Economics of Poultry Manure Use as Fertilizer in Imo State

Nkwocha, G. A.[1], Ihenacho, L. U.[2], Anukam, K. U.[3], Onuruka, A. U.[4] and Remigius, C. O.[5]*

[1]Faculty of Agriculture, Alex Ekwueme Federal University Ndufu – Alike Ikwo, P.M.B. 1010, Abakaliki, Ebonyi State
[2]Department of Agricultural Technology, Imo State Polytechnic, Omuma, P.M.B 1472, Owerri, Imo State
[3]Department of Animal Production and Health Technology, Imo State Polytechnic, Omuma, P.M.B 1472, Owerri, Imo State
[4]Department of Agricultural and Bio-Environmental Engineering, Imo State Polytechnic, Omuma, P.M.B 1472, Owerri, Imo State
[5]Department of Business Administration and Management, Imo State Polytechnic, Omuma, P.M.B 1472, Owerri, Imo State

KEYWORDS

Evaluation,
Imo state
Manure generation,
Poultry manure,
Sustainable development,

***CORRESPONDING AUTHOR**

geffmacnkwo@gmail.com
+2348035078259

ABSTRACT

The study was carried out in three agricultural zones notably Owerri, Okigwe and Orlu to evaluate the economics of poultry manure use as fertilizer in Imo State, Nigeria. A total of 240 respondents were randomly selected and interviewed from twelve local government areas drawn from the three zones. Data collected were on socio-economic characteristics, stock size and manure generation, poultry manure and environmental pollution and economic consideration of recycling poultry droppings. Structured questionnaires were used for data collection. Analytical tools used were descriptive statistics such as mean, frequency distribution and percentages. The result of the survey revealed that the dominant players in the poultry industry are those between the ages of 41-50 years implying that in future, there will be decline in productivity since youths are not actively participating in the business. The survey observed that 78.33% of poultry farmers in the state stores poultry manure within the farm premises which directly contributes to environmental pollution. Result also shows that 70.83% of poultry farmers recycle poultry manure into vegetable production while those with larger output sell the excess to crop farmers. The economic benefit of recycling poultry manure by farmers for economic prosperity is high (90.83%) and this is traced from its role in conservation agriculture and soil enrichment. The study therefore recommends the use of poultry manure by all farmers as Nigeria can conserve its foreign exchange by reducing its fertilizer importation up to 50%.

INTRODUCTION

Agriculture is the world's oldest and largest primary industry and its role in the economic life of virtually all nations regardless of their state of development cannot be underscored (Brueno, 2020).One of the most important aspect of African or Tropical Agriculture is farm animal production which according to International Institute of Rural Reconstruction (IIRR) and African Conservation Tillage (ACT) provides power, manure, hides, milk and meat to improve the standard of living of the human populace (IIRR and ACT, 2005).

Livestock with particular reference to poultry production generates waste products which directly or indirectly not utilized constitutes environmental pollution. In the poultry industry, two main types of waste are produced depending on the rearing system adopted in the farm. They are waste from the deep litter

systems and cage layer waste (Shibi Thomas *et al*., 2020). In developing countries like Nigeria, the technology for converting poultry waste into biogas or biofuel is yet to be developed hence the recycling as manure and landfill disposal.

Poultry manure (excreta) which is obtained from poultry or bird droppings is one of the best organic manures. Poultry manure is composed of poultry beads, feathers, water droplets, poultry feed and straws of rice husks which can be utilized to generate renewable energy (Agblevor *et al*., 2010). Yousaf *et al.* (2022) reported that animal manure has considerable potential as soil conditioners and fertilizers for the home gardeners, florists, crop farmers and nursery operators. Animal waste is therefore a valuable resource because it is high in salts, micro and macro elements. It contains thirteen (13) essential plant nutrients that are used by plants which include nitrogen, phosphorous, potassium, calcium, Magnesium, Sulphur, manganese, copper, zinc, chlorine, boron, iron and molybdenum (Shibi Thomas *et al*., 2020). Suffice it to say that using poultry manure as fertilizer provides both macro and micro nutrients to crops and plants for their growth and productivity.

