

## ARTICLE

# Mathematical Model to Estimate Carbon Footprint for EEG Incubation

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## ABSTRACT

This work presents a performance comparison between several incubators models including CO<sub>2</sub> and NH<sub>4</sub> emission. A mathematical model for incubators carbon foot print was developed to estimate CO<sub>2</sub> and NH<sub>4</sub> emission. The program written by C++ language including convert line. The modular structure of program consists of a main programme and series of independent subroutine: each one deals with a specific parameter of the required data. The computer programme has a wide range of applicability several values of size of the machine (NO. egg), Fertility (F), Heat production embryo (HP<sub>e</sub>), maximum CO<sub>2</sub> level (CO<sub>2</sub>)<sub>m</sub>, CO<sub>2</sub> level incoming air (CO<sub>2</sub>)<sub>i</sub>, RQ value (RQ) to estimate Heat production (HP), CO<sub>2</sub> production, Ventilation (V), Ventilation of egg (V<sub>egg</sub>) Input data: Enter size of the machine, Fertility (F), Heat production embryo (HP<sub>e</sub>), maximum CO<sub>2</sub> level (CO<sub>2</sub>)<sub>m</sub>, CO<sub>2</sub> level incoming air (CO<sub>2</sub>)<sub>i</sub>, RQ value (RQ) the results As the growth period passed from the first day of the twenty-first day, the amount of heat produced increased from 0.0001 to 0.35 w / egg, and ventilation from 0 to 352 m<sup>3</sup> / hr as well as the amount of carbon dioxide produced from 0.0000158 to 0.04318 lit/hr/Mach. As the number of eggs increased from 5,000 to 30,000 eggs, each of the heat produced increased from 923.4 to 5540.4 kg / hr, the resulting carbon dioxide from 32 to 190 lit / hr / Mach, and ventilation from 9 to 54 m<sup>3</sup>/hr

## 1. Introduction

During these last decades, the production of poultry meat increased almost 108% from 54 to 112 million tons, corresponding to a 36% growth of its share in total meat production. Incubators need to maximize chick production, and this entails not only the incubation of more fertile eggs. Today, incubators need to achieve high production efficiency in a sustainable manner, which, in our view, includes maximizing the hatchability of healthy chicks with high survival rates and

reducing carbon emissions from increased.

Carbon footprint (CFP) named Carbon profile - is the overall amount of carbon dioxide (CO<sub>2</sub>) and other greenhouse gas (GHG) emissions (e.g. methane, nitrous oxide, etc.) associated with a product. The carbon footprint is a sub-set of the data covered by a more complete Life Cycle Assessment (LCA) [6].

The non-ruminant sector is a minor N<sub>2</sub>O emissions contributor compared with ruminant N<sub>2</sub>O emissions. The poultry industry is the largest direct N<sub>2</sub>O producer of the non-ruminant livestock industries, contributing 92.8% of

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the total non-ruminant N<sub>2</sub>O emissions<sup>[8]</sup>.

Oxygen (O<sub>2</sub>) is essential for respiration in birds. It is inhaled and carbon dioxide (CO<sub>2</sub>) is a product of respiration in birds. For optimum poultry production, the concentration of carbon dioxide must not exceed 2500 ppm, also said that low concentration of hydrogen sulphide (H<sub>2</sub>S) is fatal to poultry and human health, and reported that if the temperature remains within the range of 25°C to 30°C, air velocity of 0.1 m/s to 0.2 m/s can be maintained, but if the temperature goes beyond that an increase in air velocity will help aid convective cooling. Furthermore, air velocity of 0.1 m/s to 0.2 m/s the movement pattern of air can be easily controlled through building design and ventilation within the building<sup>[5]</sup>.

During the 21 days it takes to incubate the chicken eggs to hatch, the developing embryo requires different levels of CO<sub>2</sub> at specific developmental stages. Gas exchange is closely related to respiration function<sup>[7]</sup>.

