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ESTIMATING GREENHOUSE GAS EMISSIONS FROM BROILER CHICKEN PRODUCTION SYSTEMS USING LIFE CYCLE ASSESSMENT

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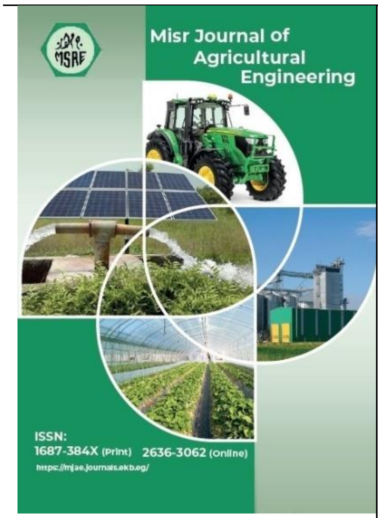

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Keywords:
Broiler chicken;
Carbon footprint;
Life cycle assessment;
Greenhouse gas;
Environmental impact.

ABSTRACT

Greenhouse gas emissions are one of the major environmental challenges facing broiler chicken production. Environmental impacts of different broiler chicken production systems, open floor (scenario A) vs. closed cage (scenario B), during summer and winter seasons through a cradle to farm-gate perspective, were evaluated using life cycle assessment approach. The main components of impacts as well as activities data, including mechanical emissions of energy use and non-mechanical emissions, were identified. Both scenarios were evaluated by calculating the inputs and outputs through the system boundary for assessing the level of greenhouse gas emissions (CO_2, CH_4, and N_2O) emitted from these production scenarios and clarify the link between productive performance and environmental impacts. According to results, scenario B had higher values of final body weight (FBW) by 4.55 and 3.95% and an improvement in feed conversion ratio by 7.27 and 6.17%. In addition, electricity usage in scenario B led to an increase in GHG mechanical emissions by 15.38 and 16.67% compared to scenario A for summer and winter seasons, respectively. For non-mechanical emissions, feed made the largest contribution to global warming potential impact category. Feed in scenario A increased emissions by 2.84 and 2.81% compared to scenario B for summer and winter seasons, respectively. Overall emissions obtained from scenario A were generally higher than scenario B during both seasons. In conclusion, the closed cage-raised broilers performance is better than floor-system, which contributed to reducing greenhouse gases emitted and achieving enhanced productive and eco-friendly performance.

INTRODUCTION

Humans are the main cause of environmental degradation on Earth. They have cumulatively triggered massive events like ozone layer depletion, global warming, climate change, and pollution **(Meena *et al.*, 2018)**. Climate change is a very severe problem and a difficult mission in the 21st century and most of the developing countries are affected by this grave problem **(Banerjee *et al.*, 2021)**. Greenhouse gases (GHGs) are atmospheric gases responsible for causing climate change and global warming. The main

GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The effect of greenhouse is caused by the sun's energy interaction with the GHGs in Earth's atmosphere **(Kweku *et al.*, 2018)**. They also added that increasing livestock emissions, in addition to expanded energy consumption are among the main reasons for the increase in the rate of GHG emissions. Infrared radiation is absorbed by GHGs, trapping heat in the atmosphere, thus preventing it from escaping into outer space **(Stępniewska and Kuźniar, 2013)**. Sustainable Development Goals (SDGs) interventions focus on air pollutants managing including life cycle methods and GHGs can reduce pollution **(Wiedmann *et al.*, 2015)**.

The United Nations Climate Change Conference COP 27 held in Sharm El-Sheikh, Egypt, resulted in countries promoting a set of resolutions to reduce GHG emissions and adapt to climate change's inevitable effects **(UNFCCC, 2022)**. The GHGs total amount emitted from operations in the agricultural sector is considered to be the carbon footprint of agriculture **(Jaiswal and Agrawal, 2020)**. The livestock sector emits GHGs mainly by transportation, manure use, feed production, and enteric fermentation. Globally, livestock participated about 66% of total agricultural GHG emissions **(Tubiello *et al.*, 2014)**, where feed production and transportation contribute 45%, while enteric fermentation contributes by 40% as the second largest share **(Gerber *et al.*, 2013)**.

To effectively reduce GHG emissions from livestock production, reduction goals have to consider both the production and consumption sides **(Weiss and Leip, 2012)**. Carbon footprint of a farm sums up the GHG emissions of the farm according to the farm's inputs and outputs. All major GHGs emitted are taken into account to estimate the carbon footprint in terms of CO_2 equivalent **(IPCC, 2014)**. Carbon footprint values depend on the year, allocation, type of management practices and farming system, location, in addition to study boundaries **(Desjardins *et al.*, 2012)**. The carbon footprint estimation methodology is based on Life Cycle Assessment (LCA) guidelines that measure GHGs. LCA is an internationally standardized tool for assessing the environmental impact of activities, processes, and products through their whole life cycle **(ISO 14040, 2006)**, via interpreting potential impact and evaluating by categories **(Lima *et al.*, 2019)**. LCA is based on the materials analysis and energy flows that characterize the studied production process and can identify tradeoffs between environmental impacts when different environmental effects are considered **(Bacenetti *et al.*, 2023)**.

Environmental performance indexes common in poultry sector are feed production and energy and water consumption **(González-García *et al.*, 2014)**. Manure management and feed delivery plus the use of energy for ventilation, lighting, heating, and feeding can leach nitrates and create GHG emissions **(Williams, Audsley and Sandars, 2010)**. Chicken production significantly impacts the environment, where these animals add to the environment large amounts of nitrogen **(Costantini *et al.*, 2021)**. Soybean meal was found to be the largest contributor to the environmental impact of feed due to transport, land transformation, and mineral fertilizer application **(Cesari *et al.*, 2017)**. A study by **Suffian *et al.* (2018)** showed that in modern broiler production, manure produces most emissions of CO_2, feed produces most emissions of CH_4, and bedding produces most emissions of N_2O. Controlling GHG emissions from broiler chicken production is essential for reducing the agriculture sector’s impact on global warming. Thus, using best rearing practices as well as improving broiler chicken production performance as mitigation strategies can reduce the contribution to greenhouse gas emissions.