European countries had achieved a milestone of 20% renewable energy in which biomass energy had major portion (Eurostat, 2019; World Bank, 2021), and these countries have set a target to achieve 30% of total electricity from renewable energy resources by 2030 (Agency, 2018). Sub-Saharan Africa and Nigeria in particular, the African giant is yet to acquire this modern technology of thermal conversion method (Pyrolysis) hence the resort to the application on agricultural land as fertilizer and landfills.

Sustainable agriculture ensures resource efficiency by integrating biochemical, economic and physical sciences to develop new practices that are safe, cost effective and environmentally friendly. However, such a system must support an ecosystem that accommodates and provides for the development of all classes of plants and animals (Si Ho Han *et al*., 2016).

Poultry manure fertilizer as a soil amendment to sustain crop yields in developing countries and the world all over has been found effective for major crops and also increases the soil's water infiltration rates directly proving the structure (Adeleye*et al*., 2010; Aniefo *et al*., 2013; Ishieze *et al*., 2019,)

A chicken will produce approximately 0.23 kilogramme of fresh manure from a kilogramme of feed consumed with a moisture content of about 75 percent (University of Georgia Extension News, 2022). The manure produced by poultry usually loses water due to evaporation, resulting to a final product of 20-40% moisture content depending on bedding type and quantity, birds' concentration, watering equipment and ventilation system.

Hamma *et al*. (2017) observed that 12t/ha poultry manure produced higher mean values of vine length, number of leaves, leaf area, fruit weight, girth and commutative yield of cucumber (Cucumis sativum) while Eze and Baiyeri, (2019) reported higher fruit yield/ha at the rate of 10t/ha but however, recorded decreased yield at a rate above 10t/ha. Ayeni *et al*. (2008) reported 30 and 43 percent increase on immediate basis, 73 and 93 percent on residual basis for poultry manure at 5t and 10t/ha on the production of crops. The impact of poultry manure on crop productivity was also measured by Ikeh *et al*. (2012) who observed significant impact on the application of 10t/ha compared than 0 and 4t/ha on plant height, number of leaves, branches and number of fruits.

Atusa (2018) recommended that 20t/ha should be adopted for the cultivation of Occimum gratissium. Furthermore, reiterated that plants that received different levels of 15t/ha, 20t/ha, 25t/ha and 30t/ha were not significantly different in the number of leaves, branches, total leaf area, weights of harvested leaves and inflorescences. Irene *et al*. (2015) opined that 6t/ha poultry manure best supports the performance of fluted pumpkin in the degraded ultisol.

In an experiment carried out by Si Ho Han *et al*. (2016) on the effect of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera lin.) in a nursery system in the Forest Practice Research Centre of Korea Forest Research Institute, it was discovered that organic manure significantly increased the soil pH and the concentration of nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium.

In Imo State, it appears that poultry manure is not used to its maximum potential because of dearth of information on its economic value as a source of plant nutrients, failure to recognize how and where to use it and the inability of crop and poultry farmers early adoption of this innovation as a strategy for environmental sustainability and hence the relevance of this study.

