https://doi.org/10.57046/RBET5362

Original Research Article

Assessing awareness of IoT-driven strategies for poultry management in mitigating increased ambient heat in Enugu, Nigeria

*Onuoha I. Okocha[1], Terser Sombu[2], Julie W. Zimoghen[3], & Anthony N. Uwajimgba[4]

Affiliation
[1,2,3,4]Department of Agricultural Education, Federal College of Education, Eha-Amufu, Enugu State, Nigeria

***For correspondence: email:** okochaonuoha@gmail.com
orcid: https://orcid.org/0000-0002-8575-0825

Abstract
The study examined awareness level of Internet of Things (IoT)-driven strategies in mitigating impacts of increased ambient heat load in poultry pens by poultry farmers in a smart city like Enugu, Nigeria. With the rising challenges of climate change, increased ambient heat load within poultry pens poses a significant threat to poultry production. Understanding farmers' perception of impact of increased ambient heat load and their awareness of IoT-driven strategies for its mitigation is crucial for sustainable poultry system management in smart cities. Multi-stage random sampling technique was used to select 240 poultry farmers from the three Local Government Areas that make up Enugu City. A structured questionnaire was used to collect data from the respondents. Descriptive statistics and Likert rating scale were used to analyze the data. The study identified socio-demographic factors influencing farmers' perception of impact of increased heat load and awareness/ adoption of IoT-driven mitigation strategies. Education level (45% secondary education), access to information (29.2%) and financial resources (22.9%) were key determinants. The findings revealed varying levels of awareness among poultry farmers regarding IoT-driven strategies while the constraints faced by farmers in implementing sustainable IoT-driven mitigation strategies included lack of awareness, lack of funding/high initial investment, limited access to technology, inadequate training, poor extension contact, water availability and climate variability. The study concluded that majority of poultry farmers shared similar perceptions about the impact of increased ambient heat load on poultry species but however were not aware of many of the IoT-driven strategies to mitigate the impact and were limited by a number of constraints or challenges to adopting IoT-driven mitigation strategies which altogether could improve poultry production system and help to achieve animal protein security in a smart city like Enugu, Nigeria. The study further recommended enlightenment of poultry farmers on the impact of increased ambient heat load on poultry species and available/sustainable/harmonized IoT-enabled guidelines or solutions to mitigate heat load in smart cities' poultry production system.

Target audience: Poultry Farmers, Animal Scientists, Policy Makers, Extension Agents and Researchers.

Keywords: *Smart-Cities, IoT, heat-load, mitigation, poultry.*

https://doi.org/10.57046/RBET5362

INTRODUCTION

Due to the anticipated increase in the global population, especially as cities get populated; it is predicted that there will be a rise in worldwide meat consumption. Consequently, there is a need to enhance meat production. In the twilight of our cities getting overpopulated, there is also a rapid evolution in cities, as they are being transformed into intelligent, interconnected hub where technology becomes an essential thread in the urban fabric. Cities are transforming beyond physical spaces and becoming smarter and more dynamic ecosystems where emerging technologies influence and enhance every aspect (Chiemeke, 2024). In the contemporary rapid urbanization coupled with technological integration, though not as a trend but an inevitable transformation, either by deliberate design or as an organic response to urban challenges; the smart city paradigm is reshaping the urban landscape with an intricate interplay between the internet of things (IoT) and poultry farming, presenting both opportunities and challenges for sustainable and inclusive development, particularly in management of increased ambient heat load as an aftermath of global climatic warming. Incidentally, tropical environments presents unique challenges for poultry farming due to high temperatures and relatively high humidity which can altogether lead to heat stress in birds (Mashaly *et al*., 2018). Heat stress can result in reduced growth rates, decreased egg production and increased mortality Lara *et al*., 2020). Traditional methods of controlling increased ambient heat load in a typical deep litter poultry pen such as ventilation and cooling systems can be costly and inefficient (Chen *et al*., 2019).

