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CARBON FOOTPRINT AND RESPIRATORY HEALTH RISKS ASSOCIATED WITH INTENSIVE POULTRY FARM OPERATIONS: A COMPREHENSIVE ENVIRONMENTAL AND OCCUPATIONAL HEALTH REVIEW

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ABSTRACT

Intensive poultry production has expanded rapidly in response to increasing demand for eggs and poultry meat, but the intensification of production has also increased concerns about greenhouse gas emissions, airborne pollutants, environmental degradation, and occupational respiratory health. Poultry production generates emissions from animal metabolism, manure decomposition and storage, feed production, transportation, heating, ventilation, electricity and fossil-fuel use. These activities contribute to the release of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ammonia (NH_3), hydrogen sulphide (H_2S), and particulate matter ($PM_{2.5}$), with potential implications for climate change, ambient air quality and human health. This review examines the relationship between intensive poultry production, carbon footprint, airborne pollutant emissions and respiratory health, with particular attention to evidence from developing countries and Nigeria. Relevant peer-reviewed literature was reviewed to synthesize evidence on major emission sources, carbon-footprint estimation approaches, pollutant concentrations and exposure pathways, respiratory health outcomes, and environmental and occupational mitigation strategies. The reviewed evidence indicates that poultry-house emissions vary considerably according to flock size, housing and ventilation systems, manure-management practices, production type, stocking density, feed characteristics, energy sources and climatic conditions. Ammonia and particulate matter are particularly important air-quality concerns, while methane and nitrous oxide contribute to the greenhouse-gas burden of poultry production. Prolonged occupational exposure to contaminated poultry-house air has also been associated with respiratory symptoms, airway irritation and impaired pulmonary function among workers. Available evidence further suggests that inadequate ventilation, poor manure management and dependence on fossil-fuel energy can increase both environmental emissions and occupational exposure. Integrated interventions,

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including improved ventilation, appropriate manure management, cleaner energy sources, improved production practices, regular environmental monitoring, worker education and suitable respiratory protection, are therefore important for reducing emissions and health risks. The review highlights the need for more comprehensive, location-specific studies in Nigeria that simultaneously quantify poultry-related carbon footprints, characterize airborne pollutants and evaluate respiratory health outcomes to support evidence-based environmental and occupational health management.

Keywords: intensive poultry production; carbon footprint; greenhouse gases; air pollution; ammonia; particulate matter; respiratory health; occupational exposure; environmental sustainability; Nigeria.

Introduction

Poultry production is an important source of animal protein and income, and intensive systems have improved the regularity and scale of egg and meat supply. These benefits must be considered alongside the environmental pressures associated with feed production, energy use, manure handling and the release of gases and airborne particles. Life-cycle reviews identify feed production and manure management as important contributors to the environmental footprint of poultry products, although the relative contribution of each process varies with production system, feed composition, productivity and the boundary of the assessment (Costantini et al., 2021; FAO, 2016).

Environmental emissions from poultry farms include greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), as well as ammonia (NH_3), hydrogen sulphide (H_2S), and particulate matter (PM). These pollutants should not be treated as interchangeable: greenhouse gases contribute to climate forcing, whereas ammonia, hydrogen sulphide, dust and bioaerosols may also affect local air quality and respiratory health. Poultry-house particulate matter can carry microorganisms and chemical compounds, and its concentration varies with bird activity, feed handling, litter condition, housing and ventilation (Wang et al., 2023; Bist et al., 2023).

The environmental and health dimensions are often evaluated separately. Life-cycle assessments quantify resource use and emissions across a defined supply chain, while occupational studies examine inhalation exposures and health outcomes among workers. Integrating these perspectives can help identify management practices that reduce climate impacts without overlooking local exposure risks. This review therefore examines poultry production systems, carbon-footprint accounting, major emissions, respiratory-health pathways, monitoring methods, mitigation options and research needs, with particular attention to

evidence gaps relevant to Nigeria and other tropical settings (Magri et al., 2021; Bawa et al., 2023).

Poultry Production Systems and Environmental Sustainability

Poultry production systems vary in flock size, bird type, stocking density, housing design, ventilation, feed conversion, manure removal and energy supply. Broiler operations generally produce meat over a relatively short production cycle, whereas layer systems maintain birds for longer periods and generate eggs and spent hens as co-products. Deep-litter systems retain bedding and manure within the house until removal, while cage systems may allow manure to be collected separately beneath cages. These differences affect the frequency of litter disturbance, manure moisture, air exchange and the location and timing of emissions (FAO, 2016; Bist et al., 2023).

Environmental sustainability cannot be assessed from flock size alone. Larger farms may use energy and materials more efficiently per unit of output, but high bird density and inadequate ventilation can increase indoor pollutant concentrations. Conversely, frequent manure removal and effective ventilation may reduce some indoor exposures while changing where emissions are released. The performance of each system therefore depends on the interaction between technology, management, local climate and production efficiency rather than on a simple ranking of housing types (Costantini et al., 2021; Bist et al., 2023).

A balanced sustainability assessment should consider climate impacts, air quality, manure nutrients, water and energy use, animal welfare, worker safety and farm viability. In Nigeria, this requires data that reflect local feed ingredients, electricity reliability, generator use, ambient temperature and humidity, manure reuse practices and the prevalence of deep-litter and battery-cage systems. Applying a consistent functional unit and system boundary is essential when comparing farms or production zones (Bawa et al., 2023; FAO, 2016).

Carbon Footprint Concepts and Measurement

A carbon footprint expresses the greenhouse-gas emissions associated with a product, activity or organisation, usually as kilograms or tonnes of carbon dioxide equivalent (CO_2-eq). Carbon dioxide equivalent converts different greenhouse gases to a common unit using their global warming potentials over a stated time horizon. The selected assessment horizon and version of the global-warming-potential values should be reported explicitly; values from different IPCC assessment reports should not be mixed in one calculation (IPCC, 2006; IPCC, 2021).

For poultry production, the functional unit may be one kilogram of live-weight gain, one kilogram of carcass, one kilogram of eggs, or a defined number of eggs. Results expressed per kilogram of meat are not directly comparable with results expressed per kilogram of eggs or per bird-place unless the

purpose and conversion basis are made clear. The system boundary may be limited to the farm gate or expanded to include feed ingredient production, feed milling, transport, pullet or chick supply, slaughter or egg processing, packaging and distribution. The chosen boundary should reflect the research question and data availability (Costantini et al., 2021; FAO, 2016).

A robust inventory records the quantities of feed, chicks or pullets, electricity, generator fuel, heating fuel, water, bedding, manure and other relevant inputs over the reporting period. Emissions are estimated by multiplying activity data by appropriate emission factors, or by using measured emission rates where reliable measurements are available. Results should be reported for the actual observation period and not annualised without a clearly stated and justified extrapolation. Uncertainty in activity data, emission factors and allocation assumptions should be acknowledged because it can affect comparisons between farms (IPCC, 2006; Costantini et al., 2021).

Greenhouse Gas Emissions from Poultry Farms

The principal greenhouse gases associated with poultry systems are carbon dioxide, methane and nitrous oxide. Carbon dioxide is associated particularly with fossil-fuel combustion and upstream energy and feed supply chains. Methane can be generated when manure decomposes under anaerobic conditions, with the magnitude depending on manure characteristics, storage duration, temperature and management. Nitrous oxide can arise from nitrogen transformations during manure storage and after manure is applied to soils. The IPCC inventory framework distinguishes emissions from livestock and manure management and recommends methods appropriate to the available data and inventory tier (IPCC, 2006).

Feed often represents a major part of poultry products' life-cycle climate impact because crop cultivation, fertiliser use, processing and transport all require resources and can generate emissions. On-farm electricity and fuel use are also important, particularly where generators provide power for lighting, ventilation, pumping and other equipment. Consequently, a farm-gate calculation that excludes feed production may underestimate the broader supply-chain footprint, while a cradle-to-farm-gate assessment should avoid counting the same input emissions twice (Costantini et al., 2021; FAO, 2016).

Manure management creates both climate and local air-quality challenges. Drying, frequent removal and appropriate storage can change the conditions under which methane and nitrous oxide form, but the net effect depends on the full management chain, including subsequent use of the manure as fertiliser or soil amendment. Emissions should therefore be interpreted in relation to the quantity and type of production, manure handling practices and the assessment boundary, rather than attributing all

emissions to the birds themselves (IPCC, 2006; Bist et al., 2023).

Ammonia and Other Toxic Gases

Ammonia is produced primarily when nitrogen compounds in excreta are converted and volatilised, with emissions influenced by manure pH, moisture, temperature, litter condition, ventilation and the length of time manure remains in the house. It is an irritant gas and can contribute to the formation of secondary fine particulate matter after reacting with acidic compounds in the atmosphere. A critical review of poultry production identifies housing, season, feed, bedding, stocking density and bird activity as important factors affecting ammonia emissions and describes a range of control options (Bist et al., 2023).

Hydrogen sulphide may form when sulphur-containing organic material decomposes under oxygen-limited conditions. It can be particularly hazardous in confined or poorly ventilated manure-storage areas, where concentrations may rise rapidly during disturbance or agitation. Carbon dioxide can accumulate in poorly ventilated spaces and is also a product of fuel combustion; methane is relevant both as a greenhouse gas and, at sufficiently high concentrations, as a flammability hazard. The presence and significance of each gas depend on the farm design and waste-management arrangements, so monitoring should be selected according to plausible sources and risks rather than assuming that every gas occurs at harmful concentrations on every farm (IPCC, 2006; Bist et al., 2023).

Odour alone is not a reliable quantitative measure of exposure or safety. Gas monitoring should use instruments appropriate to the target compound, concentration range and sampling environment, with calibration and quality-control procedures documented. Ventilation and manure management are important preventive measures, but workers should not enter manure pits or other potentially oxygen-deficient or gas-contaminated spaces without formal confined-space controls and suitable equipment. Respiratory protection must be selected for the hazard: a particulate respirator such as an N95 does not by itself protect against ammonia or hydrogen sulphide gas (Donham et al., 2002; Magri et al., 2021).

Particulate Matter and Bioaerosols

Particulate matter in poultry houses originates from feed, litter or bedding, dried faecal material, feathers, skin flakes and the movement of birds and workers. PM_{10} refers to particles with aerodynamic diameters of approximately 10 micrometres or less, while $PM_{2.5}$ refers to the finer fraction of approximately 2.5 micrometres or less. Particle size influences how far particles penetrate into the respiratory tract, and fine particles can reach deeper regions of the lungs. Poultry-house dust can also carry ammonia-related compounds,

microorganisms and other biological material (Wang et al., 2023).

Bioaerosols include airborne bacteria, fungi, endotoxins, allergens and other biological particles. Their composition and concentration depend on litter moisture, cleaning practices, stocking density, ventilation, feed handling and the activity taking place at the time of sampling. Exposure can vary substantially within a house and across the working day; short measurements may therefore fail to represent longer-term exposure if the sampling schedule does not capture routine tasks such as litter removal, sweeping or bird catching (Magri et al., 2021; Wang et al., 2023).

Controls should focus on reducing dust generation and preventing unnecessary resuspension. Practical measures include appropriate litter moisture management, careful feed handling, low-dust cleaning methods, maintenance of ventilation systems and reducing workers' time in high-dust tasks where feasible. Wetting or chemical treatment should be used only where suitable for the production system and animal welfare, since poorly managed moisture can worsen microbial growth and manure-related emissions. Monitoring should distinguish $PM_{2.5}$ from PM_{10} and report instrument type, location, duration, activity conditions and quality assurance (Wang et al., 2023).

Occupational Exposure Pathways

Workers may inhale gases, dust and bioaerosols during feeding, litter turning, manure removal, cleaning, bird catching, carcass handling and maintenance of ventilation or heating equipment. Exposure may also occur through eye and skin contact with irritant substances. Workers who spend long periods inside poultry houses, undertake dusty tasks or work in poorly ventilated areas may experience higher exposure than people who enter briefly. A systematic review of broiler-farm occupational risks identifies chemical gases, vapours and aerosols, biological hazards and unsafe work practices among the relevant concerns (Magri et al., 2021).

Exposure is influenced by concentration, duration, frequency and the combined presence of contaminants. A worker's personal exposure may differ from a fixed-point measurement because the worker moves between locations and performs tasks that generate short-lived peaks. For this reason, area monitoring and personal sampling answer different questions and, where resources permit, can be used together. Task diaries, work-shift information and ventilation records help interpret measurements and identify higher-exposure activities (Donham et al., 2002; Magri et al., 2021).

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Residents near poultry farms may be exposed to emissions transported outdoors, particularly where houses are close to farm boundaries or prevailing winds carry emissions toward settlements. The concentration reaching nearby homes depends on emission rate, wind direction and speed, atmospheric stability, rainfall, terrain, buildings and distance. Proximity alone does not establish an individual health effect; environmental measurements and appropriate health data are needed to assess exposure and possible associations. Spatial sampling should therefore include background or upwind locations where feasible and clearly describe meteorological conditions (Wang et al., 2023; Bist et al., 2023).

Respiratory Health Effects

Respiratory effects associated with poultry-house exposures can include irritation of the eyes, nose and throat, cough, wheeze, chest tightness, shortness of breath and exacerbation of asthma or other pre-existing respiratory conditions. Organic dust may contain allergens, endotoxins and microorganisms, while ammonia can irritate the mucosal surfaces of the respiratory tract. These exposures can occur together, making it difficult to attribute a symptom or change in lung function to one contaminant without careful exposure assessment (Donham et al., 2002; Magri et al., 2021).

Evidence from occupational studies indicates that combined exposure deserves attention. Donham et al. (2002) reported that simultaneous exposure to ammonia and dust was associated with adverse changes in pulmonary-function measures among poultry production workers, supporting the need to control mixtures rather than focusing on a single pollutant. A later systematic review also identified respiratory and other occupational hazards among broiler-farm workers, while noting the need for better prevention and risk-management evidence (Magri et al., 2021). These findings support concern about exposure but do not justify assuming that every worker or nearby resident will develop disease.

Respiratory-health assessment can combine a structured questionnaire, clinical history and spirometry. Common spirometric indicators include forced expiratory volume in one second (FEV_1), forced vital capacity (FVC) and the FEV_1/FVC ratio; peak expiratory flow may provide additional information but is not a substitute for full spirometry. Measurements should be obtained by trained personnel using calibrated equipment and interpreted with appropriate reference equations and quality criteria. Analyses should account, where possible, for age, sex, smoking, previous respiratory disease, exposure duration, household fuel smoke and other occupational exposures. Cross-sectional associations should be described as associations, not proof of causation (Magri et al., 2021).

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Table 1: Major Air Pollutants and Health Implications

Pollutant	Main Source	Health Effects
Ammonia (NH_3)	Litter/manure decomposition	Eye irritation, bronchitis, asthma
Methane (CH_4)	Anaerobic manure breakdown	Climate forcing
Nitrous oxide (N_2O)	Nitrification/denitrification	High global warming potential
$PM_{2.5}/PM_{10}$	Dust, feathers, feed	Reduced lung function
Hydrogen sulphide (H_2S)	Manure pits	Headache, respiratory distress

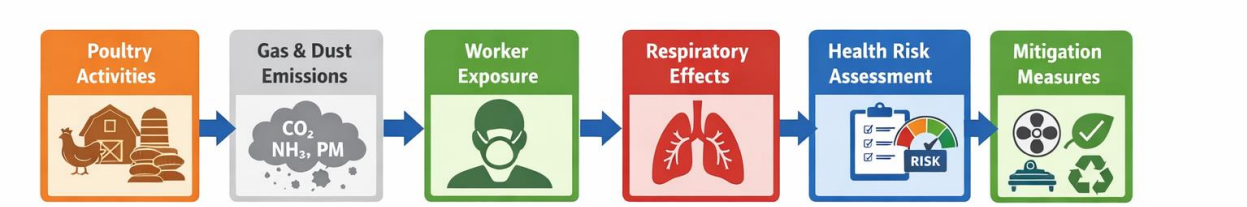


Figure 1: Conceptual Framework of Emission–Exposure–Health Pathway

Monitoring and Assessment Techniques

A defensible monitoring programme begins with a clear sampling plan that identifies pollutants, locations, sampling duration, timing, instruments, detection limits and quality-assurance procedures. Measurements inside a poultry house characterise the working environment, while measurements at defined distances outside the building help examine dispersion into surrounding areas. Where practical, upwind or background measurements can help distinguish farm-related increments from regional background pollution. Sampling should record flock size, bird type, housing system, manure-removal schedule, ventilation status, relevant work activities and meteorological conditions at the time of measurement (Bist et al., 2023; Wang et al., 2023).

Gas analysers and particulate monitors must be suitable for the target pollutant and expected concentration range. Instrument make and model, calibration date, response time, measurement principle, detection range and any limitations should be reported. Direct-reading instruments can capture variation over time, while sorbent tubes, filter sampling or other integrated methods may be needed for selected contaminants or confirmatory analysis. Replicate readings improve understanding of measurement variability, but the study must distinguish repeated instrument readings from independent farms or participants; repeated readings at one site do not automatically constitute independent biological replicates (IPCC, 2006; Wang et al., 2023).

Carbon-footprint monitoring requires a separate activity-data inventory for feed, electricity, generator fuel, manure management, transport and other inputs within the selected boundary. Health

assessment should use validated questionnaires and standardised spirometry procedures. Statistical analyses should match the design and distribution of the data, report effect estimates and uncertainty where possible, and avoid interpreting a non-significant result as evidence that no risk exists. Combining environmental, farm-management and health information allows the assessment to examine potential relationships without treating correlation as proof of causation (Costantini et al., 2021; Magri et al., 2021).

Carbon Footprint Estimation Approaches

Life-cycle assessment (LCA) provides a structured method for evaluating environmental impacts across a product system. The principal stages are goal and scope definition, life-cycle inventory, impact assessment and interpretation. For poultry, the goal may be to compare housing systems, identify emission hotspots or estimate the footprint of eggs or meat. The functional unit and system boundary should be stated before data collection because they determine which inputs and outputs are included and how results can be compared (Costantini et al., 2021; FAO, 2016).

A farm-gate inventory can include purchased feed and chicks or pullets, electricity, generator fuel, heating, bedding, manure handling and transport up to the farm gate. A broader cradle-to-farm-gate boundary also includes relevant upstream production of feed ingredients, energy and other purchased inputs. For greenhouse-gas estimation, activity data are multiplied by emission factors, with factors selected to match the gas, activity and geographical context as closely as possible. IPCC methods are widely used for livestock and manure-related emissions, while FAO LEAP guidance provides poultry-supply-chain procedures for greenhouse-gas emissions and fossil-energy use (IPCC, 2006; FAO, 2016).

Poultry farms may produce more than one useful output, such as eggs and spent hens or meat and manure. Allocation is needed where impacts are shared among co-products and cannot be directly separated. Mass-based and economic allocation can yield different results; the selected method should be justified and reported, with sensitivity analysis considered where allocation choices materially influence the result. Results should be expressed in CO_2-eq per clearly defined functional unit and should include the study period, global-warming-potential basis, data sources, assumptions and uncertainty limitations (Costantini et al., 2021; Bawa et al., 2023).

Mitigation and Control Strategies

Mitigation should follow a hierarchy: prevent emissions where feasible, improve process management, capture or treat emissions where technically and economically appropriate, and protect workers from residual exposure. Feed-related measures include improving feed conversion, reducing avoidable feed wastage and formulating diets

to meet bird requirements without excess nutrient excretion. Because feed supply chains can contribute substantially to poultry products' climate impacts, feed efficiency and the sourcing and production of feed ingredients are important considerations in carbon-footprint reduction (Costantini et al., 2021; FAO, 2016).

Manure and litter management can influence ammonia, methane, nitrous oxide, odour and bioaerosol generation. Options include keeping litter at an appropriate moisture level, removing manure on a planned schedule, avoiding unnecessary accumulation, storing manure under suitable conditions and applying manure agronomically at appropriate rates. Litter additives, acidification, covered storage, composting or other treatment options may be useful in particular circumstances, but their effectiveness, costs, secondary emissions and compatibility with local farm practices should be evaluated rather than assumed. A review by Bist et al. (2023) describes multiple ammonia-control approaches and highlights the importance of housing and management conditions.

Ventilation should maintain acceptable indoor conditions while being designed with awareness of where exhaust air is released. Dust controls include low-dust feed handling, suitable litter management, careful cleaning and maintenance of equipment. Occupational measures include training, task-specific risk assessment, hygiene facilities, limiting unnecessary exposure and providing correctly selected respiratory protection. Particulate respirators alone do not protect against toxic gases; respirator selection must follow the hazard assessment and manufacturer guidance. Controls should be checked through follow-up monitoring to establish whether emissions and exposures have actually declined (Donham et al., 2002; Magri et al., 2021).

Policy and Regulatory Frameworks

Poultry environmental management involves several policy domains: climate mitigation, air pollution control, occupational safety, waste management, public health and agricultural development. Greenhouse-gas inventories can use the IPCC framework to improve consistency in reporting livestock and manure-management emissions, while poultry life-cycle assessments can apply the FAO LEAP guidance to define comparable indicators and system boundaries (IPCC, 2006; FAO, 2016). Such frameworks do not replace national legal requirements; they provide technical methods that can support inventories, farm assessments and policy design.

In Nigeria, environmental and occupational-health responsibilities may be distributed across federal and state institutions and local authorities. Effective implementation requires clear responsibilities for inspection, reporting, worker protection, manure handling and community complaints, as well as practical guidance that small and medium-sized farms can apply. Regulatory

comparisons should cite the exact instrument, issuing authority, year and relevant pollutant or exposure limit. Ambient-air guidelines, occupational exposure limits and animal-welfare recommendations serve different purposes and should not be presented as interchangeable benchmarks (WHO, 2021; Magri et al., 2021).

Policy measures are more likely to be effective when monitoring and enforcement are accompanied by technical assistance, training and realistic financing options. Extension programmes can help farmers improve ventilation, manage litter and manure, record fuel and electricity use, and adopt practical emission-reduction measures. Data generated through standardised farm surveys and periodic environmental monitoring can inform locally relevant emission factors and support more transparent reporting. For Nigeria, strengthening the evidence base is particularly important because the existing life-cycle assessment literature identifies data quality and methodological consistency as continuing challenges (Bawa et al., 2023).

Research Gaps in Nigeria and Sub-Saharan Africa

Although research on poultry production, environmental emissions and occupational health has increased, important knowledge gaps remain in Nigeria and Sub-Saharan Africa. Existing studies have provided useful evidence on poultry-related air pollution, greenhouse-gas emissions, carbon footprint and respiratory health; however, these aspects have often been investigated independently, with limited integration of environmental and health dimensions within the same poultry production system (Costantini et al., 2021; Bawa et al., 2023). The following specific areas therefore require further investigation:

Integrated assessment of carbon footprint, air pollutants and respiratory health

Previous studies have assessed air pollutants and respiratory health among poultry workers, while life-cycle studies have mainly concentrated on environmental impacts and carbon-footprint estimation (Costantini et al., 2021; Bawa et al., 2023). However, limited evidence exists from Nigeria that simultaneously quantifies the carbon footprint of poultry farms, measures multiple airborne pollutants and evaluates associated respiratory health outcomes. Future studies should therefore integrate these three dimensions to provide a more comprehensive assessment of the environmental and occupational-health consequences of intensive poultry production.

Farm-level carbon-footprint assessment under Nigerian production conditions

Life-cycle assessment has been increasingly used to evaluate the environmental impacts of poultry production, but differences in system boundaries, functional units, allocation procedures and emission factors limit comparisons among studies (Costantini et al., 2021). In Nigeria, available evidence on poultry life-cycle assessment remains

limited compared with the scale and diversity of commercial poultry production (Bawa et al., 2023). More farm-level investigations are therefore required to quantify carbon footprints using locally generated data on feed, manure management, electricity, generator fuel, transportation and other production inputs.

Development and validation of locally appropriate emission factors

International poultry studies provide important emission factors for greenhouse gases and other pollutants; however, emission rates can vary according to climate, housing systems, manure-management practices, stocking density, feed characteristics and farm management (Costantini et al., 2021; FAO, 2016). There is consequently a need for empirical studies in Nigeria to determine whether internationally derived emission factors adequately represent local poultry production systems. Development of locally relevant emission factors would improve the reliability of farm-level carbon-footprint estimates and national emission inventories.

Comparative assessment of poultry housing systems

Housing systems can influence ventilation, manure accumulation, pollutant generation and exposure levels. Studies have reported differences in environmental conditions and pollutant concentrations between poultry housing and management systems (Wang et al., 2023; FAO, 2016). However, comparative evidence from different Nigerian poultry production systems remains inadequate. Further studies should therefore compare deep-litter, battery-cage and other commonly used systems with respect to greenhouse-gas emissions, gaseous pollutants, particulate matter and worker exposure.

Influence of farm characteristics on pollutant emissions

Poultry-house pollutant concentrations are influenced by factors such as stocking density, flock size, ventilation, manure accumulation, litter characteristics and management practices (Wang et al., 2023; FAO, 2016). Nevertheless, there is limited quantitative evidence from Nigeria establishing the relative contribution of these farm characteristics to pollutant concentrations. Future research should determine which farm-level characteristics are the strongest predictors of environmental and occupational exposure.

Spatial dispersion of pollutants around poultry farms

Existing poultry studies have largely concentrated on pollutant concentrations within poultry houses, whereas comparatively less attention has been given to the dispersion of emissions into surrounding environments. Poultry-house emissions can contribute to ambient air pollution beyond the immediate production area, particularly where ventilation is inadequate and farms are located close to residential areas (Wang et al., 2023). Research is therefore required to establish

concentration gradients at different distances from poultry farms and determine the potential exposure of neighbouring populations.

Influence of seasonal and meteorological conditions

Temperature, relative humidity, ventilation and other environmental conditions can influence the generation, accumulation and dispersion of poultry-house pollutants (Wang et al., 2023; FAO, 2016). However, there is limited longitudinal evidence on how these factors influence pollutant concentrations in Nigerian poultry farms across different seasons.

Future Directions

Future work should move beyond isolated measurements and develop integrated studies that quantify greenhouse-gas emissions, measure indoor and downwind pollutants, document farm-management practices and assess respiratory outcomes using clearly defined methods. Longitudinal or repeated seasonal sampling would help distinguish persistent exposure patterns from short-term changes caused by weather, bird age, cleaning or manure removal. Studies should include farms of different sizes and production types and report enough detail to support comparison and replication (Bawa et al., 2023; Magri et al., 2021).

A priority is to develop and validate emission factors that reflect tropical production conditions, including local feed ingredients, housing designs, power supply, temperature, humidity and manure-management practices. Researchers should report uncertainty and test how results change under alternative system boundaries, allocation procedures and global-warming-potential values. Better integration of life-cycle assessment with spatial air-quality monitoring would also help identify where climate mitigation and local exposure reduction align and where trade-offs may occur (Costantini et al., 2021; FAO, 2016).

Intervention studies are needed to determine which combinations of improved ventilation, litter management, feed strategies, manure treatment and worker protection are affordable and effective on Nigerian farms. Community studies should use suitable comparison locations, measured exposure indicators and careful adjustment for other pollution sources. Research partnerships among universities, veterinary and public-health professionals, environmental regulators and poultry producers can improve data access and help translate findings into practical guidance. The objective should be not only to document emissions and symptoms, but to test interventions and measure whether they deliver sustained environmental and health benefits (Bist et al., 2023; Magri et al., 2021).

Conclusion

Intensive poultry production contributes to greenhouse-gas emissions and airborne pollution, with important implications for

environmental sustainability and respiratory health. The reviewed evidence shows that emissions and health risks are influenced by farm size, housing and ventilation systems, manure management, energy use and other production practices. However, evidence from Nigeria and Sub-Saharan Africa remains limited and fragmented. There is therefore a need for integrated, farm-level research that links carbon footprint, pollutant exposure and respiratory health to support sustainable poultry production and effective environmental and occupational-health management.

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