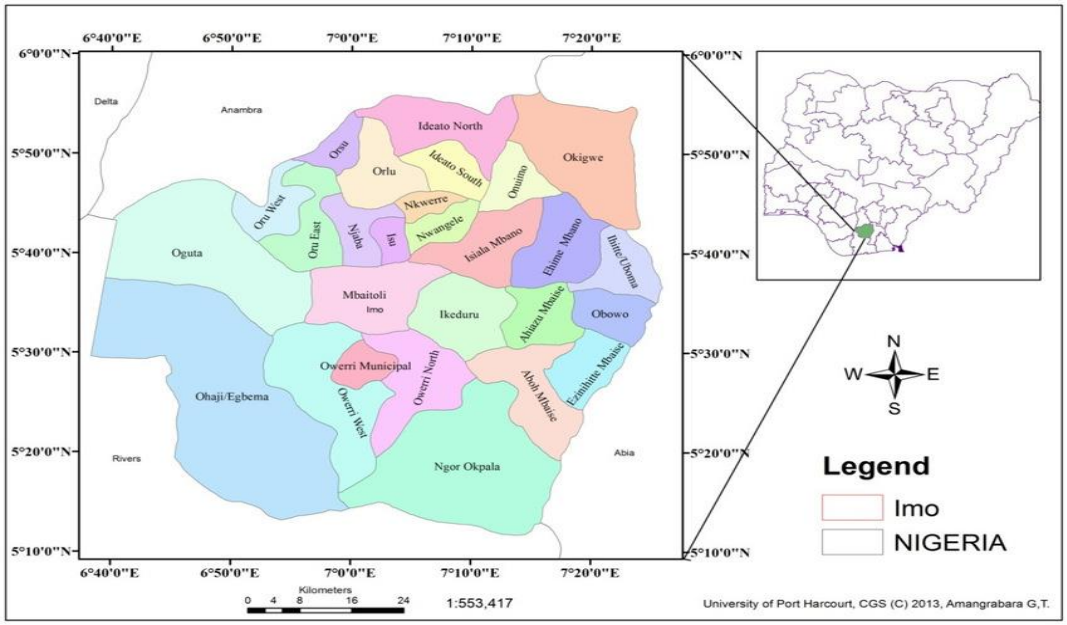
MATERIALS AND METHODS

The Study Area.

The study was conducted in three agricultural zones of Imo State notably, Owerri, Orlu and Okigwe, respectively (Fig 1). Imo State is a state in the South-East geopolitical zone of Nigeria, bordered to the north by Anambra State, River State to the west and South, and Abia State to the East (Encyclopaedia Britannica, 2022). Geographically, the state is divided between the Niger Delta swamp forests in the Far East and the drier Cross-Niger transition forests in the rest of the state. The State is located between latitude 4°45′N and 7°15′N and longitude 6°50′E and 7°25′E, with an area of about 5100 km^2. It lies within the humid tropics and is generally characterized by a high surface air temperature regime year-round. Mean minimum temperature is 23.5°C and mean maximum temperature is 32.1°C. Imo typically receives about 234.25 millimeters (9.22 inches) of precipitation and has 268.89 rainy days (73.67% of the time) annually. Two seasons, wet and dry, are observed in the year. The rainy season begin in April and lasts till October. The State experiences climate variations following rainfall variability (NIMET, 2018).

The major occupation of the people is farming while livestock production which borders on the rearing of poultry, pigs, sheep, goat, fisheries etc though more of a small holder dimension is an integral part of the people of Imo State.

Fig 1: Map of Imo State showing her Local Government Areas



Source: Ministry of Works and Housing Owerri, Imo state

Sampling Technique

Multi-stage procedure involving stratified, purposive and random sampling technique was used in the selection of sample. Imo State was stratified based on the three existing agricultural zones namely Owerri, Okigwe and Orlu. Four local government areas were selected from each agricultural zone making a total of twelve local government areas out of the 27 local government areas in Imo State. In Owerri agricultural zone, Ezinihitte -Mbaise, Owerri West, Owerri North and Ngor okpala were purposively selected, in Okigwe Zone, Isiala Mbano,Onimo, Okigwe and Obowo were chosen while in Orlu zone, Ideato South, Oru West, Ohaji/Egbema and Nkwere were purposively selected (Table 1). Twenty (20) poultry farmers were randomly selected from each LGA making up a total population of 240 sampling size (Table 1).