The ammonia emission rates averaged 19.7 and 18.1 mg.h<sup>-1</sup> per bird in the summer and winter, respectively, and increased with indoor temperature ( $r^2 = 0.51$  in summer;  $r^2 = 0.42$  in winter). Emissions are mainly produced at the end of the summer cycle, whereas in winter, their production begins earlier in the cycle. Also he found CH<sub>4</sub> emissions of 0.44 and 1.87 mg.h<sup>-1</sup> per bird in summer and winter, respectively. Also found in a study that the average nitrous oxide emissions were 1.74 and 2.13 mg.h<sup>-1</sup> per bird in summer and winter, respectively<sup>[1]</sup>.

The a direct relationship between NH<sub>3</sub> emissions and indoor temperature was also observed. Although indoor temperature was identified as main variable influencing NH<sub>3</sub> emissions, other variables, such as ventilation rate and bird activity, may also be influencing those emissions<sup>[10]</sup>.

The authors suggested paying greater attention to air circulation in incubators and decreasing the temperature during the second stage of incubation for heavier eggs. It is known that during the incubation period, as the embryo develops, oxygen (O<sub>2</sub>) consumption and carbon dioxide (CO<sub>2</sub>) production increase. Therefore, the levels of CO<sub>2</sub> and O<sub>2</sub> in the incubator are also crucial factors for embryonic development and may affect performance both at hatching as well as post-incubation<sup>[3]</sup>.

The different concentrations of CO<sub>2</sub> applied in different stages of embryo development depress hatchability and that a concentration higher than 1% increased gradually in the first 10 days of incubation enhanced embryo growth, and improved hatchability. However, when applied after the 10th day of incubation it had no effect on hatchability<sup>[9]</sup>.

Many studies focused on CO<sub>2</sub> levels during the early and middle stages of incubation. Results showed that CO<sub>2</sub>

concentrations over 1% during the first 4 to 8 days of incubation, up to 4% from 10 to 18 days of incubation and more than 6% between day 9 and day 12 of incubation decelerated embryonic growth, increased late mortality and depressed hatchability<sup>[2]</sup>.

It is known that retention of CO<sub>2</sub> in the body due to impaired respiratory function, leads to an elevation of body fluid PCO<sub>2</sub> and results in respiratory acidosis or primary hypercapnia. The removal of extra CO<sub>2</sub> during incubation is therefore thought to be one of the vital functions of good ventilation. The normal CO<sub>2</sub> level is around 0.1-0.5%<sup>[4]</sup>.

## 2. Problem

Increase the concentrations of carbon dioxide and ammonia in incubation. Reducing growth rates due to increased mortality rates in chickens and consequently lower egg production rates.

## 3. Materials and Methods

Experiment was carried out through 2019 in an incubator factory at a private closed system egg production farms in Gamasa, Governorate of Dakahlia, Egypt. To estimate carbon footprint and other greenhouse gas (GHG) emissions. Also study the factors affecting the increase of greenhouse gas emissions in incubator.

The incubator has a capacity of 5,000 eggs, (Fig. 1) spent 21 days, and we expect what will happen in incubator with a capacity of 20,000 and 30,000 eggs.

Incubator dimensions were (173 \* 117 \* 172 cm) had a nominal capacity of 5000 hens in production period, in Table 2.

**Table 1.** Cobb characteristics

Breeder	Performance
Age at depletion	65 weeks
Age at 5% production	24 weeks
Total eggs / hen housed	181.3 %
Hatching eggs / hen housed	176.3 %
Peak hatchability	90 %
Cumulative hatchability	85.6 %
Broiler chicks / hen housed	150.9 %
Livability from 24 weeks	92.3 %

**Table 2.** Technical specifications for incubation

The size of the incubation	173 * 117 * 172 cm
Weight	220 Kg
Egg Capacity	5280 egg
Range of The temperature	5 - 50 °C
Hatching rate	≤ 96%

Precise temperature control	0 , ±1 °C
Operating voltage	AC220V-240V, 50Hz
Relative humidity	Less than 85%
Ambient temperature	10°C - 40°C
Electricity	800 Watt
Work forever	10 - 12 years



Figure 1. Incubation capacity of 5000 eggs

A mathematical model for incubators carbon foot print was developed to estimate CO<sub>2</sub> and NH<sub>4</sub> emission. The program written by C++ language including convert line. The modular structure of programm consists of a main programme and series of independent subroutine: each one deals with a specific parameter of the required data from image.