Specifically, assessing the implications of awareness levels of IoT-driven strategies to mitigate the impact of increased ambient heat load in poultry system management is essential by all critical stakeholders to guide smart city poultry production subsector towards ensuring animal food security within the densely populated Enugu, in the humid tropical environments. The poultry subsector is a significant contributor to the global food supply, with over 19 billion chickens raised annually (FAO, 2020). However, poultry system management in tropical environments faces significant challenges, particularly in terms of heat stress management. High temperatures and humidity in these regions can lead to increased ambient heat load in poultry pens, resulting in reduced productivity, decreased egg production and even mortality (Nascimento and Naas, 2020). To mitigate this issue, Internet of Things (IoT) technology has emerged as a potential solution. Some of the IoT-driven strategies for managing increased ambient heat load in poultry pens include; use of IoT-sensors to monitor environmental temperature, humidity and other environmental factors in real-time; which enable farmers to respond promptly to changes in conditions inside the poultry pen (Wang *et al*., 2020), use of automated ventilation and cooling systems enabled by IoT technology which optimizes ventilation and systems that ensure optimal air quality and temperature control (Chen *et al*., 2020), use of IoT-driven smart feeding and watering systems which optimizes nutrient intake and water consumption, thereby reducing heat stress and improving chicken welfare etc. IoT-driven strategies offer a more effective and efficient solution by enabling real-time monitoring and control of poultry pen conditions.

Despite the increasing concern about increased ambient heat load in poultry pens, many poultry farmers in smart cities lack awareness of IoT-driven strategies to mitigate heat stress inside poultry pens. This lack of awareness hinders adoption of innovative solutions to address heat stress. In assessing the level of awareness of IoT-driven strategies, farmers need education and training to understand the benefits and applications of IoT-driven strategies especially for deep litter systems of smallholder poultry management systems in smart cities.

https://doi.org/10.57046/RBET5362

The application of IoT technology has dramatically revolutionized agriculture with major effect being optimization effect in using natural and economic resources (Pathak *et al*., 2019). Also, many researches within the use of IoT in agriculture have ranged from impact of smart phones on the access of the farmers to new agricultural information and knowledge (Gunasekera *et al*., 2018), investigation of impact of agricultural IoT on deep learning (Bu and Wang, 2019), architectural framework based on IoT for food and agricultural systems (Verdou *et al*., 2019), the IoT academic endeavors for acquiring precision agriculture (Khanna and Kaurs, 2019), application of IoT in agriculture based on computer cloud (Hsu *et al*., 2020) etc.

Statement of problem

In a typical smart cities' poultry system management, some of the challenges of poultry production include high feed cost, disease outbreak, issues surrounding the inclusion of antibiotics in poultry feed, nutrition-related environmental issues, issues of water quality, inadequate investment, increased hatchability, limited access to markets, issues relating to water, electricity and disease control issues (Abbas *et al*., 2022). However, heat stress occasioned by increased ambient heat load in poultry pens has been reported to adversely affect feed intake, body weight, carcass characteristics and other traits associated with successful production, and is the principal cause of mortality for birds in tropical environments (Roberts and Ball, 1998).

Enugu has well-drained soil and favorable weather conditions year round, with an elevation of approximately 232 meters (732 feet) above sea level (Enugu State Agricultural Development Program, ENADP, 2021). The climate is characterized by two distinct seasons; rainy and dry season. The influence of climate change on poultry production and food security is evident in the study area (Annual Flood Outlook AFO, 2021).

Enugu State experiences a humid tropical climate with high temperature and rainfall throughout the year. The combination of high temperature and humidity exposes the broiler chicken to experiencing heat stress due to increase in ambient heat load. Poultry, sheep, goat and cattle are among the livestock reared in Enugu State (Enugu State Government Official Gazette No. 25, 1997).

IoT-driven strategies can help monitor and manage temperature, humidity and other environmental factors that contribute to heat stress in poultry pens. These strategies can also optimize feeding, breeding and health monitoring to reduce the impact of heat stress. Ozor and Nnaji (2011) had ascertained the different effects or impacts, adaptive/resilience capacities of vulnerable people to climate change in Enugu State. Enete (2014) had also concluded that climate have potential to lead to large disruptions in agricultural sector, including poultry production in Enugu State and have adverse impacts on food security. It also identified potential farming practices to adapt to climate change. Therefore, the mission to achieve robust poultry farming in smart cities of hot humid environments like Enugu, Nigeria, requires that concerted efforts be directed to assess the awareness level of IoT-driven mitigation strategies by poultry farmers. Hence, the implications of these findings for achieving animal protein security in a densely populated smart city like Enugu, Nigeria are significant. Addressing the gap in awareness and promoting the adoption of appropriate IoT-driven mitigation strategies of increased ambient heat load can enhance poultry productivity, improve farmers' livelihoods and contribute to overall food security. Policy makers and agricultural stakeholders can utilize these insights to develop targeted interventions, provide training programs, and enhance support mechanisms to bolster the resilience of poultry farming

https://doi.org/10.57046/RBET5362

systems in smart cities especially in the face of climate change challenges.

Incidentally, empirical studies that document poultry farmers' level of awareness of IoT-driven mitigation strategies in a smart city like Enugu, Nigeria cannot be found at the time of this study. This gap makes it difficult for the government or any other non-governmental organization that are interested in helping poultry farmers mitigate the negative impact of increased ambient heat load on poultry production to lay hands on any IoT-driven mitigation strategy. It is based on this gap that the study sought to assess the awareness level of IoT-driven mitigation strategies by poultry farmers in smart cities and its far-reaching implications for achieving sustainable animal protein security in Enugu, Nigeria.

Purpose of the study

The general purpose of the study was to determine the awareness level of IoT-driven strategies to be adopted by poultry farmers to mitigate increased ambient heat load inside poultry pens in smart cities and its implications for animal protein security in a smart city like Enugu, Nigeria. Specifically, the objectives of the study were to:

a. Describe the socio-demographic characteristics of poultry farmers in a smart city like Enugu, Nigeria.
b. Assess poultry farmers' perception of effect of increased ambient heat load on poultry species,
c. Assess poultry farmers' level of awareness of IoT-driven strategies to be adopted in poultry management systems of smart cities to mitigate increased ambient heat load in poultry pens and
d. Determine the challenges faced by poultry farmers in adopting IoT-driven mitigation strategies of increased ambient heat load in smart cities.

Research questions

The following research questions guided the study:

i. What are the socio-demographic characteristics of poultry farmers in Enugu?
ii. What are the poultry farmers' perceptions of effect of increased ambient heat load on poultry species in Enugu?
iii. What are the poultry farmers' levels of awareness of IoT-driven strategies to be adopted in mitigating the impact of increased ambient heat load inside poultry pens in Enugu?
iv. What the challenges faced by poultry farmers in adopting IoT-driven mitigation strategies to increased ambient heat load in Enugu?

METHODOLOGY

The study area

The research was conducted in a smart city called Enugu, Nigeria, situated at coordinates 6°30'N and 7°30'E. Enugu has well-drained soil and favorable weather conditions year round, with an elevation of approximately 232 meters (732 feet) above sea level (Enugu State Agricultural Development Program, ENADP, 2021). The climate is characterized by two distinct seasons; rainy and dry season.

The influence of climate change on poultry production and food security is evident in the study area (Annual Flood Outlook AFO, 2021). The presence of the Registered Poultry Farmers Association of Nigeria (PAN), Enugu State Chapter, and the preponderance of poultry production

https://doi.org/10.57046/RBET5362

make Enugu City appropriate for the study.

Population for the study: The population of the study is made up of randomly selected poultry farmers within the Enugu urban areas making up Enugu North, Enugu South and Enugu East Local Government Areas of Enugu State.

Sample selection procedure: 240 poultry farmers were selected from the urban areas within the study area. Snowball sampling technique was used to select the respondents. In this method, one identified poultry farmer referred the researchers to another poultry farmer.

Instrument for data collection: The instrument for data collection was a set of well-structured questionnaire. The questionnaire was made up of four sections. Section A contained items on the socio-demographic characteristics of the respondents. Section B elicited information on the farmer's perceptions about effect of increased ambient heat load on poultry species. The perceptions of the farmers were to be ticked against a 4-point Likert Rating Scale of Strongly Agree (4), Agree (3), Disagree (2) and Strongly Disagree (1). Section C obtained data on the farmer's level of awareness of IoT-driven strategies to mitigate the effect of increased ambient heat load on poultry species. This was done with a 4-point Likert rating scale of Highly Aware (4), Moderately Aware (3), Slightly Aware (2) and Not Aware (1). Section D elicited information on the constraints to adoption of IoT-driven strategies to mitigate the impact of increased ambient heat load in poultry species in the study area.

Validation of the instrument: The face validation of the instrument was established by three experts from the Department of Agricultural Education, Federal College of Education, Eha-Amufu, Enugu State, Nigeria.

Reliability of the instrument: Reliability of the questionnaire was established using Cronbach alpha method and reliability coefficient of 0.78 was obtained, showing high consistency of the test items.