Table 1: Global Positioning System (GPS) of sampled zones in Imo State

S/N	Zone	LGAs Selected	GPS Coordinates	Total Number of Respondents
1	Owerri	4	$5^0\,29^1\,20.6124^0$ N and $7^0\,1^1\,3.3168^{11}$ E	80
2	Orlu	4	$5^0\,47^1\,44.34^{11}$ N and $7^0\,02^1\,6.47^{11}$E	80
3	Okigwe	4	$5^0\,47^1\,45.01^{11}$ N and $7^0\,21^1\,2.02$ E	80

Source: Imo State GPS Coordinate, www.countrycoordinate.com

Method of Data Collection

The researchers collected both primary and secondary data for this study. Primary data came through the use of structured questionnaires and personal observation by the researcher. In collecting such data, the researcher asked the larger and smaller farm holders relevant questions pertaining to poultry production and recycling of poultry dropping (manure). The secondary data for this survey were gathered from existing findings in form of books, Journals, Newspapers, Magazines, Bulletins, Project work etc. through literature review.

Data Analysis Techniques

The data collected were analyzed using descriptive statistics which include measure of central tendencies such as mean, frequencies and percentages.

RESULTS AND DISCUSSION

Socio-economic characteristics of poultry farmers in the study area

Age is one of the socio economic characteristics influencing output and labour availability in the poultry industry. Respondents whose ages ranged between 41to 50 years dominated the farming population (33.33%)(table 1). This was followed by age range of 31-40 years (29.17%). According to Nigerians National bureau of statistics, (2020) about 65% of the population was aged between 16-40 in 2015 and of these 37% (about 42 million people) were engaged in agriculture (Alawode, 2016). However, the dominant players in the poultry industry are those between the age of 41-50 years implying that in the years to come there will be a decline in productivity since ageing is a complex multifactorial process characterized by progressive changes in body tissue, which eventually lead to decline in function and death of individual (Jayanthi *et al.*, 2010).

40% of poultry farmers have secondary education followed by tertiary education which recorded 29.17%.Poultry farming on global outlook is going scientific and technical training is required for entrepreneurial skills and competence. Greater proportions of the farmers are males (58.33%). Poultry production is a seven day a week job and intensive labour is needed for maximum efficiency and profitability which of course may not be achieved by the female counterparts.70% of poultry farmers population in the area are married and the implication is that high level of responsibility would be ensured and married couples are better considered in loan/credit grants from financial institution than youths and moreover, their children also contributes in daily routine operations which hitherto enhances productivity (Mgbakor and Nzeadachie, 2013). 33.33% of poultry farmers in the area have 6-9 years cognate experience while those of 20 years and above farming experience is only 5%. The data on farming experience shows that the awareness on poultry production just came a decade ago.

59.17% of poultry farmers reared their stocks intensively while 33.33% are on semi-intensive system. Intensive system generates birds with faster growth rate and gives room for record keeping which is an efficiency assessment factor.

Table 2: Socio-Economic characteristics of respondents in the study area

i. Age range	**Frequency**	**Percentage**
21-30	40	16.67
31-40	70	29.17
41-50	80	33.33
>50	50	20.83
Total	**240**	**100.00**
ii. Sex	**-**	**-**
Male	140	58.33
Female	100	41.67
Total	**240**	**100.00**
iii. Marital status	**-**	**-**
Married	168	70.00
Single	72	30.00
Total	**240**	**100.00**
iv. Educational Level	**-**	**-**
No. Formal Education	30	12.50
Primary Education	44	18.33
Secondary Education	96	40.00
Tertiary Education	70	29.17
Total	**240**	**100.00**
v. Years of farming Experience	**-**	**-**
<5	68	28.33
6-9	80	33.33
10-15	60	25.00
16-19	20	8.34
20 and above	12	5.00
Total	**240**	**100.00**
vi. System of poultry management	**-**	**-**
Intensive	142	59.17
Semi-intensive	80	33.33
Extensive	18	7.50
Total	**240**	**100.00**
vii. Types of feed used in feeding Stock (Poultry)	**Frequency**	**Percentage**
Commercial formulated feed	154	64.17
Locally formulated feed	86	35.83
Total	**240**	**100.00**

Source: Field Survey, 2022

Stock size and manure generation.