The computer programme has a wide range of applicability several values of size of the machine (NO. egg), Fertility (F), Heat production embryo (HPe), maximum CO<sub>2</sub> level (CO<sub>2</sub>)<sub>m</sub> , CO<sub>2</sub> level incoming air (CO<sub>2</sub>)<sub>i</sub> ,RQ value (RQ) to estimate Heat production (HP( , CO<sub>2</sub> production , Ventilation (V) , Ventilation of egg (Vegg)

### 3.1 Input Data

Enter size of the machine, Fertility (F), Heat production embryo (HPe), maximum CO<sub>2</sub> level (CO<sub>2</sub>)<sub>m</sub> , CO<sub>2</sub> level incoming air (CO<sub>2</sub>)<sub>i</sub> ,RQ value (RQ)

### 3.2 Calculate Data

HP (kj/hr)=HPe (watt) × (F (%))/100 × (3600/1000) × size of the machine (egg)

CO<sub>2</sub>/O<sub>2</sub> production (lit/kj) = 16.2 / (RQ Value) + 5

CO<sub>2</sub> production (lit/hr/mach) = (HP (kj/hr))/(CO<sub>2</sub>/O<sub>2</sub> production (lit/kj))

V (m<sup>3</sup>/hr)=( CO<sub>2</sub> production ×1000 )/((CO<sub>2</sub>)<sub>m</sub> - (CO<sub>2</sub>)<sub>i</sub> )

Vegg (m<sup>3</sup>/hr)=([ size of the machine (egg) × (F / 100) × (3600 / 1000) × HP (W/egg )] / (CO<sub>2</sub> / O<sub>2</sub> production ) (lit/kj)) / ((CO<sub>2</sub>)<sub>m</sub> - (CO<sub>2</sub>)<sub>i</sub> ) ×1000

### 3.3 Output Data

Heat production (HP(, CO<sub>2</sub> / O<sub>2</sub> production , CO<sub>2</sub> production , Ventilation (V) , Ventilation of egg (Vegg).

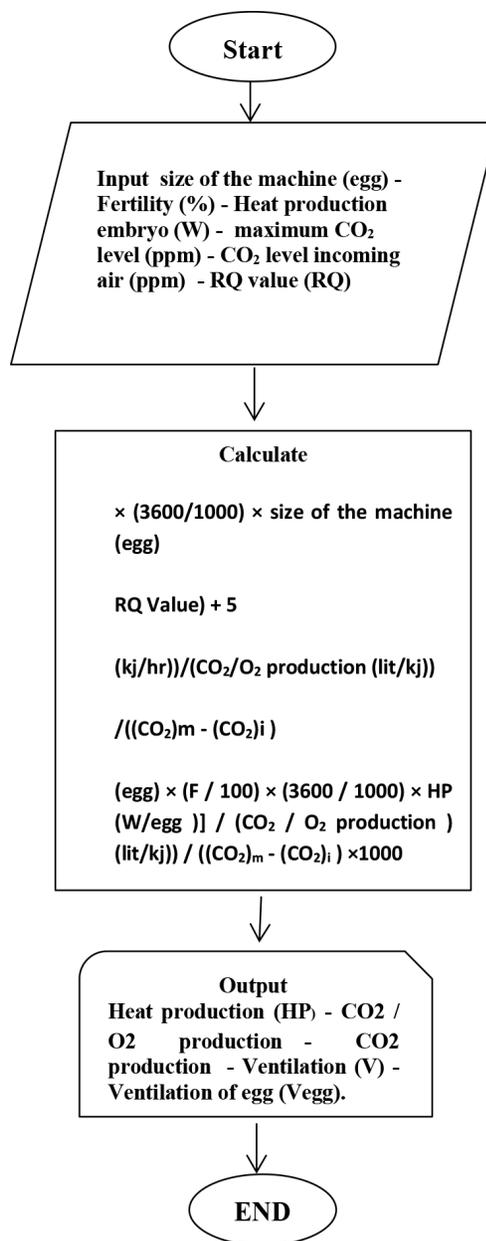


Figure 1. showing the inputs and outputs

## 4. Results and Discussion

### 4.1 The Effect of the Change in Egg Growth in Days on the Amount of Heat Produced

As the growth period passed from the first day of the twenty first day, the amount of heat produced increased linearly from 0.0001 to 0.35 W/egg (Fig. 2). A linear relationship was obtained between the the growth period and the amount of heat produced.

$$y = 0.0136x - 0.0666 \quad R^2 = 0.8077$$

#### 4.2 The Effect of the Change in Egg Growth in Days on the Ventilation

As the growth period passed from the first day of the twenty first day, the Ventilation increased linearly from 0 to 352 m3/hr (Fig. 3). A linear relationship was obtained between the the growth period and the Ventilation.

$$y = 6.8196x - 33.473 \quad R^2 = 0.8077$$

#### 4.3 The Effect of the Change in Egg Growth in Days on the Amount of CO<sub>2</sub> Produced

As the growth period passed from the first day of the twenty first day, the amount of CO<sub>2</sub> produced increased linearly from 0.0000158 to 0.04318 Lit/hr/mach (Fig. 4). A linear relationship was obtained between the the growth period and the amount of CO<sub>2</sub> produced.

$$y = 0.0017x - 0.0082 \quad R^2 = 0.8077$$

#### 4.4 The Effect of the Change in the Number of Eggs on the Amount of Heat Produced

The number of eggs linearly increased from 5,000 to 30,000 eggs with increased heat produced from 923.4 to 5540.4 KJ/hr (Fig. 5). A linear relationship was obtained between the number of eggs and the amount of heat produced

$$y = 0.1847x + 0.2 \quad R^2 = 1$$

#### 4.5 The Effect of the Change in the Number of Eggs on the Amount of CO<sub>2</sub> Produced

The number of eggs linearly increased from 5,000 to 30,000 eggs with increased CO<sub>2</sub> produced from 32 to 190 Lit/hr/mach (Fig. 6). A linear relationship was obtained between the number of eggs and the amount of CO<sub>2</sub> produced

$$y = 0.0063x + 0.1333 \quad R^2 = 1$$

#### 4.6 The Effect of the Change in the Number of Eggs on the Ventilation

The number of eggs linearly increased from 5,000 to 30,000 eggs with increased Ventilation from 9 to 54 m3/hr (Fig. 7). A linear relationship was obtained between the number of eggs and the Ventilation.

$$y = 0.0018x \quad R^2 = 1$$

### 5. Conclusions

As the growth period passed from the first day of the twenty-first day, the amount of heat produced increased from 0.0001 to 0.35 w / egg , and ventilation from 0 to 352 m3 / hr as well as the amount of carbon dioxide produced from 0.0000158 to 0.04318 lit/hr/mach . As the number of eggs increased from 5,000 to 30,000 eggs, each of the heat produced increased from 923.4 to 5540.4 kg / hr , the resulting carbon dioxide from 32 to 190 lit / hr / mach , and ventilation from 9 to 54 m3/hr

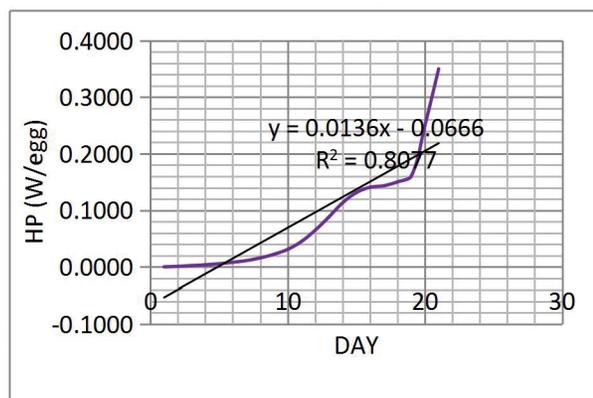


Figure 2. Relationship between day and Heat production

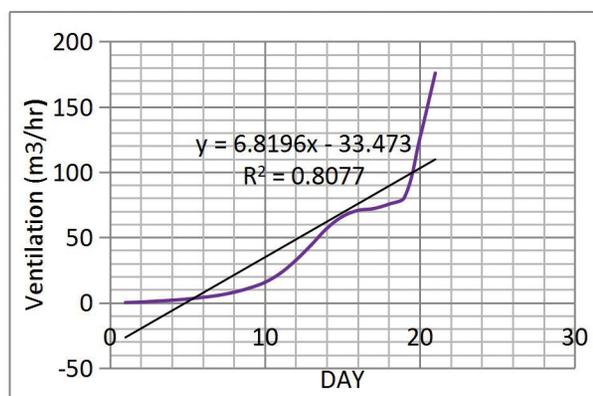


Figure 3. Relationship between day and ventilation

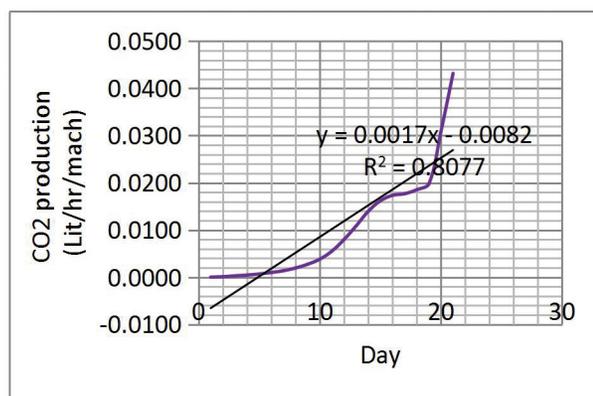
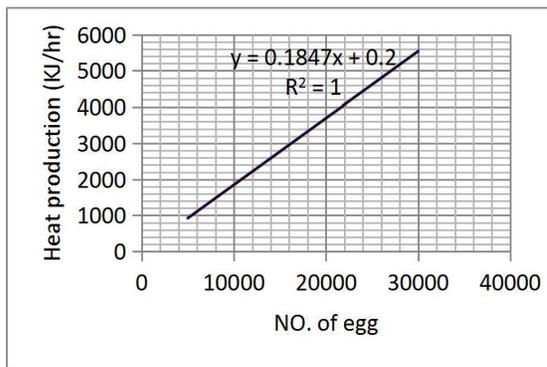
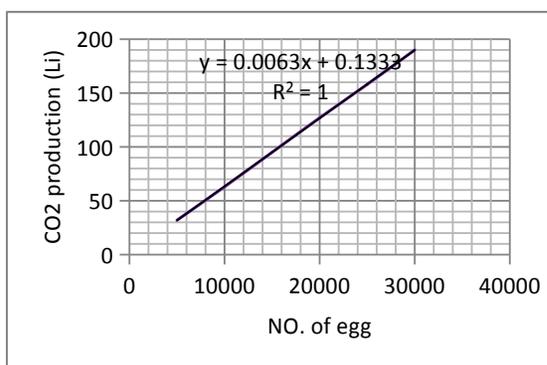


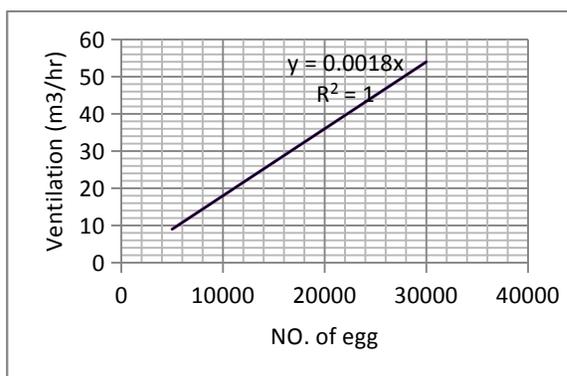
Figure 4. Relationship between day and CO<sub>2</sub> production



**Figure 5.** Relationship between number of eggs and Heat production



**Figure 6.** Relationship between number of eggs and CO<sub>2</sub> production



**Figure 7.** Relationship between number of eggs and ventilation

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