Method of data collection: The respondents were visited in their homes and in their farms to obtain the information. 240 copies of the questionnaire were administered to the farmers and verbally explaining the contents with the help of two trained research assistants. Selected poultry farmers for the study were only those who could give reliable information. Their responses were then ticked in the questionnaire accordingly. All the 240 (100%) copies of the questionnaire were correctly filled out and returned.

Informed consent: A verbal consent was obtained from the respondents before the study commenced. The purpose of the study, the voluntary nature of participation and confidentially of data were duly explained to them, after which they gave their consent.

Data and statistical analysis: Descriptive statistics such as frequency, percentage and means were used to analyze data.

RESULTS AND DISCUSSION

Research question one: What are the socio-demographic characteristics of poultry farmers in the study area?

https://doi.org/10.57046/RBET5362

Table 1: Socio-demographic characteristics of poultry farmers in Enugu, Nigeria (N= 240).

Variables	Frequency	Percentage	Mean (x)
Age (years)			
31-40	28	11.6	
41-50	117	48.8	
51-60	55	22.9	
Above 60	40	19.11	45yrs
Gender			
Female	214	89.2	
Male	26	10.8	
Marital status			
Married	180	75	
Single	35	14.6	
Widow	25	10.4	
Education			
No formal education	38	15.8	
Primary education	78	32.5	
Secondary education	108	45	
Tertiary education	16	6.7	
Household size			
1-5	78	32.5	
6-10	127	52.9	
Above 10	35	14.6	8
Farm size			
Small scale	150	62.5	
Medium scale	48	20	
Large scale	42	17.5	
Farming experience (years)			
1-10	30	12.5	
11-20	40	16.8	
21-30	112	46.6	
31-40	38	15.8	
Above 40	20	8.3	21yrs
Cooperative membership			
Nonmember	206	85.8	
Member	34	14.2	
Annual income (N)			
<600,000.00	80	33.3	
600,001.00-700,000.00	102	42.5	N700,000.5
700,001.00-800,000.00	41	17.1	
>800,000.00	17	7.1	

Field Survey, 2024

https://doi.org/10.57046/RBET5362

Research question two: What are the poultry farmers' perceptions about the effect of increased ambient heat load on poultry species in the study area?

Table 2: Farmers' perceptions about the effect of increased heat load on poultry species in the study area.

S/N	Statement Item	Mean	SD	Remarks
1.	*I am concerned about the impact of increased ambient heat load on my poultry species*	3.17	0.72	Agree
2.	I have noticed some changes in the behavior of my poultry during hotter weather	3.11	0.49	Agree
3	I believe that increased heat affects the overall health and productivity of my poultry species.	3.22	0.53	Agree
4	I should take some specific measures to mitigate the effects of increased ambient heat load on my poultry species	3.21	0.53	Agree
5	Increased ambient heat load affects egg production in chicken	3.40	0.91	Agree
6	Increased ambient heat load affects feed intake in chicken	3.10	0.71	Agree
7	Increased ambient heat load affects weight gain in chicken	2.62	0.50	Agree
8	Increased ambient heat load leads to higher mortality in chicken	2.91	0.59	Agree
9	Increased ambient heat load affects quality of meat or egg	3.11	0.49	Agree
10	Increased ambient heat load leads to financial losses due to heat-related issues in poultry farming operations.	3.09	0.55	Agree
11	I need to stay informed about best practices for mitigating the impact of increased ambient heat load.	2.73	0.49	Agree

SD= Standard error
Source: Field Survey, 2024

Research question three: What are the poultry farmers' levels of awareness of IoT-driven strategies to mitigate the impact of increased ambient heat load on poultry species in the study area?

https://doi.org/10.57046/RBET5362

Table 2: Farmers' perceptions about the effect of increased heat load on poultry species in the study area.

S/N	Item Statement	Mean	SD	Remark
1	Are you familiar with IoT-driven strategies aimed at mitigating increased heat load in poultry farming?	2.9	0.72	Aware
2	Are you aware of implementation of any IoT-driven solutions to manage heat stress on your poultry farm?	2.9	0.68	Aware
3	Are you aware of challenges in adopting IoT-enabled technologies for heat management?	3.2	0.71	Aware
4	Are you aware IoT-enabled technologies can effectively monitor and regulate temperature fluctuations on your farm?	2.9	0.86	Aware
5	Are you aware of the specific IoT device or sensors designed for monitoring heat stress in poultry species?	2.7	0.70	Aware
6	Are you aware of reliability of IoT-based solutions in predicting heat related issues on your farm?	2.3	0.16	Not Aware
7	Are you aware of any training or guidance on integrating IoT technologies for heat stress management?	2.3	0.62	Not Aware
8	Are you aware of the long run cost-effectiveness of investing in IoT technologies for heat load mitigation?	2.4	0.86	Not Aware
9	Are you aware of any factor that can influence your decision to invest in IoT-enabled solutions for heat stress management?	3.10	0.71	Not Aware
10	Are aware of how to stay informed about new advancements in IoT-enabled technology for poultry farming?	2.20	0.68	Not Aware
11	Are you aware of any concerns regarding data privacy and security when using IoT devices on your poultry farm?	1.92	0.39	Not Aware
12	Are you aware of any technical difficulties or limitations with existing IoT solutions for heat stress management?	1.78	0.42	Not Aware
13	Are you aware of any collaborations with other farms or agricultural experts to share insights on IoT applications for heat load management?	2.30	0.68	Not Aware
14	Are you aware of government policies or incentives that could encourage adoption of IoT technologies for heat stress management?	1.99	0.58	Not Aware
15	Are you aware of the perceived potential impact of IoT-driven strategies on improving livestock productivity during heat waves?	2.20	0.68	Not Aware

SD= Standard Deviation
Source: Field Survey 2024

Research question four: What are the challenges poultry farmers face in adopting IoT-driven strategies to mitigate the impact of increased ambient heat load on poultry species in the study area?

https://doi.org/10.57046/RBET5362

Table 4: Challenges or Constraints limiting Poultry Farmers from adopting IoT-driven strategies to mitigate impact of increased ambient heat load on poultry species in the study area (N= 240).

S/N	Challenges of Constraint	Frequency	Percentage
1	Lack of awareness	70	29.2
2	Lack of fund/high initial investment	55	22.9
3	Limited access to technology	43	17.9
4	Inadequate training	34	14.2
5	Poor extension contact	20	8.3
6	Water availability	13	5.4
7	Climate variability	5	2.1

Field Survey, 2024

Discussion of the results

Table 1 revealed that the majority of the poultry farmers (48.8) were within the age range of 41-50 years with the mean age of 45 years. This indicates that the poultry farmers in Enugu, Nigeria are still within active and productive age which is a requirement for effective poultry farming. Because poultry farming is quite strenuous, it implies that people within the active productive age are more likely to engage in it as a means of livelihood with its attendant daily activities. This is likely to enhance their economic activities and family food security. This agrees with the findings of Ekwe (2019) who asserted that most of the respondents are still at the productive age of 48 years and are still able to provide family food security. The gender distribution indicates that majority of the poultry farmers (89.2%) were females. This is true as Babayem *et al*., (2017) asserted that women were more involved in poultry production.

Education as a status indicates that greater proportion (45%) had secondary education. However, it was shown that approximately 84.7% of the respondents had formal education which is expected to increase their level of awareness of the impact of thermal stress on poultry production and the mitigation strategies. This agrees with the findings of Ibok, Bassey, Atairet and Obot (2014). When farmers are averagely younger or still within their reproductive age, have formal education up to secondary school level, have reasonable number of years of experience in poultry farming, associate with other poultry farmers through membership of cooperative societies, have access to fund through earning of income from poultry farming; they are more likely to acquire and utilize IoT devices and may as well be informed, be aware of the impacts of heat stress on poultry production, have positive perception of some of the IoT-driven strategies used in mitigating heat load in poultry farming. Household size indicates that greater proportion (52.9%) had a size ranging from 6-9 with a mean of 8 persons which is large and a ready source of labour. Okocha *et al*., (2022) had reported household labor as a major source of labor in egg-farming enterprises in Enugu East Local Government of Enugu State.

Farm size revealed that majority (62.5%) engaged in small scale poultry farming which could be as a result of lack of credit facilities and mostly being operated within the homestead of the poultry farmers. It is expected poultry farming at small scale level will be able to mitigate thermal stress more effectively than those engaged in large scale poultry farming. Also, a reasonable number of the farmers (46.6%) having between 21-30 years of farming experience implied a higher level of awareness of mitigation strategies of thermal stress which could affect their farming output.

The majority (42.5%) had an average annual farm income of between N600,000.00 and

https://doi.org/10.57046/RBET5362

N700,000.00 while monthly income was estimated to be N72,500.00. The finding implies that the farmers had relatively low income despite their larger households. They may not the much needed financial capacity to cope with the negative effect of thermal stress in their poultry farming. This is true as the mitigating strategies require finance. This conforms with the findings of Okocha *et al*., (2022). Cooperative membership indicates that most farmers (85.8%) do not belong to any cooperative society. It implies that they may not have financial and input supports like members from cooperatives to mitigate the threat of the thermal stress. Henri-Ukoha, Ibekwe, Chidiebere-Mark, Ejike and Oparadim (2013) asserted that cooperative membership influence productivity positively.

The results on socio-economic characteristics of the poultry farmers in the study area agrees with Below et al., (2012) who had used an activity-based adaptation index (AAI) to explain the relation between socio-economic variables of farmers and farmer's adaptation towards climate change in Tanzania while Adger and Vincent (2005), Fussel and Klein (2006); had advocated for an understanding of the socio-economic status of farmers as key determinants of adaptive capacities to climate change. They both stated that this is critical to developing well-targeted adaptation policies to mitigate the impact of increased heat load.

The result shown in Table 2 indicated that the items had a mean range of 2.62 to 3.22. All of the mean scores were above 2.50. The result shows that the respondents agreed with all the identified items as their perception about the impact of increased ambient heat load on poultry species inside poultry pens in the study area. The standard deviation ranged from 0.49 to 0.91, indicating closeness in the response of the poultry farmers. This implied that the respondents shared similar perceptions about the impact of increased ambient heat load on poultry species.

Table 3 results indicated that the items had a mean range of 1.78 to 3.20. The respondents were not aware of majority of identified IoT-driven strategies outlined to mitigate the impact of increased ambient heat load in the study area. This majority of lack of awareness of internet of things (IoT) could be attributed the about total of 93.3% of the respondents having only basic and post-basic level of education. This resulted can be extrapolated on the findings of Mohamed, (2020) who identified influential factors including socioeconomic factors in the adoption and then application of IoT in smart farming by farmers with a contextual approach in Iran. The standard deviation ranged from 0.86 to 1.02, indicating closeness in the response of the poultry farmers. However, the awareness of the respondents regarding their awareness could be related to the findings of Gunasekera *et al*., (2018) that about 230 interviewed farmers were using their smart phones for improving the conditions of their farm operations. Regarding the adoption of a particular stress mitigation strategies out of the several strategies adopted by same farmer, Fatuase and Ajibefun (2014), stated that most farmers adopt several climate change adaptation or heat load mitigation strategies to avert the negative impact of increased ambient heat load and its attendant effect such as thermal stress. Adewale (2023) had asserted that the socioeconomic condition of the farmer will influence the farmers' adoption of mitigation strategy while Deressa *et al*., (2009) argued that the farmers' level of education determines the kind of strategy to be adopted.

Table 4 presents the frequency distribution of the challenges or constraints limiting poultry farmers from adopting IoT-driven strategies in mitigating the negative impact of increased ambient heat load in the study area. Lack of awareness ranked highest with 29.2% of the farmers. This reflects the observation by Adewale (2023) on how poultry farmers adopt the available adaptation or

https://doi.org/10.57046/RBET5362

mitigation strategies and the socio-demographic factors responsible for their choice, particularly in their socioeconomic capability to mitigate heat stress related challenges. Approximately, 22.9% indicated that lack of fund/high initial investment which limited farmers' access to productive resources could be linked to the report by Hassan and Nhemachena (2008) highlighting socioeconomic status of a poultry farmer among other things to limit farmers' climate change adaptation. Limited access to technology (17.90%), inadequate training (14.20%), poor extension contact (8.3%), water availability (5.4%) and climate variability (2.10%) were expressed by farmers. Limited access to technology and inadequate training could be linked to lack of awareness of workshops, industry guidelines, government policies/programs, lack of formal education or lack of access to sources of information such as radio and television which is supported by George and Stylianou, (2018).

CONCLUSION AND RECOMMENDATION

Increased ambient heat load resulting from climate change has a pronounced influence on poultry species and its production system. The study determined the animal protein security implications in smart cities if poultry farmers are aware of IoT-driven strategies in mitigating increased ambient heat load inside poultry pens, especially in the wake of the prevailing vagaries of climate change. 240 poultry farmers within the urban areas of Enugu, Nigeria where interviewed with structured questionnaires to obtain primary data. The data were analyzed using descriptive statistics and likert-rating scale. Hence, the study concluded that majority of poultry farmers shared similar perceptions about the impact of increased ambient heat load on poultry species but however were not aware of many of the IoT-driven strategies to mitigate the impact and were limited by a number of constraints or challenges to adopting IoT-driven mitigation strategies which altogether could improve poultry production system and help to achieve animal protein security in a smart city like Enugu, Nigeria.

Recommendations

It was recommended that:

1. Poultry farmers in smart cities should be exposed to an interactive session with extension agents within their localities to be enlightened on the impact of increased ambient heat load on poultry production systems,
2. Extension agents and poultry farmers in smart cities should be trained by ICT experts on the use of ICT devices to enable them get exposed to IoT-driven strategies used to mitigate the impact of increased ambient heat load inside poultry pens
3. Poultry farmers should be assisted with credit facilities, improved and adaptable species of day-old chicks,
4. Government and all the stakeholders in the poultry industry should harmonize and establish guidelines regarding adoption and implementation of IoT-driven strategies in the mitigation and management of heat load in poultry farming in humid tropical,
5. Poultry farmers should be well informed on efficient, cost-effective and sustainable IoT-driven strategies to ensure efficient poultry production systems as these would ensure the achievement of animal protein security in a smart city like Enugu, Nigeria.
6. It is lastly recommended that further research is needed in the different and most effective awareness methods to be adopted by poultry farmers, location-specific IoT-enabled mitigation strategies and the cost of implementing a location-specific IoT-enabled mitigation strategy as this will bridge the gap in knowledge of utilizing IoT-driven strategies in

https://doi.org/10.57046/RBET5362

mitigation of increased ambient heat load within poultry management systems to ensure sustainable animal protein security in smart cities.

References

Abbas G, Jaffey S, Hashmi AH, & Tanveer AJ (2022). Prospects and Challenges of adopting and implementing smart technologies in poultry production. Pakistan Journal of Science 74(2).

Adger WN & Vincent K (2006). Uncertainty in adaptive capacity. *Comptes Rendus Geosciences,* 337:399-410

Annual Flood Outlook (AFO) (2021). Annual Publication of Nigeria Hydrological Services 2021.

Adewale IO (2023). Intensity of adaptation to heat stress in poultry farms: A behavioral analysis of farmers in Ondo State, Nigeria. *Journal of Thermal Biology* 115. Available at https://doi.org/10.10164/j.thrbio.2023.103614

Annual Flood Outlook (AFO) (2021). Annual Publication of Nigeria Hydrological Services 2021.

Babayemi OJ, Ajayi MO, Akinsola SO, & Dauda MO (2017). Assessment of meat demand: A case study of University of Ibadan for beef enterprise. *Nigerian Journal of Animal Production*, 44(3), 186-193.

Below TB, Mutabazi KD, Kirchke D, Franke C, Sieber S, Sirbert R, & Tscherning K (2012). Can farmer's adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change* (22) pp. 223-235.

Bu F & Wang X (2019). A smart agriculture IoT system based on deep reinforcement learning. J. Future Generation Computer Systems (99), 500-507. https://doi.org/10.1016/j.future.2019.04.041

Chen Y, Liu X, & Li Z (2020). Development of an IoT-based smart feeding system for poultry. Journal of Intelligent Information Systems, 57(2), 257-271.

Chiemeke SC (2024). Smart Cities and Emerging Technologies. Lead Paper Presentation at the 5th Scientific Conference of the Nigeria Academy of Science, 24th January 2024. Available at https://www.nas.org.ng

Deressa I, Hassan RM, Ringler C, Alemu T, & Yusuf M (2008). Determinants of farmers' choice of adaptation method to climate change in the Nile Basin of Ethiopia. *Global Environ. Change*, 19(2), pp. 248-255. https://www.doi.org/10.1016/j.gloenvcha.2009.01.002

ENADP (2021). Enugu State Agricultural Development Program, Annual Report. Pp. 35. Published by Enugu State Government of Nigeria.

Enugu State Government Official Gazette (1997). Enugu State Official Gazette No. 25.

Enete IC (2014). Impacts of climate change on agricultural production in Enugu State, Nigeia. *J. Earth Sci. Clim. Change* 5:234 https://doi.10.4172/2157-7617.1000234

https://doi.org/10.57046/RBET5362

Ekwe KC (2019). Consumption frequency of selected Animal protein sources among rural households in Enugu State, Nigeria. *Journal of Community and Communication Research*. 4(2), 53-61.

Fatuase A & Ajibefun I (2014). Perception and adaptation to climate change among farmers in selected communities of Ekiti State, Nigeria. *Gaziosmanpasa Universitesi Ziraat Fakultesi Dergisi*, 31(3), pp. 100-113.

Food and Agricultural Organization (2020). Food and Nutrition. FAO Fifth *World Food Survey*, 11(2), 53-63. Food and Agricultural Organization.

Fusel HM & Klein RJT (2006). Climate Change vulnerability assessment: an evolution of conceptual thinking. *Climate Change* 75, 301-329.

George A & Stylianou A (2018). Evaluation of the radio as an agricultural information source in rural areas. *Journal of Agricultural and Food Information* 19(4). Pp. 362-376.

Gunasekera K, Barero AN, Vasulan F, & Bryceson KP (2018). Experiences in building an IoT infrastructure for agricultural education. J. of Procedia Computer Science (135), 155-162. https://doi.org./10.1016/j.procs.2018.08.161

Hassan RM & Nhemachena C (2008). Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. *Afri. J. Agric. Resour. Econ*., 2(311-2016-552). Pp. 83-104.

Henr-Ukoha A, Ibekwe UC, Chidiebere-Mark NM, Ejike R, & Oparadim H (2013). Determinants of food security in female-headed households under tenure system in Abia State, Nigeria. *Global Journal of Agricultural Research*. 1(2):48-57.

Hsu T, Yang H, Chung Y, & Hsu C (2020). A creative IoT agriculture platform for cloud fog computing. J. of Sustainable Computing Informatics and Systems (28), 100285. https://doi.org/10.1016/j.suscom.2018.10.006

Ibok OW, Bassey NE, Atairet EA, & Obot O (2014). Food Security Determinants among Urban Food Crop Farming Households in Cross River State, Nigeria. *Asian Journal of Agricultural Extension, Economics and Sociology*. 3(1), 76-90.

Khanna A & Kaur S (2019). Evolution of Internet of Things (IoT) and its significant impact in the field of Precision Agriculture (157), 218-231. https://doi.org/10.1016/j.compag.2018.12.039

Lara LJ & Rostagno MH (2020). Heat stress in poultry: A review. Journal of Animal Science, 98(11), 1-12.

Mashaly MM & Abdel-Moneim AE (2018). Heat stress in poultry: A review. Journal of Animal Science, 96(11), 4511-4523.

Nascimento ST & Naas IA (2020). IoT applications in poultry production: A review. Journal of Agricultural Science and Technology, 20(3), 537-548.

https://doi.org/10.57046/RBET5362

Okocha OI, Uloh EV, Ede AE, Uwajimgba AN, & Sombu T (2022) Socio-demographic Characteristics and Economics of Egg-farming Enterprise among households in Enugu East Local Government Area of Enugu State. *Journal of Family and Society Research* 1(2), December 2022, pp.150-158.

Ozor N & Nnaji C (2011). The role of extension in agricultural adaptation to climate change in Enugu State, Nigeria. *Journal of Agricultural Extension and Rural Developmen*t 3(3), pp. 42-50. Available online at https://academicjournals.org/JAERD

Pathak A, AmazUddin M, Abedin MJ, Andersson K, & Mustafa R (2019). IoT based Smart System to support agricultural parameters: A case study. J. Procedia Computer Science (155), 648-653. https://doi.org/10.1016/j.procs.2019.08.092

Roberts JR & Ball W (1998). Effect of Heat Stress on Egg and Egg Shell Quality in five Strains of laying hen. *Proc. Aust. Poult. Sci. Sym*. 53(2):295-296

Verdouw C, Sundmaeker H, Tekinerdogan B, Conzon D, & Montanaro T (2019). Architecture framework of IoT-based food and farm systems: A multiple case study. J. of Computers and Electronics in Agriculture (165). https://doi.org/10.1016/j.compag.2019.104939,

Wang L, Nishida H, Ogawa Y, & Konishi T (2020). Prevention of oxidative injury in PC12 cells by a traditional Chinese medicine, Shengmai San, as a model of an antioxidant-based composite formula. *Biological and Pharmaceutical Bulletin*, 26(7):1000-1004.