In this regard, the major targets of this research are to assess the environmental impacts of different broiler chicken production systems (open floor system and closed cage system) during the summer and winter seasons through a cradle to farm-gate perspective using an assessment LCA approach, determine processes that have major contributions to GHG and energy used in broiler chicken production, and offer some effective options for mitigation strategies for reducing the environmental burden of broiler chicken production on the environment in order to achieve enhanced productive and eco-friendly performance.

MATERIALS AND METHODS

The study was conducted during 2022/2023 in private farms located at Burj Al Arab city, Alexandria Governorate, Egypt for evaluating the GHG emissions from different broiler chicken production systems. All animal care procedures were reviewed and approved by Institutional Animal Care and Use Committee in ZU-IACUC, Zagazig University, Egypt with the approval number ZU-IACUC/2/F/181/2023.

Life cycle assessment methodology

LCA is a technique to account for the environmental impacts of a product, process, or activity throughout its entire life cycle **(Müller *et al.*, 2020)**. There is a four-step framework standardized by the **(ISO 14040, 2006)** to perform an LCA that includes defining a goal and scope, inventory analysis, life cycle impact assessment, and interpretation to ensure completeness of the study.

Goal and scope definition

LCA methodology following the ISO 14040 guidelines **(ISO 14040, 2006)** was used in order to evaluate the environmental impacts throughout the life cycle of broiler chicken production through a cradle-to-gate perspective from the transportation of one-day-old chick to the broiler farm until the transportation of the manure with/without litter at the end of the rearing cycle. Since the productive performance, and consequently the environmental impacts of broiler chicken production systems depend on the quantity of meat produced and the feed conversion ratio, scenarios characterized by different housing broiler chicken rearing production systems during summer (March to August) and winter (September to February) seasons were investigated as follow:

Scenario A: Open floor system of broiler chicken production.
Scenario B: Closed cage system of broiler chicken production.

Systems description

Due to the high variability of parameters that characterized broiler chicken production and the accurately relationship between productive performance (final body weight, FBW; feed consumption, FC; feed conversion ratio, FCR; mortality rate, MR; livability percentage, LP) and rearing factors (rearing system, stocking density, and production cycle), average data of productive parameters and different scenarios were investigated for explaining the link between productive performance and environmental impact.

One-day-old chicks (*Cobb 500*) with 41.5 g weight were transported from the hatchery lab to the broiler farm and after 5 weeks they reached a live weight of about 2.30 kg, then were delivered to the mechanized slaughterhouse. In this study, the conducted processes in the slaughterhouse were not considered. The broiler chickens were housed in two different housing rearing systems: open floor system and closed cage system. Concerning open floor rearing system (Scenario A), chicks were reared on concrete floor area covered with uniformly distributed bedding of wood shavings to a depth of 5 and 8 cm during summer and winter seasons, respectively. The system dimensions are 160 x 12 x 2.8 m divided into two sections (80 x 12 x 2.8 m), has a service room in the middle (4.0 x 3.0 x 2.8 m) and use a propane gas as a heating source for supplying the heat needed for brooding period, in an open ventilated system. Birds are housed at a stocking density of 10 birds/m^2 during the summer and 11 birds/m^2 during the winter.

Relating to closed cage rearing system (Scenario B), chicks were reared in the system dimensions 47 x 12 x 2.8 m with seven longitudinal batteries; each battery consists of four floors (lower, central 1, central 2, and upper). The dimensions of cage were 140 x 15 x 220 cm. Cooling pads with length of 12.5 m each are located at the front of the house on both sides of the walls (left and right). Six exhaust fans divided into two similar groups (three exhaust fans) on two floors are placed at the back of the house. The main parameters corresponding to different scenarios of broiler chicken production under assessment during summer and winter seasons are shown in Table 1.

Birds in both systems were allowed free access to fresh water and feed of starter (1 to 21 d) and finisher (22 to 35 d) rations which were given to satisfy the strain requirements stated in the broiler management guide of *Cobb 500*. All birds were drinking fresh water and fed the same commercial rations which offered *ad libitum*.

Table 1: Characteristics of different broiler chicken production scenarios under assessment during summer and winter seasons.

Item	Scenario A		Scenario B	
	Summer	Winter	Summer	Winter
Number broiler	19270	21000	21260	21260
Production cycle, d	35	34	32	32
Stocking density, birds/m^2	10.04	10.94	42.18	42.18
BW at day one, g	40.70	42.00	40.50	42.10
Total broiler meat yield, ton	39.98	45.55	46.53	48.17
FC, kg/bird	3.62	3.70	3.52	3.60
Starter FC, kg/bird	1.30	1.05	1.02	0.96
Finisher FC, kg/bird	2.32	2.65	2.50	2.64
MR, %	5.70	6.90	4.00	4.40
Livability, %	94.30	93.10	96.00	95.60
Bedding, kg/bird	0.75	1.10	-	-

Adequate numbers of designated manual feeders and water drinkers for scenario A, while automatic feeders and nipple drinkers were provided for scenario B to ensure similar feeding and drinking space. Both housing systems received the same managerial condition. All birds remained under the same administrative, hygienic, and environmental conditions.

System boundary and functional unit

System boundary consists of all processes which contribute in life cycle of product. The boundary of the LCA was defined as from cradle-to-farmgate, consisting of all inputs to the broiler houses represented in the transportation of inputs (feeding material, one-day-old broiler chicks, and bedding materials) and in the transportation of outputs (marketing age of broiler chicken to the slaughterhouse and manure (with/without litter). Therefore, this study did not account for emissions attributed to the slaughter phase beyond the farm gate. Fig. 1 shows the schematic flow diagram of the life cycle of broiler chicken rearing systems and system boundary of this study. The quantified functional unit (FU) is the production of 2.30 kg of FBW at farm gate. FU is a key aspect when performing an LCA, as it is the unit to which the results are expressed and permits accurate comparison across studies **(Djekic *et al.*, 2018)**.

