, goose, duck, pigeon, sea fowl, pheasant, quail, guinea fowl and ostrich. Each of these is of diverse varieties [1]. Poultry is of great importance to man because they serve as a good source of protein and its consumption by man is widely accepted by people of different religious beliefs. It is highly valued for its competitive quality when compared to meat from other livestock.

Poultry birds have short production cycle [2]. A twenty - week old chicken starts laying and once the laid eggs are fertile with favorable incubation condition, the eggs are hatched within 3 weeks to produce day old chicks. The day old chicks are reared naturally by mother hen or artificially by brooding system. The brooding stage lasts for four to six weeks.

Incubation is the provision of favourable conditions that will make the eggs to develop from embryo to healthy birds and hatch at high efficiency (more than 80% of the fertilized eggs). There are various types of poultry and each has its incubation period. Artificial incubation takes place in an incubator which is a device that provides the appropriate environmental condition for development of embryo in fertile eggs into chicks.

The appropriate favourable conditions are to be maintained to yield good and efficient results. One of the conditions is maintenance of proper temperature. This is the major criterion for successful incubation of poultry eggs. The embryonic development starts when the egg is exposed to a temperature of 26.6-29.4°C [3]. Good embryonic development is achieved at temperature range of 37.2-39°C and the exact temperature depends on the types of poultry eggs and the age of the eggs in the incubator.

Another important factor is proper humidity which is necessary to keep the eggs from losing too much water during the incubation period. Chicks' eggs should lose between 11-14% of their weight. Control of humidity is necessary to control weight loss. Humidity should be balanced with temperature, as different temperature requires different relative humidity. In the first eighteen days of incubation, the needed relative humidity is 60-65% but it should be close to 70% during the last three days. Reduction of evaporation from eggs is provided for by optimum relative humidity [1]. Adequate ventilation for the eggs is necessary for the embryo which is a living tissue to exchange Oxygen (O_2) and Carbon dioxide (CO_2) throughout the growth process. To obtain optimum hatching result the best source of ventilation is atmospheric air, which contains 21% Oxygen (O_2). Also towards the end of incubation period Carbon dioxide (CO_2) is needed to achieve sufficient muscle, for the embryo to pick its way out of the shell, for emergence [3]. However too much of this is

undesirable and ventilation is needed to rid the incubator of excess carbondioxide and other noxious substances that may arise from spoiled or broken eggs or fumigation of incubator. [3] Positioning and turning of eggs is another vital factor in eggs incubation. Eggs are set horizontally or with broad end up in the eggs trays in the incubator. This is for the embryo to benefit from oxygen cell. Eggs incubated with small end up most often do not hatch because the embryos develop with their head in the small end of the eggs. Eggs need to be turned regularly to prevent embryo from sticking to the shell which leads to death. They must be turned at least three times daily to prevent them laying on the same side every night. [1, 4]

There is an enormous increase in energy demand in Nigeria both domestically and industrially. The generation and transmission of energy do not meet up with the demand. To plan for adequate energy supply to farms, there is need to ascertain what quantity of energy is needed for hatching of eggs and raising chicks to maturity. This will help in the national planning in greater measure and help poultry farmers to plan for meeting the cost of energy consumption in their projection.

Much has not been done in the area of energy consumption in poultry industry. Aiyedogbon [5] worked on computerization of poultry record of NEFRADAY Farm, which focused on poultry record keeping based on information and communication technology (ICT). Olorunsanya [6] in her work on egg production

in Kwara State, Nigeria considered the economic analysis of egg production with no reference to energy consumption.

Adeniyi [3] worked on energy consumed by incubator; he determined this by analysing the heat transfer in the incubator. Smith [7] reported that energy saving tips could be successful if good and accurate records of energy consumption in poultry outfit are kept.

Biscarini, *et al* [8] reported that the control of environmental condition in farm buildings has great importance on energy consumption which will have a great effect on the total production cost. Tabler, *et al* [9] in their work on energy cost associated with commercial broiler production, found that approximately 25% of gross farm income is required to pay for fuel (popane) and electricity annually.