Majority of poultry farmers (52.50%) reared less than 100-110 birds in the area implying that they are mainly small holder poultry dimension while 40% kept stocks ranging from 110-1000 birds. 7.5% of poultry farmers are under the category of medium scale keeping 1100-10,000 birds. Stocking rate in the poultry industry determine the quantity of waste that are generated from poultry units (Barura and Omodara, 2018). Moreover, the quantity of waste generated varies depending on the rate of consumption of feed and water intake. Statistics revealed that poultry farmers housing 110, 1000 and 10,000 birds generates 5,913.6, 53,760 and 537,600 kg of droppings (approximately 30-40% moisture content) on yearly basis respectively (Mariusz *et al*., 2019; University of Georgia Extension News, 2022) and this aligns with the findings of Baruwa and Omodara (2018) that effective waste management method is a panacea for a long-term productivity, growth and environmental sustainability of poultry enterprises. 70.83% of poultry farmers in the area recycle their manure into vegetable production while those with larger output sell the excess to crop farmers.

Table 3: Stock size and manure generation

Characteristics	Frequency	Percentage
i. How many birds do you keep	-	-
100-110	126	52.50
111-1000	96	40.00
1100-10,000	18	7.50
Total	**240**	**100.00**
ii. Do you recycle your poultry manure	**-**	**-**
Yes	170	70.83
No	70	29.17
Total	240	**100.00**
iii. Do you consider the use of Poultry Manure in Crop production laudable?		
Yes	186	77.50
No	54	22.50
Total	240	**100.00**

Source: Field Survey, 2022

Poultry manure as pollutant

72.50% of poultry farmers are of the view that poultry manure is a very serious threat to HUMAN health and THE environment while 27.50% of respondents maintained that the use of poultry manure should be intensified considering the fact that it doesn't constitute environmental menace (Table 3). 78.33% of respondents stores poultry manure within the farm premises despite their contention that the product is an environmental menace while 21.67% dispelled the notion that it doesn't constitute health nuisance but rather binds soil particles together, provides home for earthworms and other beneficial organisms and improves the soil. 81.67% of respondents agreed that channeling this by product in crop production will help in reducing environmental pollution emanating from the odour threshold and directly improves irrigation efficiency, soil retention and uptake of plant nutrients (Shibi Thomas *et al.*, 2020).

Economic consideration of recycling poultry manure.

Table 4 indicated that 90.83% of poultry farmers in the state are of the opinion that poultry manure is the best manure in conservation agriculture, because it improves soil fertility and leads to higher yields of crops in terms of increased productivity, and soil health improvement

On the rate of manure utilization, 59.16% of respondents applied poultry manure at the level of 10-20t/ha while 29.17% applied 40t/ha. 8.34% of respondents apply at the rate of 45-50t/ha while 3.33% of respondents are ignorant of any specific application rate but rather contented that the utilization depends on output or stocking capacity.

91.66% of poultry farmers in the state reported that poultry manure can be used to cushion the effect of high cost of poultry feed. For instance, at an estimated rate of N400.00 per bag of poultry manure (mixed with wood shavings and other organic materials), a poultry farm that uses 225 bags of feed, would generate about 75 bags of poultry waste which attracts N30,000 on monetary terms and when added to farm income raises the profit margin for broiler enterprise to about 16.80% (Bamire, and Amuyoyegbe, 2013).

Table 4: Poultry manure as a pollutant

Characteristics	Frequency	Percentage
i. Does air emission from poultry manure constitute a threat to human health or environment?	-	-
Yes	174	72.50
No	66	27.50
Total	**240**	**100.00**
ii. Do you store your poultry manure within the farm premises?	-	-
Yes	188	78.33
No	52	21.67
Total	**240**	**100.00**
iii. Do you consider poultry manure as environmental menace?	-	-
Yes	172	71.66
No	68	28.34
Total	**240**	**100.00**
iv. Does Poultry manure constitute handling problems due to the formation of crust and sediments during storage?	-	-
Yes	93	77.50
No	27	22.50
Total	**120**	**100.00**
v. Does the use of poultry manure in crop production offers solution to environmental pollution in the state?	**Frequency**	**Percentage**
Yes	196	81.67
No	44	18.33
Total	**240**	**100.00**