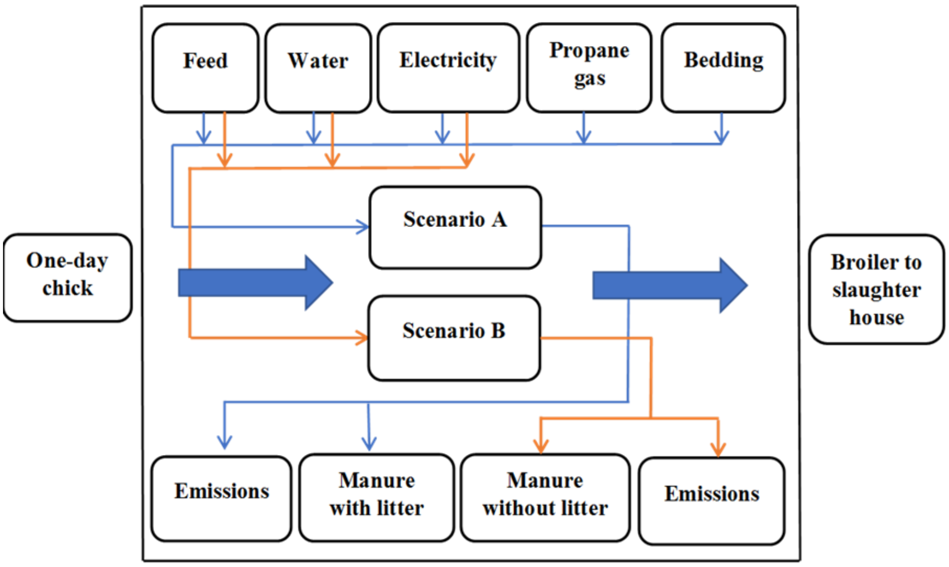

Fig. (1): The schematic flow diagram and system boundary of different broiler chicken production scenarios under assessment.

Life cycle inventory analysis

For evaluating the environmental impact, all inventory data including inputs (transportation, feed, water, electricity, propane gas, and bedding) and outputs (transportation, and manure with/without litter produced) related to different scenarios and seasons of broiler chicken production were identified and quantified by taking average measurements and readings throughout life cycle of broiler chicken for analyzing the results, as summarized in Table 2.

Various activities taking place during rearing period of broiler chicken, resulted in producing emissions which are divided into mechanical and non-mechanical emissions. The activity data included mechanical emissions (diesel fuel use for transportation in liter, electricity usage in kilowatts per hour, and propane gas use in gallons) and non-mechanical emissions (feed, water, bedding, and manure with/without litter). Emissions from electricity use are considered an indirect emission because the emissions do not occur on the farm, they do occur as a result of activities on the farm **(Dunkley *et al.*, 2015)**.

The values presented in Table 2 were recorded based on average consumption of the broilers per cycle. Transportation was taken into consideration along rearing period including transport of one day old chicks, feed, bedding, manure with/without litter, and broiler to slaughterhouse. Yellow corn, soybean meal, corn gluten, supplements of vitamins, minerals, and amino acids were used as variety ingredients in broiler chickens feed during a rearing cycle. Broiler chickens consumed an average of 3.60 kg feed according to the collected data from both scenarios. Wood shaving was used as bedding material in scenario A. For both scenarios, electricity was used in lighting and ventilation systems, moreover for scenario B electricity was used for machinery operation including automatic feeders and electric heaters. Propane gas fuel was used in the heating system of scenario A.

Table 2: Life cycle inventory data for different broiler chicken production scenarios during summer and winter seasons.

	Scenario A		Scenario B	
Inputs	**Summer**	**Winter**	**Summer**	**Winter**
Transportation, km/ton FBW				
Chicks one day old	4.13	3.70	3.52	3.43
Feed	13.01	12.72	12.02	11.90
Bedding	7.79	11.03	-	-
Feed, kg ingredient/ton FBW				
Starter feed	1225	990	961	905
Finisher feed	2180	2491	2350	2481
Water, Liter/ton FBW	4830	3940	3290	3140
Electricity, kWh/ton FBW	650	900	750	1050
Propane gas, kg/ton FBW	56.8	274.1	-	-
Bedding, kg/ton FBW	790	950	-	-
Outputs				
Transportation, km/ton FBW				
Litter	12.72	13.59	-	-
Manure	-	-	4.36	4.48
Broiler to slaughterhouse	24.35	15.23	23.29	14.65
Litter produced, kg/ton FBW	583.2	622.8	-	-
Manure produced, kg/ton FBW	-	-	200.0	205.1

Life cycle impact assessment

Life cycle impact assessment is considered as the most important phase in LCA guidelines, in which the environmental impact is assessed and calculated, based on the basis of inventory analysis results. In this phase, the inventory results are converted into impact categories. In the present study, Global Warming Potential (GWP) impact category has been considered. Climate change can be investigated by defining the greenhouse effect and calculate the emissions (CO_2, CH_4, and N_2O) to determine the GWP.

In order to investigate the climate change, emissions were computed based on its source and type. GHG emissions were evaluated using Environmental Protection Agency **(EPA, 2022)** worksheets as one of the methodologies for assessing the environmental impact of the activities occurring in the broiler chicken production systems **(Hill, Bramwell and Harris, 2017)**. Environmental impact assessment was also carried out using emission factors based on region, animal type, and manure (with/without litter) management system from Intergovernmental Panel on Climate Change guidelines of National Greenhouse Gas Inventories **(IPCC, 2006)** for livestock emissions. EPA worksheets were used for each source (diesel use, electricity use, propane use, feed, water, and bedding) of emissions. For manure (with/without litter) management, IPCC worksheets were used for tier 2 methodology. CH_4 as well as direct and indirect emissions of N_2O arising from manure management were estimated using tier 2 equations from **(IPCC, 2006)** as follows:

- CH_4 emissions from manure management:

$$CH_{4\,Manure} = \sum_{(T)} \frac{\left(EF_{(T)} * N_{(T)}\right)}{10^6} \tag{1}$$

Where:

$CH_{4\,Manure}$ = CH_4 emissions from manure management, Gg CH_4 yr^{-1}
$EF_{(T)}$ = emission factor, kg CH_4 $head^{-1}$ yr^{-1}
$N_{(T)}$ = the number of head of livestock species
T = species of livestock

- CH_4 emission factor from manure management:

$$EF_{(T)} = \left(VS_{(T)} * 365\right) * \left[B_{o\,(T)} * 0.67\,kg/m^3 * \sum_{S,K} \frac{MCF_{S,K}}{100} * MS_{(T,S,K)}\right] \tag{2}$$