Poultry keeping is a cottage industry in Nigeria because there is hardly any home in rural area where chicken are not kept. However there are many commercial farms where poultry keeping on a large scale is done. Chicken is the most popular among poultry birds and account for about 90% of local poultry production in Nigeria. Chicken is about 80% of 120million poultry types as at 1987 of which 86.5% are found in the northern part of Nigeria. [10]

The objective of this work presented in this paper is to determine the energy consumed for hatching poultry birds at NEFRADAY Farm and relate it with environmental condition and the cost of energy consumed.

2. EXPERIMENTAL METHODS

Experimental data were gathered at the hatchery section of the NEFRADAY Farm Limited. This is an integrated farm, located at Km 20, Ilorin-Ogbomosho Road. The data gathering instruments are Fluke 971 temperature-humidity meter made by Fluke Corporation, and single phase, 2-wire, CL 147 x 13 Watt-hour meter, made in Nigeria by EMCON. The incubator worked on single phase electricity supply. The energy meter was installed to monitor the energy consumed by the incubator.

The eggs from various customers were loaded into the incubator and these eggs were of various poultry birds such as turkey, chicken, duck, and geese. These eggs were loaded into the incubator whenever they were received from customers. There was no time when the incubator was filled to capacity during the period of the experiment.

The hourly readings of temperature and relative humidity (RH) were taken for the air in the incubator and the ambient air outside the incubator. The following parameters were also measured hourly: dry bulb temperature (T_{db}), wet bulb temperature (T_{wb}) and relative humidity (RH) of air outside the building and inside the building. Readings of energy consumption were also taken using the energy meter installed.

Whenever there was power outage, a period of about 3 minutes was allowed to see if the power would be restored otherwise a generator is put on or a kerosene stove is lit. If the kerosene stove is to be used, the ventilation port size will be reduced so as to conserve the heat energy in the setter. The kerosene stove was weighed twice daily; first thing in the morning and last thing at night to determine the mass of kerosene

consumed for space heating with the stove when electricity was not available. The readings taken in the morning served as the final reading for previous night session and initial reading for the day session. While the evening readings serve as the final reading for the day session and initial readings for the following immediate night session. The experimental data were taken on the average for 10 hours per day for a period of thirty (30) days.

3. RESULTS AND DISCUSSION

3.1 Results

$$D_H = \sum_i \frac{1}{24} f(T_i) \quad (1)$$

$$\text{Where } f(T_i) = \begin{cases} T_b - T_i & \text{if } T_b > T_i \\ 0 & \text{if } T_b \leq T_i \end{cases} \quad (2)$$

Where D_H = Heating degree day
 T_i = hourly ambient dry-bulb temperature.
 T_b = Temperature in the incubator which is the base temperature.
 n = number of hours over which temperature values were measured.
The base temperature used is the daily average temperature of the incubator and it varies from day to day.

Table 1 shows the average values of dry-bulb temperature (T_{DB}) inside and outside the

The major requirement of the hatchery is heating the space in it. There is a relationship between the energy used for space heating and the difference between the operating temperature and outside temperature. This leads to the concept of heating degree-days [11]. Heating degree-day is defined as the addition of all the positive differences between the base temperature (T_b) and the observed values of ambient temperature (T) that is $(T_b - T)$ multiplied by time interval in days. In calculating the heating degree-day, the formula given by Olorunmaiye [12] was used:

incubator, heating degree-days, number of hours over which reading was taken during the day, and electrical energy consumed.

The energy consumed by the incubator for heating the space in it and driving the incubator fans over the period of the experiment each day (E_H) was obtained by multiplying the values in columns 6 and 7 in Table 1. The values of E_H and D_H are presented in Table 2.

Table 1: Average values of dry-bulb temperature inside and outside the incubator, heating degree-days (D_H), number of hours over which readings were taken during the day and average electrical energy consumed per hour.