Source: Field Survey, 2022

Table 5: Economic consideration of recycling poultry droppings characteristics

Characteristics	Frequency	Percentage
i) Does the use of poultry manure conform to the principles of conservation Agriculture?	-	-
Yes	218	90.83
No	22	9.17
Total	**240**	**100.00**
ii. What is the rate of Poultry manure utilization in your farm?	**Frequency**	**Percentage**
(a) 10-20t/ha	142	59.16
(b) 21-40t/ha	70	29.17
(c) 45-50t/ha	20	8.34
(d) No specific level	08	3.33
Total	**240**	**100.00**
iii. Does the use of poultry manure in organic agriculture save cost?	**Frequency**	**Percentage**
Yes	220	91.66
No	20	8.34
Total	**240**	**100.00**
iv) Do you think that the use of poultry manure has positive effect on the farmer's net revenue?	**Frequency**	**Percentage**
Yes	210	87.50
No	30	12.50
Total	240	**100.00**

Source: Field Survey, 2022

CONCLUSION AND RECOMMENDATION

The study investigated the economics of poultry manure use as fertilizer in Imo State. Poultry farmers in the study area uses poultry manure in the fertilization of their crops because of its availability, least cost involvement and leaching repellent properties on erosion prone soils. Based on the findings of this study, the following recommendations are made;

i. Government should assist poultry farmers by giving them loans/subsidies so as to enhance their productive capacity and by extension establish crop farms as 50-65% of grains utilized in livestock feed manufacture are obtained from crop farms.

ii Government should intensify the use of poultry droppings by embarking on public enlightenment campaigns in the rural areas to change the philosophy and mindset of rural conservative farmers on the adoption of new technology aimed at boosting food security.

iii. Apart from recycling poultry waste as fertilizer in the crop farm, waste can also be channeled into biogas production for energy generation.

iv. Synergy between animal agriculture and organic farming in Nigeria will open a window of opportunity for the utilization of these benefits.

REFERENCES

Adeleye, E.O., Ayeni, L.S. and Ojeniyi, S.O. (2010). Effect of Poultry manure on soil Physical- chemical properties, leaf nutrient contents and yield of yam (Dioscorearotundata) on altisol in South Western Nigeria, Journal of American Sciences, 6(10)871-878.

Agency, (2018).World Energy Outlook 2018.Flagship report, November 2018.www.iea.org

Alawode, O. (2016). Attracting young people to farming.In spore.cta.int.A global perspective on agribusiness and sustainable agriculture. Spore (181): 6-7.

Agblevor, F.A., Beis, S.S., Kim, S.S., Tarrant, R. and Mante, N.O. (2010).Biocrude oils from the fast pyrolysis of poultry litter and hardwood. Waste Management, Vol.30, Issue 2, Feb. 2010, pages 298-307

Atusa Kingsley, (2018). Effects of five rates of poultry manure on growth and yield of scent leaf (ocimumgratissium) in Delta State. Proceedings of the 5th Annual Conference of Crop Science Society of Nigeria held at University of Nigeria, Nsukka 08-10th October, 2018. Pp 103-105.

Ayeni, L.S., Adetunji, M.T., Ojeniyi, S.O, Ewulo, B.A., Adeyemo, A.J. (2008). Comparative and cummulative effect of cocoa pod husk ash and poultry manure on soil and maize nutrient and yield. American European Journal of sustainable Agriculture, 2(1):92-97.