Where:

$EF_{(T)}$ = annual CH_4 emission factor, kg CH_4 $animal^{-1}$ yr^{-1}

$VS_{(T)}$ = daily volatile solid excreted, kg dry matter $animal^{-1}$ day^{-1}

365 = basis for calculating annual VS production, days yr^{-1}

$B_{o\,(T)}$ = maximum methane producing capacity for manure produced by livestock species T, m^3 CH_4 kg^{-1} of VS excreted

0.67 = conversion factor of m^3 CH_4 to kilograms CH_4

$MCF_{(S,\,k)}$ = methane conversion factors for each manure management system S by climate region k, %

$MS_{(T,\,S,\,k)}$ = fraction of livestock category T's manure handled using manure management system S in climate region k, dimensionless

- Volatile solid excretion rates:

$$VS = \left[GE * \left(1 - \frac{DE\%}{100}\right) + (UE * GE)\right] * \left[\left(\frac{1 - ASH}{18.45}\right)\right] \tag{3}$$

Where:

VS = volatile solid excretion per day on a dry-organic matter basis, kg VS day^{-1}

GE = gross energy intake, MJ day^{-1}

DE% = digestibility of the feed in percent

(UE • GE) = urinary energy expressed as fraction of GE.

ASH = the ash content of manure calculated as a fraction of the dry matter feed intake

18.45 = conversion factor for dietary GE per kg of dry matter (MJ kg^{-1}). This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.

- Direct N_2O emissions from manure management:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} * Nex_{(T)} * MS_{(T,S)}\right)\right] * EF_{3(S)}\right] * \frac{44}{28} \qquad (4)$$

Where:

$N_2O_{D\ (mm)}$ = direct N_2O emissions from Manure Management, kg N_2O yr^{-1}

$Nex_{(T)}$ = annual average N excretion per head of species, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,\ S)}$ = fraction of total annual nitrogen excretion for each livestock species T that is managed in manure management system S, dimensionless

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system S, kg N_2O-N/kg N in manure management system S

S = manure management system

44/28 = conversion of (N_2O-N) (mm) emissions to N_2O (mm) emissions

- N losses due to volatilization from manure management:

$$N_{Volatilization-MMS} = \sum_S \left[\sum_T \left[\left(N_{(T)} * Nex_{(T)} * MS_{(T,S)}\right) * \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)}\right]\right] \qquad (5)$$

Where:

$N_{volatilization-MMS}$ = amount of manure nitrogen that is lost due to volatilization of NH_3 and NO_x, kg N yr^{-1}

$Frac_{GasMS}$ = percent of managed manure nitrogen for livestock species T that volatilizes as NH_3 and NO_x in the manure management system S, %

The conversion of the gases to carbon dioxide equivalent (CO_2 eq) is done using the global warming potential (GWP) of each gas, where GWP values for CO_2, CH_4, and N_2O are 1, 25 and 298 CO_2 eq/kg, respectively, assuming a 100-year time horizon as reported in the 4th Assessment Report (AR4) of the **(IPCC, 2007)**.

$$kgCO_2e = kgCH_4 \times 25 + kgN_2O \times 298 + kgCO_2 \qquad (6)$$

Life cycle interpretation

Life cycle interpretation is the final phase of the LCA procedure, in which the results of either the inventory analysis or the impact assessment, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

RESULTS AND DISCUSSIONS

Productive performance

The differences in growth performance of broiler chickens are affected by feed consumption, body weight, the amount of manure produced, and energy consumed. Results showed that scenario B had lower MR, greater FBW, and better FCR compared with scenario A due to the availability of good environmental conditions, that efficiently convert feed to meat, this is in accordance with **Rojano *et al.* (2015)** who reported that the closed house cage enhanced conditions to broiler chickens during the period of rearing. Broiler chickens of scenario A had a higher feed consumption (3.62 and 3.70 kg feed/ bird) compared to broiler chickens of scenario B (3.52 and 3.60 kg feed/ bird) for summer and winter seasons, respectively. A floor system's birds are in the habit of consuming more feed than in a cage system's birds to save energy for heat production **(Çavuşoğlu *et al.*, 2018)**. This is attributed to the wide space that have birds reared on the floor, that promote the normal physiological responses of the birds, which led to an increase in feed intake compared to the cage system **(Khan and Khan, 2018)**. Where birds raised in well-ventilated areas consumed more feed than those in fans ventilated areas, due to the availability of optimal temperature and fresh air compared to high temperatures in other house areas, which lead to lower feed consumption.

As shown in Table 2, the amount of litter produced from scenario A during summer (583.2 kg/ton BW) is lower than winter (622.8 kg/ton BW), as well as, the amount of manure produced from scenario B during summer (200 kg/ton BW) is less than winter (205.1 kg/ton BW). This is could be a result of the decrease of feed consumption for summer compared to winter, moreover for scenario A, the difference of bedding thickness during summer and winter has remarkable effect on the amount of litter produced, consequently on the quantity of emitted emissions. These results are in consonance with those presented by **Leinonen *et al.* (2012)**, that the amount of feed consumed affects the quantity of manure produced; Which in turn affects emissions from housing. As shown in Fig. 2, it was noted that performance between A and B rearing scenarios was Significantly different. Broiler chickens of scenario B had a higher weight and a better feed conversion ratio. Scenario B chickens weighted (2.3 and 2.37 kg) versus scenario A chickens (2.2 and 2.28 kg) for summer and winter, respectively. The performance of cage-raised broilers is better than that of floor system birds **(Thamilvanan *et al.*, 2001)**.

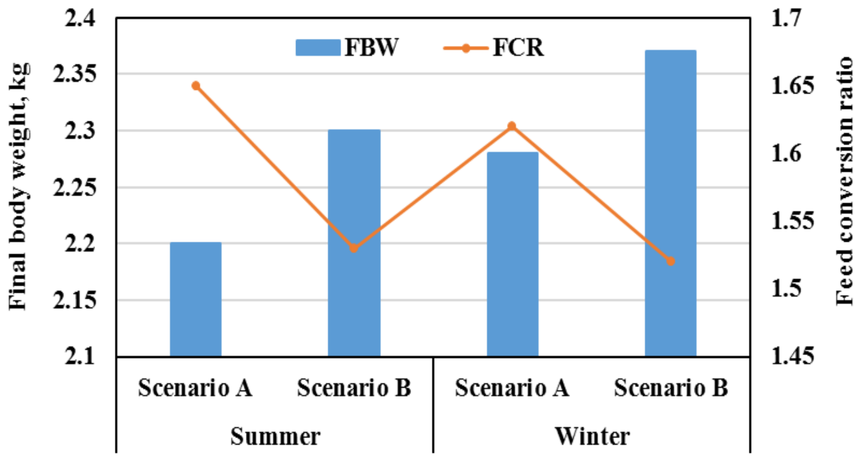

Fig. (2): Productive performance of different broiler chicken production scenarios during summer and winter.

As FBW is a qualitative trait, influenced by the environment, it was noted that scenario B birds were significantly superior in FBW at the end of experiment than scenario A birds. Growth performance difference is due to the freedom of birds in scenario A compared to birds in scenario B; Hence, scenario B birds make better use of the feed and convert it to meat more than scenario A birds **(Olawumi, 2015)**. Average FBW and FCR values showed an improvement for scenario B compared to scenario A by (4.55 and 3.95%) and (7.27 and 6.17%), for summer and winter seasons, respectively. The improvement in FCR of scenario B may be attributed to the feed utilization more efficiently as well as the good environmental conditions, leading to increasing FBW resulting in better FCR compared to scenario A. The higher weight gain of birds reared in cages may be attributed to better use of feed **(Alam *et al.*, 2008)**. Moreover, the ventilation rate increasing and fresh air availability in scenario B, leads to temperature reducing and environment relaxing setting up, resulting in performance improving. This is in keeping with **Feddes, Emmanuel and Zuidhoft (2002)** who concluded that the exposure of broiler chickens to well-ventilated circumstances leads to an improvement in their growth.

Housing system has a noticeable impact on mortality rate, where mortality rates of scenario B (4.0 and 4.4 %) were lower than those of scenario A (5.7 and 6.9 kg), while scenario B livability percentages (96.0 and 95.6 %) were higher than those of scenario A (94.3 and 93.1 %) for summer and winter seasons, respectively. This is because of the increase of ventilation and heating rates for scenario B that leads to reduce mortality and improve the birds' vigor; this is in line with **Abdel-Azeem *et al.* (2019)**. The lower mortality rate may be attributed to the ease of indoor climate control, the facilitation of monitoring the health and production status of individual birds, the increased stocking density of birds in cages, and the simplicity of waste disposal **(Pištěková *et al.*, 2006)**. The lower mortality rates and the higher total broiler meat yield (46.53 and 48.17 ton) of scenario B compared to (39.98 and 45.55 ton) of scenario A, indicates that scenario B represents the best production system in this study. The causes of broiler chickens' mortality are attributed to the meteorological conditions' changes and the rearing scenarios difference. It is noticeable from results that GHGs emissions are lower for scenario B than for scenario A, this due to the lower mortality rate in case of scenario B than A. This is in agreement with **Kalhor *et al.* (2016)** who reported that a lower mortality has less impact on the environment.

Assessment of environmental impact during summer

Activities of the different broiler chicken rearing scenarios during summer were screened to examine their impact on GHG emissions. Representative greenhouse gas emissions are given for both scenarios during summer through various activities in Fig. 3. Results showed that for mechanical emissions of GHG from both scenarios during summer, electricity use is the main contributor to total energy consumption that gives the highest emissions percentages compared to other activities. According to the results obtained from Fig. 3, it was noted that electricity usage in scenario B led to an increase in GHG mechanical emissions by 15.38 % compared to scenario A. Results also indicated that transportation gives the highest mechanical emissions of CO_2 (166.78 and 116.18 kg CO_2 eq/ton) compared to CH_4 emissions (0.37 and 0.26 g CH_4 eq/ton) and N_2O emissions (1.66 and 1.16 g N_2O eq/ton) for scenario A and scenario B, respectively. As for propane gas used only in scenario A, it was found that it contributes to GHG emissions with values of 147.68 kg CO_2 eq/ton, 6.93 g CH_4 eq/ton, and 1.28 g N_2O eq/ton. Previous results showed that the total mechanical emissions of scenario A, are higher by 15.32 % when compared to scenario B, this is due to the propane gas used only in scenario A for heating and brooding purposes, resulting in increasing GHG mechanical emissions of scenario A compared to scenario B.

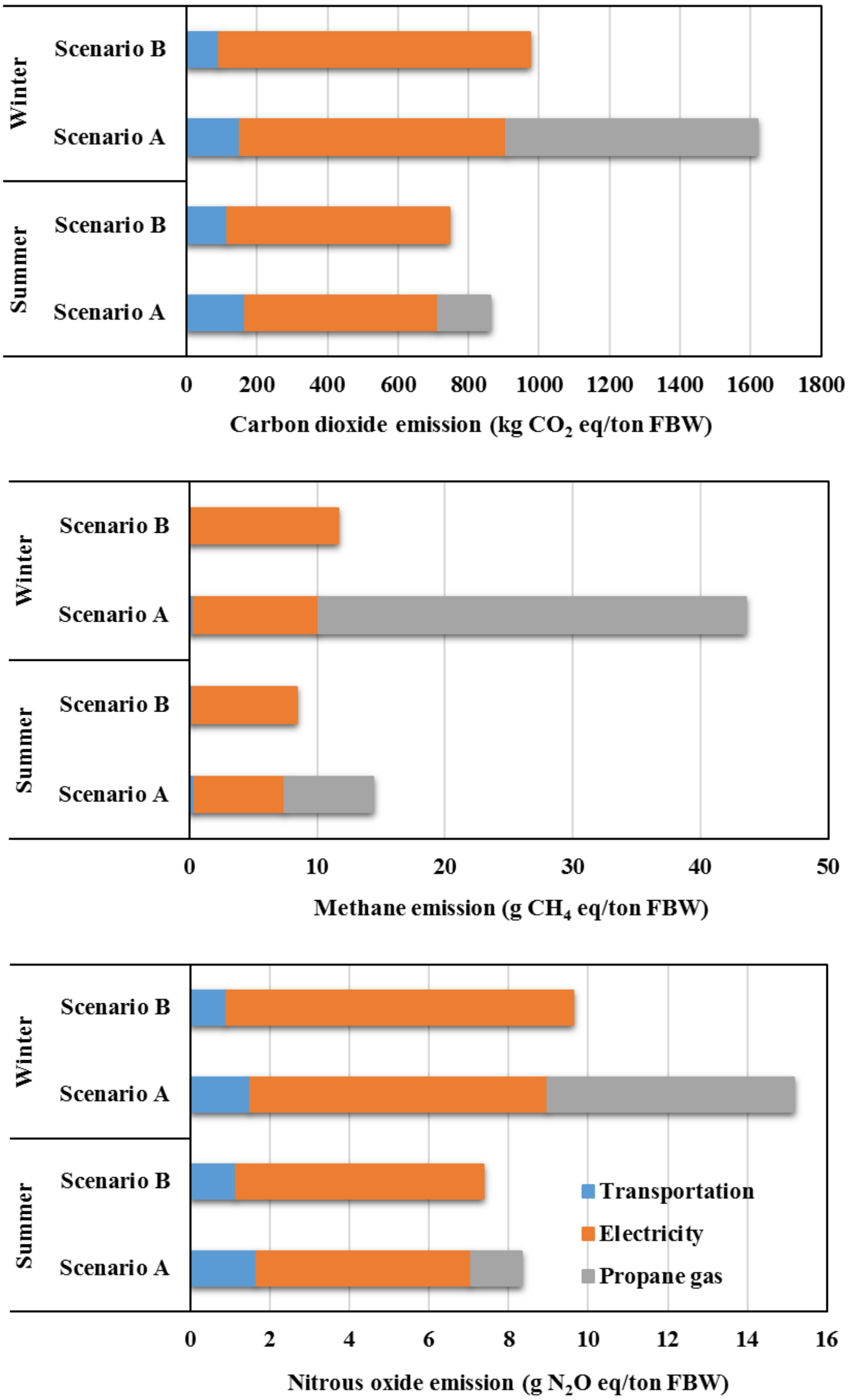

Fig. (3): Mechanical greenhouse gas emissions of broiler chicken production scenarios during summer and winter.

Considering non-mechanical emissions, results in Fig. 4 showed that feed contributes to the most of the GHG emissions followed by manure (with/without litter), bedding, and water that gives the lowest values of emissions. Feed gives emissions of (10896 and 10595 kg CO_2 eq/ton), (898.92 and 874.10 g CH_4 eq/ton**)** and (119.18 and 115.89 g N_2O eq/ton**)** at feed consumptions of (3.62 and 3.52 kg/bird) for scenarios A and B, respectively. It has been observed that there is a direct relationship between feed consumption and environmental burdens, as decreasing feed consumption causes a direct reduction in the environmental loads. This is in accord with **Pelletier (2008)** reported that a range of 45 % to 82.4 % in generation of GHG emissions is resulting of feed production. Primary feed production has participated significantly to the general impact of chicken.

Manure of broiler chicken is the origin of direct gaseous emissions of ammonia (NH_3), nitrous oxide (N_2O), and methane (CH_4), which occurs during housing **(Owen and Silver, 2015)**. According to results, manure with litter in scenario A increases the GHG emissions to the environment by 65.71 % compared to manure without litter in scenario B. The higher values of CH_4 and N_2O emissions observed from scenario A versus scenario B could be a result of the method of manure collection. Whereas, the manure in scenario B is with no bedding to absorb moisture, and therefore both CH_4 and N_2O emissions are relatively lower, but these emissions are higher if the manure were diluted with bedding material as in scenario A, this is in line with **Dunkley *et al.* (2015)**. For bedding material used only in scenario A, emissions accounted for 1295.6 kg CO_2 eq/ton, 99.54 g CH_4 eq/ton, and 49.77 g N_2O eq/ton. While, water gives emissions with the lowest values of (3.86 and 2.63 kg CO_2 eq/ton), (6.04 and 4.11 g CH_4 eq/ton), and (0.60 and 0.41 g N_2O eq/ton) for scenarios A and B, respectively, this is in line with **Vaarst, Steenfeldt and Horsted (2015)** showed that poultry has the lowest environmental footprint as regards water usage per kilogram of meat produced. The high-water emissions of scenario A compared to scenario B is attributed to the increase in the bird's water consumption as a result of its feeling of high temperatures because of the lower ventilation rates, moreover increased water losses. As noted, Scenario A has higher total non-mechanical emissions by 28.04 % than scenario B, because of the way in which manure (with/without litter) is managed in both scenarios, where the presence of bedding resulting in producing high amounts of manure with litter than manure without litter, thus increasing emissions.

Assessment of environmental impact during winter

Concerning the effect of various activities of broiler chicken production on greenhouse gas emissions for both scenarios during winter, results illustrated that for mechanical emissions, electricity usage made the largest contribution to GWP. High GHG emissions values were achieved for scenario B than scenario A by 16.67%. The share of transportation in different GHG emissions of both scenarios in winter showed that CO_2 emissions are by far the greatest contributor (151.37 and 92.70 kg CO_2 eq/ton), CH_4 emissions (0.33 and 0.20 g CH_4 eq/ton), and N_2O emissions (1.51 and 0.92 g N_2O eq/ton) for scenarios A and B, respectively. As can be seen in Fig. 3, The GHG emissions values of propane gas used only in scenario A were calculated as 712.66 kg CO_2 eq/ton, 33.44 g CH_4 eq/ton, and 6.19 g N_2O eq/ton. Relating to non-mechanical emissions, feed made the largest contribution to the GWP impact category. Feed emissions values accounted (11139.2 and 10835.2 kg CO_2 eq/ton**),** (918.98 and 893.90 g CH_4 eq/ton**)** and (121.84 and 118.51 g N_2O eq/ton**)** at feed consumptions of (3.70 and 3.60 kg/bird) for scenarios A and B, respectively. CH_4 emissions were calculated from manure (with/without litter) as illustrated in Fig. 4, and the results showed that scenario A emits around (198.05 g CH_4 eq/ton) compared to (65.22 g CH_4 eq/ton) for scenario B. Also, scenario A had higher N_2O emissions (26.16 g N_2O eq/ton) compared to scenario B (8.61 g N_2O eq/ton). The higher CH_4 emissions values observed from scenario A versus scenario B could be attributed to the presence of the bedding in scenario A only, resulting in increasing the amount of litter produced, thus emissions. Concerning NH_3, an investigation on broilers different flooring systems indicated a decrease in the concentration of NH_3 using a no-litter flooring system compared to conventional litter flooring **(Boggia *et al.*, 2019)**. Bedding emissions estimated 1558 kg CO_2 eq/ton, 119.7 g CH_4 eq/ton, and 59.85 g N_2O eq/ton. As for water emissions, it was estimated (3.15 and 2.51 kg CO_2 eq/ton), (4.93 and 3.93 g CH_4 eq/ton), and (0.49 and 0.39 g N_2O eq/ton) for scenarios A and B, respectively. The higher water emissions during summer than winter for both scenarios, is due to the increase of water consumption for summer compared to winter. Obtained results indicated that total emissions for scenario A are higher when compared to scenario B by 33.63 %. This is due to propane gas use in scenario A for heating during brooding, resulting in high emissions, thus increasing GHG emissions of scenario A compared to scenario B.