Day	Date	Average T_{DB} inside incubator (T_b)	D_H	Average T_{DB} outside incubator	Hours of the day (h_D)	Average Electrical energy consumed per hour (kWh)	
						Day	Night
1	25/10/2006	36.06	2.25	29.7	8	1.273	1.42
2	26/10/2006	36.00	3.23	28.25	10	1.158	1.36
3	27/10/2006	36.26	2.70	29.4	9	1.047	1.38
4	28/10/2006	36.3	1.83	30.45	7	1.237	1.56
5	29/10/2006	36.43	2.62	29.75	9.5	1.432	1.62
6	30/10/2006	36.07	3.45	28.05	9.5	1.7	2.0
7	31/10/2006	36.66	3.45	28.8	9.5	2.232	1.81
8	1/11/2006	36.71	3.36	29.45	9.5	1.768	0.86

9	2/11/2006	33.63	1.45	29.3	3	1.567	1.54
10	3/11/2006	36.3	2.97	29.8	9.5	1.189	1.30
11	4/11/2006	34.78	1.97	29.6	8.5	1.045	1.25
12	5/11/2006	36.18	2.45	29.1	8	1.3	1.70
13	6/11/2006	36.33	2.90	29.25	9.5	1.397	1.61
14	7/11/2006	37.05	2.98	30	9.5	1.556	1.80
15	8/11/2006	36.72	3.66	28.45	10	1.596	1.80
16	9/11/2006	36.93	3.53	28.3	8	1.864	1.40
17	10/11/2006	37.08	3.27	28.1	8	1.55	1.30
18	11/11/2006	37.17	3.01	29.35	8.5	1.465	1.80
19	12/11/2006	36.89	3.45	28.2	8.5	1.812	1.67
20	13/11/2006	36.99	3.93	27.7	11	1.618	1.47
21	14/11/2006	36.5	4.07	27.25	11	1.722	1.70
22	15/11/2006	36.56	4.56	26.6	12	1.7	1.77
23	16/11/2006	36.75	3.82	28.85	11	1.6	2.03
24	17/11/2006	36.45	4.29	25.9	11	1.727	1.87
25	18/11/2006	35.74	4.00	26.8	11	1.638	1.63
26	19/11/2006	36.14	3.95	25.1	9	1.678	1.93
27	20/11/2006	36.99	1.12	27.99	7	1.871	1.99
28	21/11/2006	34.86	2.56	28.05	5	1.652	1.98
29	22/11/2006	36.84	3.32	28.55	9	1.794	1.82
30	23/11/2006	37.1	3.21	29.05	8.5	1.582	

Table 2: Statistical data for determining correlation coefficient between energy consumed (E_H) and heating degree-days (D_H)

Day	D_H	E_H			
	X	Y	X^2	Y^2	XY
1	2.25	10.18	5.06	103.63	22.905
2	3.23	11.58	10.401	134.10	37.3455
3	2.70	9.42	7.29	88.74	25.434
4	1.83	8.66	3.35	75.00	15.84058
5	2.62	13.60	6.86	184.96	35.60933
6	3.45	16.15	11.90	260.82	55.71755
7	3.45	21.20	11.93	449.44	73.22839
8	3.36	16.80	11.28	282.24	56.42
9	1.45	4.70	2.11	22.09	6.826241
10	2.97	11.30	8.80	127.69	33.52333
11	1.97	8.88	3.89	78.85	17.5195
12	2.45	10.40	6.00	108.16	25.48018
13	2.90	13.27	8.39	176.09	38.42771

14	2.98	14.78	8.85	218.45	43.97053
15	3.66	15.96	13.41	254.72	58.45348
16	3.53	14.91	12.46	222.31	52.63547
17	3.27	12.40	10.69	153.76	40.54686
18	3.01	12.45	9.04	155.00	37.43648
19	3.45	15.40	11.90	237.16	53.13
20	3.93	17.80	15.47	316.84	70.01334
21	4.07	18.94	16.54	358.72	77.02264
22	4.56	20.4	20.78	381.03	88.97867
23	3.82	17.60	14.57	309.76	67.17333
24	4.29	19.00	18.38	361.00	81.4625
25	4.00	18.02	16.03	324.72	72.15509
26	3.95	15.10	15.60	228.01	59.645
27	1.12	13.10	1.25	171.61	14.62833
28	2.56	8.26	6.57	68.23	21.17485
29	3.32	16.15	11.00	260.82	53.56417
30	3.21	13.45	10.32	180.90	43.20813
Σ	93.34344	419.86	310.1	6329.99	1379.476

The values of correlation coefficient between Energy consumed E_{Ht} and heating degree-days D_{Ht} was determined using:

$$\text{Correlation } R = \frac{n \sum_{i=1}^n x_i y_i - \left(\sum_{i=1}^n x_i \right) \left(\sum_{i=1}^n y_i \right)}{\sqrt{\left(n \sum_{i=1}^n x_i^2 - \left(\sum_{i=1}^n x_i \right)^2 \right) \left(n \sum_{i=1}^n y_i^2 - \left(\sum_{i=1}^n y_i \right)^2 \right)}} \quad (3)$$

Where in this case $y_i = E_{Ht}$ values, $x_i = D_{Ht}$ values, and $n = 30$. See Table 2.

The value of R was found to be 0.8154. This R value shows a good relationship between heating degree days and energy consumed by the incubator.

An appropriate linear equation relating E_{Ht} and D_{Ht} is of the form,

$$y = mx \quad (4)$$

Using the values of E_{Ht} and D_{Ht} as y_i and x_i respectively in Table 2, the scatter diagram of energy consumed by the incubator versus heating degree-days was plotted using Microsoft Excel 2007 version and it is presented in Figure 1 below. The trendline passing through the origin of the axes is also shown in the Figure. Thus the slope $m = 4.448$ in equation (4) above and we can write

$$E_H = 4.448D_H \quad (5)$$

Equation (5) is the major result obtained in this work from the experimental data gathered for 30 days. The equation can be applied to determine energy consumed by the incubator for each of the twelve months in the year once the values of heating degree-days for those months are known. Table 3 shows the average monthly heating degree-days (D_H) for Ilorin based on hourly Dry-bulb temperature data obtained from National Meteorological Agency, Oshodi, Lagos State for five years (1983-1987) by Raheem [13] and seven years (2000-2006) by the authors of this paper, and the computed values of Energy consumed (E_H) using these values of D_H in equation (5).

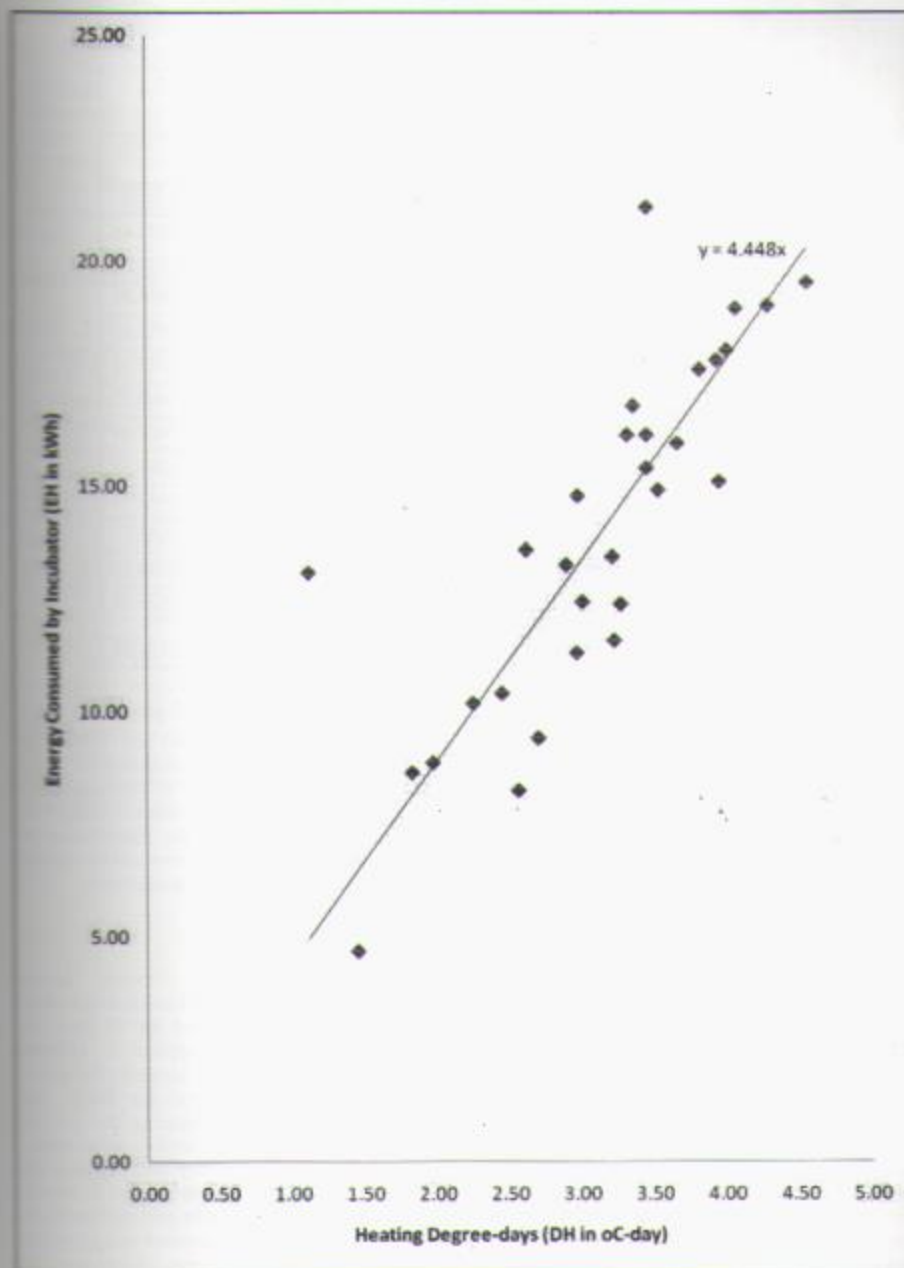


Figure 1: Energy consumed by incubator (E_H) versus heating degree-days (D_H) along with the trendline that pass through the origin.

Table 3: Heating degree-days (D_H) for Ilorin computed from hourly dry-bulb temperature data by Raheem [13] for 1983-1987 and values of D_H computed in the present work for 2000-2006 along with the values of energy consumption (E_H) calculated from equation (5)

S/No	Month	D_H ($^{\circ}\text{C-day}$) for $T_b = 37^{\circ}\text{C}$		E_H (kWh)	
		1983-1987	2000-2006	1983-1987	2000-2006
1	January	340.40	313.21	1514.10	1393.16
2	February	241.20	233.76	1072.86	1039.76
3	March	252.20	234.92	1121.79	1044.92
4	April	255.90	254.53	1138.24	1132.15
5	May	304.80	302.59	1355.75	1345.92
6	June	342.40	335.82	1523.00	1493.73
7	July	385.90	373.02	1716.48	1659.19
8	August	389.30	391.54	1731.61	1741.57
9	September	369.30	362.84	1642.65	1613.91