Ayub, Y., Ren, J., Shi, T., Shen, W. and He, C. (2023). Poultry litter volarization: Development and optimization of an electrochemical and thermal tri-generation process using an extreme gradient boosting algorithm. EnergyJournal

Bamire, A.S. and Amuyoyehgbe, B.J. (2008). Economics of poultry manure utilization in land quality improvement among integrated poultry-maize-farmers in South Western Nigeria. Journal of Sustainable Agriculture. Vol. 23, 2004, Issue 3. https://doi.org/10.1300/j064v23n03_04

Baruwa, I. and Omodara, O.D. (2018). Poultry waste management practices and policy implications for environmental sustainability in urban areas of Osun State, Nigeria. Applied Tropical Agriculture, Vol. 23, No. 1, 25-34.

Brueno, R.R. (2020). Farming is one of the worlds' oldest profession. The value Journal. Good News publication. Valley Journal.org

Dauda, S.N., Ajayi, F.A. and Ndor, E. (2008).Growth and yield of watermelon (Citrulluslanatus) as affected by poultry manure application. Journal of Agriculture and Social Sciences 4:121-124.

Eurostat, (2019). Waste hierarchy index for circular economy in waste management. Edited by Ana Pires , and GracaMartinho. Waste management 95, 298-305.

Eze, P.O. and Baiyeri, K.P. (2019). Influence of poultry manure rates on growth and yield pattern of Green Pepper (Capsicum annum L) and the residual effect of applied manure on productivity of Raddish. Proceedings of 6th Annual Conference of crop Science Society of Nigeria at FUTO. 13th-17th October, 2019. Pp 58-68

Hamma, I.C., Ibrahim, U. and Haruna, N. (2017).Effect of poultry manure on the growth and yield of cucumber (CucumisSativum L.) in Samara, Zaria. Nigeria Journal of Agriculture, Food and Environment 8(1): 94-98.

International Institute of Rural Reconstruction and African Conservation Tillage (IIRR and ACT), (2005).Conservation Agriculture.A manual for farmers and extension workers in Africa.Printed in Kenya by majestic printing works Ltd. Nairobi, Kenya.

Ikeh, A.O., Ndaeyo, U.N., Uduak, I.G., Ugbe, L.A., Udoh, E.I. and Effiong, G.S. (2012). Growth and yield responses of Pepper (Capsicum annum) to varied poultry manure ratesin UTO, South Eastern Nigeria. Journal of Agric and Biological Science, 7 (9): 735-742.

Irene, O.B., Uwah, I.B. and Ekpenyong, V.E. (2015). Response of fluted pumpkin (Telfariaoccidentalis Hook F) to different levels of poultry manure in aultisol of South Eastern Nigeria. Journal of Organic Agriculture and Environment. PP 5-14.

Jayanthi, P., Joshua, E. and Ranganathan, K. (2010).Ageing and its implications. J. Oral MaxillofacPathol. 14 (2): 48 (PMC free article) (Pub Med) (Google Scholar).

Mgbakor, M.N. and Nzeadachie, E.C. (2013).Economic analysis of broiler production (a case study of Orumba South L.G.A. of Anambra State, Nigeria). American Eurasian Journal of Agronomy 6 (2): 25-31. DOI : 10.5829/idosci.aeja. 2013. 6.2.1102.

Mariusz, T., Robert, J., Alicja, K. and Patrycja, N. (2019).Assessment of the energy potential of chicken manure in Poland. Energies 2019, 12 (1244): (1-18). www.mdpi.com/journal/energies

Nimet (Nigerian Institute of Meteorology) (2018).Seasonal Rainfall Predictions.www.nimet-srp.com

Nigerian National Bureau of Statistics (2020).National Youth Survey, 2020. Nigerianstat.gov.ng

Shibi Thomas, K., Jayalalitha, V. and Richard Jagathesan, P.N. (2020). Poultry farm waste disposal management. Veterinary University Training and Research.Centre, Tamil Nadu Veterinary and Animal Sciences University (TANUVAS 7/2, Tamil Nadu.Poultrypunch.com.

Si Ho Han, Ji Young An, Jaehong Hwang, Se Bin Kim and ByungBae ark. (2016). The effect of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera lin.) in a nursery system. Forest Science and Technology. