Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 4, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CARBON FOOTPRINT ESTIMATION IN POULTRY PRODUCTION FARMS

Tarek FOUDA[1], Ahmed AWNY[2], Mohamed DARWISH[1], Nourhan KASSAB[1], Mohamed GHONAME[1]

[1]Agriculture Engineering Department, Faculty of Agriculture, Tanta University, Egypt. Emails: tfouda628@gmail.com, rmdarwish@yahoo.com, nour_kassab2308@gmail.com, mohamed.ghonaim@agr.tanta.edu.eg
[2]Central Laboratory for Agricultural Climate, 6 El-nour Street, Dokki, 12411 Giza, Egypt. Email: awny_a@yahoo.com

Corresponding author: tfouda628@gmail.com tfouda@agr.tanta.edu.eg

Abstract

The aim of the experiments was determine the amount of greenhouse gases emitted (nitrous oxide ,ethane and carbon dioxide equivalent) resulting from poultry farms and the effect of these gases on energy productivity of poultry, as well as determining carbon footprint of laying hens production farms to reduce the negative effects of greenhouse gases emissions. In addition to providing necessary information on the performance of laying hens and providing guidance to poultry farmers on the relative merits of different climatic conditions to help set standards for different production traits. The experiments were conducted in one of the farms in the city of Mansoura during the period from June to October 2021 and the capacity of the farm was 40,000 laying hens. The results showed that the amount of methane gas produced from the farm was 0.4 ton CH_4 yr^{-1} and nitrous oxide gas was 0.677 ton N_2O yr^{-1} for manure management. Thus, the total emissions of manure management are estimated at 50.365 tons of CO_2-eq. The amount of greenhouse gas emissions for diesel is 434.59 tons of CO_2-eq. The amount of greenhouse gas emissions (GHG) for the electricity used in the farm is 8 tons of CO_2-eq. In the end, the total amount of emissions produced from the farm is 492.96 tons of CO_2-eq.

Key words: *laying hens, carbon footprint, egg production, methane, nitrous oxide, carbon dioxide equivalent*

INTRODUCTION

In Egypt the poultry industry is one of most important agricultural industries. The labor force consists of approximately 3.5 million permanent workers and approximately two million temporary workers. with an estimated investment of 90 billion LE. The industry provides a significant portion of the country's animal protein supply (white meats and eggs). Local meat production averaged 1,454.856 kt in 2019, while egg production averaged 617.521 kt in the same period. According to (FAO, 2019) [4].

Daghir (2008) said that during the final two decades of the twentieth century, the Middle East experienced significant expansion in the poultry business. Huge expenditures have been made in the construction of environmentally controlled chicken houses with evaporative cooling systems. Over 22 billion table eggs are produced annually in the Arab world, accounting for more than 2.5 percent of total world output (the top producers being Morocco, Algeria, Egypt, and Syria) [2].

Thornton *et al*. (2019) said that greenhouse gases emitted into the atmosphere by human activities and other sources are the primary driver of climate change. Livestock production is a substantial source of air pollution, particularly carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (NO_x) [10].

Mesarović (2019) stated that that many natural phenomenon influence the temperature of the globe to change and the scientists discovered that the Earth's climate is constantly changing because various natural phenomena such as changes in biotic processes, the Earth's orbit, variations in solar radiation received by the Earth, oceanic, volcanic eruptions and orogenic changes caused by plate tectonics, and the nature of the Earth. Furthermore, human activities have been identified as the major drivers of continuous climate change, often known as global warming [7].

Du Toit *et al*. (2013) said that in comparison to ruminant N_2O emissions, the non-ruminant sector contributes only a small amount to N_2O emissions. The poultry industry is the largest direct N_2O generator in the non-ruminant animal industry, accounting for 92.8 percent of total non-ruminant N_2O emissions [3].

Pratt *et al*. (2014) said that N_2O emissions come from a variety of sources, both direct and indirect, in poultry and pig farms. These include fertilizer storage, urine, and barn flooring surface deposition, and it was discovered that the maximum concentrations of nitrous oxide per 1 kg of LBW were 30% higher in the broiler chicken building than in the pig fattening [8].

Walker *et al*. (2014) showed that a direct link between NH3 emissions and interior temperature. Also identified indoor temperature as the primary variable influencing NH_3 emissions, other factors such as ventilation rate and bird activity may also have an impact on those emissions [11].

Fouda and Kassab (2020) concluded that the amount of heat produced increased from 0.0001 to 0.35 w/egg, and ventilation from 0 to 352 m^3/hr. as the growth period passed from the first day of the twenty-first day, also the amount of carbon dioxide produced from 0.0000158 to 0.04318 lit/hr/mach. With the number of eggs increased from 5,000 to 30,000 eggs, the heat produced increased from 923.4 to 5,540.4 kg/ hr., and carbon dioxide increased from 32 to 190 lit/hr/mach and ventilation from 9 to 54 m^3/hr [5].

Kenny *et al*. (2009) explained that a carbon footprint is a measurement of a person's contribution to global warming in terms of greenhouse gas emissions, and it is expressed in units of carbon dioxide equivalent. It is made up of the total of two parts, The direct or primary footprint is a measurement of our direct carbon dioxide (CO_2) equivalent emissions from the burning of fossil fuels, which includes home energy use, transportation (e.g., automobile and aircraft), and other activities. The indirect or secondary footprint is a measure of the indirect carbon dioxide (CO_2) equivalent emissions from the whole life cycle of the products and services we use, including those associated with their manufacture and final decomposition [6].

Brander (2012) explained that "carbon dioxide equivalent" or "CO_2-eq" is a word used to characterize the different greenhouse gases in a single unit. CO_2-eq is the quantity of CO_2 that will have an equal greenhouse effect for any amount and kind of greenhouse gas. By multiplying the amount of greenhouse gases by the global warming potential, the amount of greenhouse gases may be represented as CO_2-eq. For example, if 1 kilogram of methane is released, it is equivalent to 25 kg of carbon dioxide (1 kg CH_4 * 25 = 25 kg CO_2 equivalent). "CO_2-eq" is a highly useful term for several reasons: it allows "package" of greenhouse gases to be stated as a single quantity; it allows for simple comparison of various packages of greenhouse gases (in terms of the overall effect of global warming) [1].

According to (IPCC) (2006), the carbon dioxide equivalent of a substance is calculated over a set time period and must be provided whenever a global warming potential (GWP) is mentioned. It is anticipated that it will contribute to global warming. For example, the GWP of nitrous oxide over a 100-year period is 298. This indicates that the emission of 1 million ton N_2O is equivalent to the emission of 298 million tons CO_2-eq over a 100-year period. Methane has a global warming value of 25 over 100 years [9].

The research problem was an increase in concentrations of CO_2 and NH_3 inside laying hens housing. Carbon emissions have a negative impact on growth rates in chickens due to increased mortality rates, resulting in lower egg production rates. The study's goal was to evaluate the nitrous oxide, methane, and carbon dioxide equivalents produced by laying hens over a one-year period, as well as the carbon footprint of poultry production.

MATERIALS AND METHODS

The experiment was conducted in a farm in Dakahlia Governorate, city of Mansoura, Egypt. during the month of *June* until *October 2021* A cup 500 chicken was used, and the capacity of the farm was 40,000 laying hens. To estimate the carbon footprint and emissions of other greenhouse gases.

Work was carried out in farm with a closed system for the production of eggs. consists of 6 floors, each floor has two houses without side dimensions (25 m wide x 150 m long), the dimensions of the house (55 m x 12.5 m x 3 m) with a nominal capacity of 4,000 chickens in the production period, the house system is dark for breeding. The drinking system was used on three per line, containing 17 pieces, the length of the piece is 3 meters, and each piece has 12 nipples, one of which is sufficient for 10 birds. And the heating system on an air-driven heater consists of (stainless steel furnace, counter flow heat exchanger, axial fan) and an electronic control box. And a ventilation system that contains 5 hoods, each with a length of 140 cm width of 140 cm width, circulating air for 44,000 m^3/h with 6 brushes. Made of stainless steel, 3-phase electrically operated, evaporative cooling system was used, and the feeding system is a closed floor chain feeding system.

A set of mathematical equations was used to calculate the amount of emissions generated from poultry farms such as methane gas, nitrous oxide, carbon dioxide and carbon dioxide equivalent, as presented below.

-CH4 emissions from manure management:

$$\mathbf{CH_{4_{manure}}} = \sum_{(\mathbf{T})} \frac{(\mathbf{EF_{(T)}} * \mathbf{N_{(T)}})}{\mathbf{10^6}}$$

where:

$CH_{4Manure}$ = Measured in (Gg CH_4 yr^{-1}), it is CH_4 emissions for a layers.

$N_{(T)}$ = number of hens.

$EF_{(T)}$ = Measured in (kg CH_4 $head^{-1}$ yr^{-1}), it is emission factor for layers.

-Annual N excretion rates:

$$\mathrm{Nex}_{(\mathrm{T})} = N_{\mathrm{rate(T)}} * \frac{TAM}{1{,}000} * 365$$

where:

$Nex_{(T)}$ = Measured in (kg N hen^{-1} yr^{-1}), It is annual N secretion for layers.

$N_{rate\ (T)}$ = Measured in (kg N (1,000 kg hen $mass)^{-1}$ day^{-1}), It is default N secretion rate.

$TAM_{(T)}$ = Measured in (kg $animal^{-1}$), It is standard layers mass.

-Emissions of direct N_2O from manure management:

$$\boldsymbol{N_2O_{D(mm)}} = \left[\sum_{S}\left[\sum_{T}\left(\boldsymbol{N_{(T)}} * \boldsymbol{Nex_{(T)}} * \boldsymbol{MS_{(T,S)}}\right)\right] * \boldsymbol{ES_{3(S)}}\right] * \frac{\mathbf{44}}{\mathbf{28}}$$

where:

$N_2O_{D\ (mm)}$ = Measured in (kg N_2O yr^{-1}), It is direct N_2O emissions from hen.

$Nex_{(T)}$ = Measured in (kg N $animal^{-1}$ yr^{-1}), it is annual average N secretion per hen.

$EF_{3(S)}$ = Measured in (kg N_2O-N/kg N), it is emission factor for direct N_2O emissions.

$MS_{(T,S)}$ = Measured in (dimensionless), it is part of total annual nitrogen secretion for layers.

$N_{(T)}$ = number of hens

S = with litter

44/28 = diversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $(N_2O)_{(mm)}$ emissions.

-N Losses because volatilization from manure management:

$$\mathbf{N_{volatilization-MMS}} = \sum_{S}\left[\sum_{T}\left[(\mathbf{N_{(T)}} * \mathbf{Nex_{(T)}} * \mathbf{MS_{(T,S)}}) * \left(\frac{\mathbf{Frac_{GasMS}}}{\mathbf{100}}\right)_{(T,S)}\right]\right]$$

where:

$N_{volatilization\text{-}MMS}$ = Measured in (kg N yr^{-1}), it is amount of manure nitrogen that lost because Volatilization of NH_3 and NO_x.

$N_{(T)}$ = number of hens.

MS (T,S) = Measured in (dimensionless), it is part of total annual nitrogen secretion for layers.

$Nex_{(T)}$= Measured in (kg N hen^{-1} yr^{-1}), it is annual average N secretion per hen.

$Frac_{GasMS}$ = percent of manure nitrogen for hens that volatilises as NH_3 and NO_x.

-Indirect N_2O emissions because volatilisation of N from manure management:

$$N_2O_{G(mm)} = (N_{volatilization-MMS} * EF_4) * \frac{44}{28}$$

where:
$N_2O_{G\ (mm)}$ = Measured in (kg N_2O yr^{-1}), it is indirect N_2O emissions because volatilization of hen.
EF_4 = Measured in (kg NH_3-N + NO_x-N volatilized)$^{-1}$, it is emission factor for N_2O emissions.

-Carbon dioxide equivalent (CO_2e):

$$\text{Kg } CO_2e = \text{Kg } CH_4 * 25 + \text{Kg } N_2O * 298 + \text{Kg } CO_2$$

-GHG emissions from generator:

$$E = \frac{Q \times EC \times EF}{1{,}000}$$

Where:
E = Measured in (ton CO_2-eq), it is the total emissions released.
EC = Measured in (G/kl), it is the energy content factor of the fuel
Q = Measured in (kl), it is the quantity of fuel combustion.
EF = Measured in (kg CO_2-eq / GJ), it is emission factor for the fuel.

-GHG emissions from purchased main electricity grid:

$$E = \frac{Q \times EF}{1{,}000}$$

where:
E = Measured in (ton CO_2-eq), it is the scope 2 emissions measured.
EF = Measured in (0.72 kg CO_2-eq / kW. hr), it is the emission factor for the electricity in the farm.
Q = Measured in (kW. hr), it is quantity of electricity purchased from the electricity grid.

RESULTS AND DISCUSSIONS

Emissions of CH_4 for layers from manure management by (ton CH_4 yr^{-1})

Figure 1 depicts Emissions of CH_4 were calculated for laying hens, it was estimated at 0.1 ton of methane per year for 10,000 chickens, which is less than the standard value of methane gas, which is equal to 0.2 ton of methane per year while the emissions per year for 100,000 chickens were equal to 1 ton CH_4 yr^{-1} and thus the amount of methane emitted from the farm is equal to 0.4066 ton of methane per year.

Emissions of CH_4 for layers from manure management by (ton CO_2-eq)

Figure 2 depicts Emissions of CH_4 for laying hens, for 10,000 chickens, it was estimated at 2.5 ton CO_2-eq.

N Losses because volatilization from manure management

Figure 3 depicts the amount of nitrogen that lost was calculated for laying hens and it was estimated at 8.619 ton nitrogen per year for 10,000 chickens. Thus, the amount of nitrous emitted from the farm equals 34.479 ton nitrogen per year.

Direct N_2O emissions for hen from manure management by (ton N_2O yr^{-1})

Figure 4 depicts the direct nitrous oxide emissions were calculated for laying hens, for 10,000 chickens it was estimated 0.033 ton N_2O yr^{-1} chickens, while for 100,000 chickens the emissions were equal to 0.0338 ton N_2O yr^{-1}. Thus, the amount of source nitrous oxide emitted from the farm equals 0.137 ton N_2O yr^{-1}

Direct N_2O emissions for hen from manure management by (ton CO_2-eq)

Figure 5 depicts the direct nitrous oxide emissions; it was estimated at 10.09 ton CO_2-eq 10,000 chickens, while the emissions per year for 100,000 chickens were equal to 100.91 ton CO_2-eq. Thus, the amount of source nitrous oxide emitted from the farm equals 40.98 ton of nitrous oxide per year.

Indirect N_2O emissions due to volatilisation of N for hen by (ton N_2O yr^{-1})

Figure 6 depicts the indirect nitrous oxide emissions were calculated because nitrogen volatilization from manure management for laying hens, it was estimated at 0.136 ton N_2O yr^{-1} for 10,000 chickens, while the emissions per year for 100,000 chickens were equal to 1.35 ton N_2O yr^{-1}. Thus, the amount of indirect nitrous oxide emitted from the farm equals 0.554 ton of nitrous oxide per year.

Indirect N_2O emissions due to volatilisation of N for hen by (ton CO_2-eq)

Figure 7 depicts the indirect nitrous oxide emissions due to nitrogen volatilization from manure management for laying hens, it was estimated at 40.36 ton CO_2-eq 10,000 chickens While the emissions per year for 100,000 chickens were equal to 403.65 ton CO_2-eq. Thus, the amount of indirect nitrous oxide emitted from the farm equals 2.62 ton CO_2-eq

Fuel emissions from laying hens farms

Figure 8 shows the emissions of diesel use from the use of heating heaters and generators from the farm and was calculated for laying hens and was estimated at 108.64 ton CO_2-eq for 10,000 chickens. Thus, the amount of diesel emissions from the farm is equal to 434.59 ton CO_2-eq.

Emissions from electricity from laying hens farms

Figure 9 shows the emissions of electricity use from the farm and was calculated for laying hens and was estimated at 2 ton CO_2-eq for 10,000 chickens. Thus, the amount of electricity emissions from the farm is equal to 8 ton CO_2-eq.

Total CO_2-eq Emissions from Poultry Farms

Figure 10 depicts Total CO_2-eq emissions were calculated from poultry farms, it was estimated at 123.23 ton CO_2-eq for 10,000 chickens. Thus, the amount of CO_2-eq emitted from the farm equals 493.96 ton CO_2-eq.

The relationship between laying hens number and total CO_2-eq emissions can be expressed by regression equation as:

$$y = 0.164x - 0.0228 \quad R^2 = 1$$

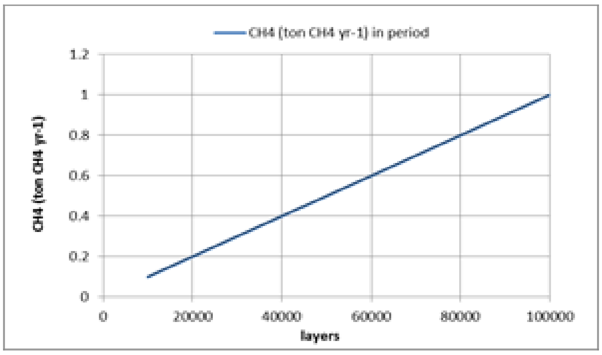

Fig. 1. Emissions of CH_4 for layers from manure management by (ton CH_4 yr^{-1}).
Source: Authors' determination.

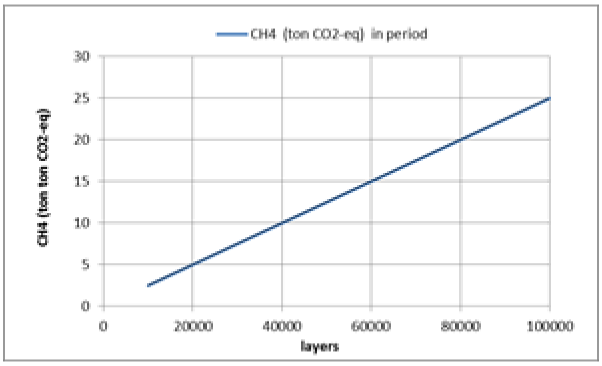

Fig. 2. Emissions of CH_4 for layers from manure management by (ton CO_2-eq).
Source: Authors' determination.

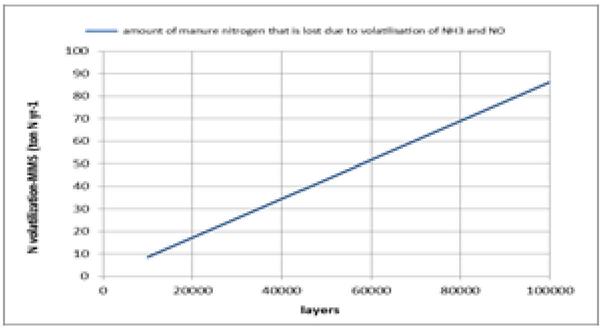

Fig. 3. N losses because volatilization for hen
Source: Authors' determination.

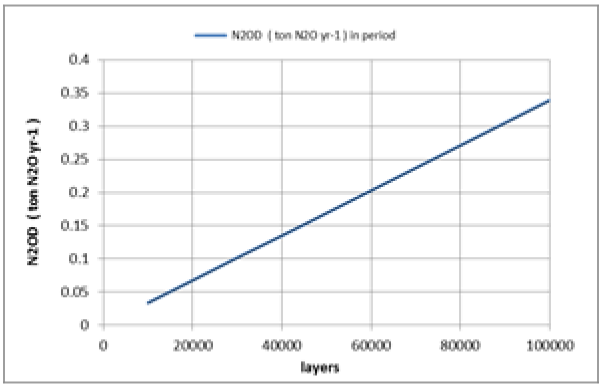

Fig. 4. Direct N_2O emissions for hen(ton N_2O yr^{-1}).
Source: Authors' determination.

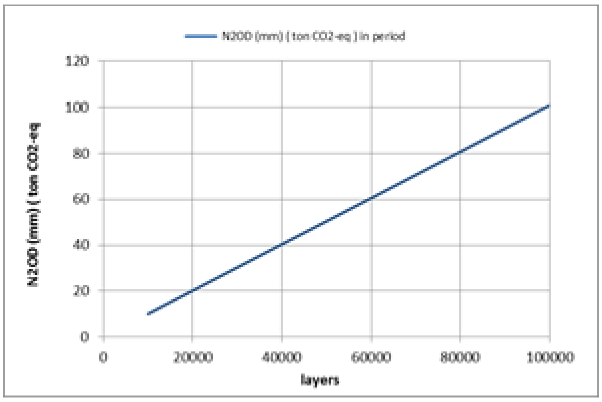

Fig. 5. Direct N_2O emissions for hen (ton CO_2-eq)
Source: Authors' determination.

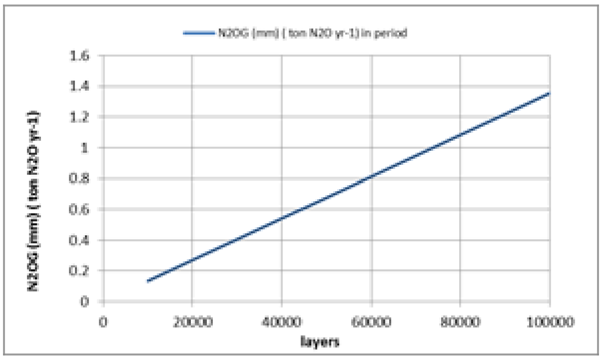

Fig. 6. Indirect N_2O emissions because volatilization of N for hen (ton N_2O yr^{-1}).
Source: Authors' determination.

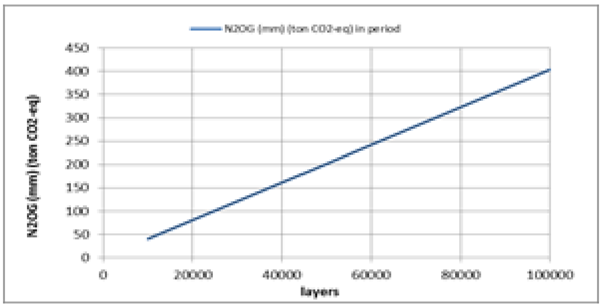

Fig. 7. Indirect N_2O emissions because volatilization of N for hen (ton CO_2-eq).
Source: Authors' determination.

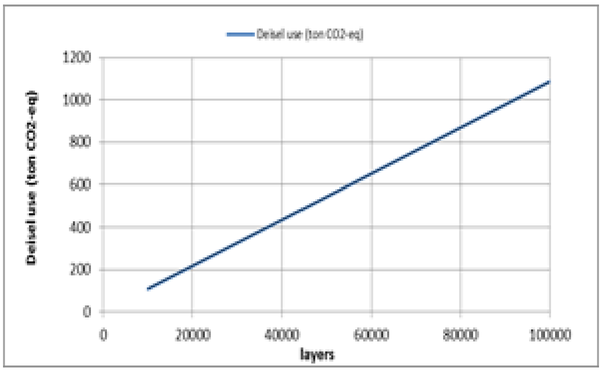

Fig. 8. Diesel use emissions for hen (ton CO_2-eq)
Source: Authors' determination.

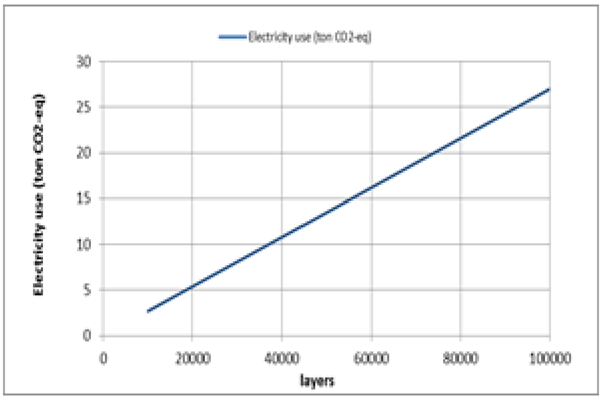

Fig. 9. Electricity use emissions for number of laying hens
Source: Authors' determination.

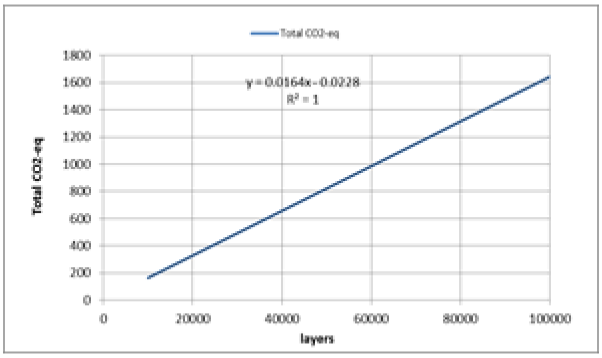

Fig. 10. Total CO_2-eq Emissions (ton CO_2-eq) for layers
Source: Authors' determination.

CONCLUSIONS

The amount of methane gas produced from the farm was 0.4 ton CH_4 yr^{-1} and nitrous oxide gas was 0.677 ton N_2O yr^{-1} for manure management. Thus, the total emissions of manure management are estimated at 50.365 tons of CO_2-eq. The amount of greenhouse gas emissions for diesel is 434.59 tons of CO_2-eq. The amount of greenhouse gas emissions for the electricity used in the farm is 8 tons of CO_2-eq. In the end, the total amount of emissions produced from the farm is 492.96 tons of CO_2-eq.

REFERENCES

[1]Brander, M., 2012, Greenhouse Gases, CO2, CO2e, and Carbon: What Do All These Terms Mean?. Ecometrica, pp.1-3, https://ecometrica.com/assets/GHGs-CO2-CO2e-and-Carbon-What-Do-These-Mean-v2.1.pdf, Accessed on 19/10/2021.
[2]Daghir, N.J., 2008, Poultry production in hot climates. 6th Edition, pp.1-12. Cromwell Press, Trowbridge, UK. Accessed on 19/10/2021.
[3]Du Toit, C.J.L., Meissner, H.H., Van Niekerk, W.A., 2013, Direct methane and nitrous oxide emissions of monogastric livestock in South Africa. South African Journal of Animal Science 43, 362. DOI: 10.4314/sajas.v43i3.9, Accessed on 19/10/2021.
[4]FAO, 2019, FAO Statistics Division, Poultry protubeion. http//faostat.fao.org./Site/569, Accessed on 19/10/2021.
[5]Fouda, T.Z., Kassab, N., 2020, Mathematical Model to Estimate Carbon Footprint for EEG Incubation. Journal of Zoological Research, Vol.02 (03), July 2020. https://ojs.bilpublishing.com/index.php/jzr/article/view/2109, Accessed on 19/10/2021.
[6]Kenny, T., Gray, N.F., 2009, Comparative performance of six carbon footprint for use in Ireland.

Environmental Impact Assessment Review, Vol. 29(1): 1-6.https://doi.org/10.1016/j.eiar.2008.06.001, Accessed on 19/10/2021.

[7]Mesarović, M. M., 2019, Global warming and other climate change phenomena on the geological time scale. Thermal Science, Vol. 23, Suppl. 5, 1435-1455, https://doi.org/10.2298/TSCI190208320M, Accessed on 19/10/2021.

[8]Pratt, C., Hill, J., Redding, M., Shilton, A., Chung, M., Guieysse, B., 2014, Good science for improving policy: greenhouse gas emissions from agricultural manures. Animal Production Science 55(6):691-701, https://doi.org/10.1071/AN13504, Accessed on 19/10/2021.

[9]The intergovernmental Panel on Climate Change (IPCC), 2006, Task Force on National Greenhouse Gas Inventories (TFI), Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.). 2006, IPCC Guidelines for National Greenhouse Gas Inventories. Japan: Institute for Global Environmental Strategies. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm, Accessed on 19/10/2021.

[10]Thornton, P. K., Notenbaert, A., Van de Steeg, J., Herrero, M., 2009, The impacts of climate change on livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems. Vol. 101, pp. 113-127. http://dx.doi.org/10.1016/j.agsy.2009.05.002. Accessed on 19/10/2021.

[11]Walker, J.T., Austin, R., Robarge, W.P., 2014, Modeling of ammonia dry deposition to a pocosin landscape downwind of a large poultry facility. Agriculture, Ecosystems and Environment, 185. 161–175.https://doi.org/10.1016/j.agee.2013.10.029, Accessed on 19/10/2021.