10	October	341.70	346.97	1519.88	1543.32
11	November	299.80	302.62	1333.51	1346.05
12	December	360.10	319.33	1601.72	1420.38
Σ				17271.59	16774.06

3.2 Discussion of results

From the results, it was discovered that there is a strong correlation between heating degree-days and energy consumption in hatchery. The coefficient of correlation between energy consumption and the heating degree-days is 0.8154. From Table 3 the highest heating degree-days and hence Energy consumption occurs in August for both 1983-1987 and 2000-2006 meteorological data. The other months with lower heating degree-days have lower energy consumptions.

The lowest energy consumption per month occurs in February. Therefore, it is cheaper to incubate eggs in February than any other month. From Table 3, it can be seen that the values of average monthly heating degree days (and hence energy consumed by incubator) for each month of the year except August, October and November are lower for the period 2000-2006 than for the period 1983-1987. From Table 3, the estimated average energy consumed per year in operating the incubator for the periods 1983-1987 and 2000-2006 are 17,271.59 kWh and 16,774.06 kWh respectively. The average energy

per year is 2.9% lower for the 2000-2006 period. This is due the phenomenon of global warming. This in a way is favourable for incubation of eggs which requires heating. This is one instance in which the phenomenon of global warming is advantageous unlike in most cases where it is considered undesirable.

4. CONCLUSION

The linear relationship between energy consumed by incubator and heating degree-days obtained from data gathered for 30 days has been presented. It was applied to estimate energy consumption by the incubator for all the twelve months in the year for Ilorin. The equation is useful in estimating the cost of energy consumption for operating an incubator at the planning stage at any location once the heating degree days over the period is known. The results are also useful in guiding farmers on what month of the year minimum energy will be consumed for incubating eggs. Global warming is favourable for incubation of eggs because of reduced energy consumption in the incubator.

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