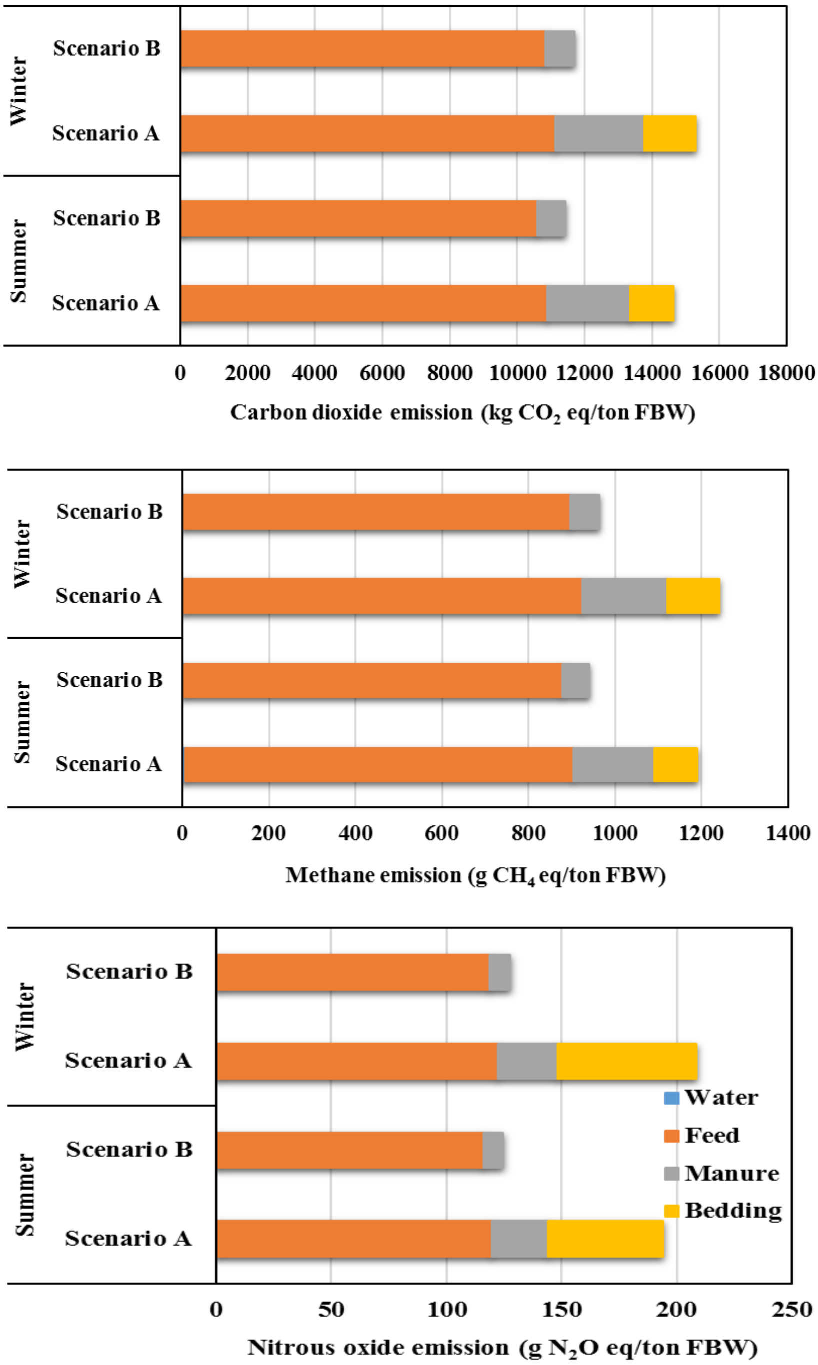

Fig. (4): Non-mechanical greenhouse gas emissions of broiler chicken production scenarios during summer and winter.

Environmental impact assessment analysis results

Energy usage is one of the largest overall contributors to environmental risk from broiler production process **(Skunca *et al.*, 2018)**. According to GHG emissions for both scenarios during summer and winter through various activities, results demonstrated that the total emissions of both scenarios in summer are less than that in winter.

Obtained results showed that for mechanical emissions of GHG for both scenarios during summer and winter seasons, electricity usage in winter increased the GHG emissions by 38.46 % and 40 % compared to summer for scenarios A and B, respectively. This is because of the less of number daylight hours in winter than summer, which necessitates providing more hours of artificial lighting in winter compared to summer (in case of scenario A). As for scenario B, the increase in winter emissions is attributed to the dependence of this system on providing higher rates of artificial ventilation and lighting programs throughout the rearing period in winter. Likewise, it was observed that the propane gas used in case of scenario A, caused an enormous increase in GHG emissions during winter compared to summer by up to 382.57 %, in other words, the GHG emissions in winter is estimated as 4.8 times the emissions in summer. This is due to the lower temperatures in winter compared to summer, which necessitates providing higher heating rates through winter. The environmental burden in the GWP impact category is higher in the months of winter than in summer months due to higher natural gas consumption because of heating **(Éva *et al.*, 2022)**.

For non-mechanical GHG emissions for both scenarios and seasons, water consumption achieved an increase in summer emissions by 22.59 % and 4.78 % compared to winter emissions for scenarios A and B, respectively. The difference among both seasons may be caused by the differing of environmental thermal conditions. For scenario A, winter emissions increased by 2.23, 20.25, and 6.79% compared to summer emissions for feed, bedding, and manure with litter, respectively. For litter, low ventilation rates in the winter resulted in the litter getting wet earlier in the rearing period; leading to the enhancement of biological interactions that cause the production of emissions. In contrast, the litter in the summer was dry at a later time in the rearing period due to higher ventilation flows, which causes biological interactions in litter to take place towards the closing of the rearing cycle. According to **Calvet *et al.* (2011)**, gas concentrations were lower in the summer than in the winter, due to the higher ventilation flow. As for scenarios B, winter emissions increased by 2.27 and 2.55% compared to summer emissions for feed and manure without litter, respectively. This is due to the increase of feed consumption in winter than summer, thus increasing amount of manure (with/without litter), consequently increasing emissions. The increase in bedding emissions for scenario A in winter compared to summer is attributed to the increase in bedding thickness during winter. It is remarkable that the overall emissions obtained in scenario B were generally lower than in scenario A during both seasons, because the indoor environment in scenario B is strongly controlled. A study by **Pakage *et al.* (2015)** indicated that in closed housing, the cage system permits microclimate control within the facilities, enhances productivity, and initiates an environmentally friendly environment.

CONCLUSION

In this research, life cycle assessment was applied to assess the environmental impacts of different broiler chicken production systems during the summer and winter seasons. The different examined rearing scenarios for the goal of comparison were the open floor system (scenario A) and the closed cage system (scenario B).

According to the results, the broiler chicken rearing phase is a highly significant contributor to environmental impacts within the chicken production life cycle, as emissions of GHG originate from various sources in broiler production, which are principally related to energy usage. Evaluations indicated that climate conditions effectively controlled improves the performance of birds, leading to lowering GHG emissions and achieving enhanced productive and eco-friendly performance. The broiler production environmental impacts were higher in winter season than in summer season. Electricity and feed representing the mechanical and non-mechanical emissions, respectively were the most participants to the overall emissions of GHG.

A profound look is required to review rearing implementations for getting a sustainable system of broiler chicken production, thus decreasing GHG emission percentages. Hence, environmental control strategies inside broiler chicken production systems have to be implemented to improve the quality of indoor conditions, thus enhancing productive performance and making broiler chicken production environmentally friendly.

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تقدير انبعاثات الغازات الدفيئة من أنظمة إنتاج دجاج التسمين باستخدام تقييم دورة الحياة

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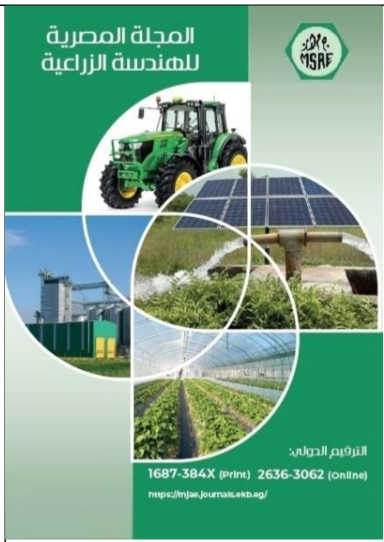

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الملخص العربي

تعد انبعاثات الغازات الدفيئة أحد التحديات البيئية الرئيسية التي تواجه إنتاج دجاج التسمين. تم تقييم التأثيرات البيئية لأنظمة إنتاج دجاج التسمين المختلفة، العنبر المفتوح ذات التربية الأرضية (السيناريو أ) مقابل العنبر المغلق ذات التربية في أقفاص (السيناريو ب)، خلال فصلي الصيف والشتاء من خلال منظور المهد إلى بوابة المزرعة باستخدام نهج تقييم دورة الحياة. تم تحديد المكونات الرئيسية للتأثيرات وكذلك بيانات الأنشطة، بما في ذلك الانبعاثات الميكانيكية لاستخدام الطاقة والانبعاثات غير الميكانيكية. تم تقييم كلا السيناريوهين من خلال حساب المدخلات والمخرجات من حدود النظام لتقييم مستوى انبعاثات الغازات الدفيئة (ثاني أكسيد الكربون، الميثان، أكسيد النيتروز) المنبعثة من سيناريوهات الإنتاج هذه وتوضيح العلاقة بين الاداء الإنتاجي والآثار البيئية.

وفقًا للنتائج، كان للسيناريو (ب) قيم أعلى لوزن الجسم النهائي لدجاج التسمين بنسبة ٤,٥٥ و٣,٩٥٪ وتحسن في معدل تحويل العلف بنسبة ٧,٢٧ و٦,١٧٪ وكذلك استخدام الكهرباء في السيناريو (ب) أدى إلى زيادة في الانبعاثات الميكانيكية للغازات الدفيئة بنسبة ١٥,٣٨ و١٦,٦٧٪ مقارنة للسيناريو (أ) لفصلي الصيف والشتاء على التوالي. بالنسبة للانبعاثات غير الميكانيكية، قدمت الأعلاف أكبر مساهمة في فئة التأثير المحتمل لظاهرة الاحتباس الحراري. أدت التغذية في السيناريو (أ) إلى زيادة الانبعاثات بنسبة ٢,٨٤ و٢,٨١٪ مقارنة بالسيناريو (ب) لموسمي الصيف والشتاء على التوالي. وكانت الانبعاثات الإجمالية الناتجة عن السيناريو (أ) أعلى بشكل عام من السيناريو (ب) خلال الموسمين. في الختام، فإن تربية دجاج التسمين في العنابر المغلقة ذات التربية في أقفاص ساهمت في تقليل انبعاثات الغازات الدفيئة عن التربية في العنابر المفتوحة ذات التربية الأرضية، وتحقيق أداء إنتاجي معزز وصديق للبيئة.

الكلمات المفتاحية:
دجاج التسمين؛ البصمة الكربونية؛ تقييم دورة الحياة؛ الغازات الدفيئة؛ التأثير البيئي.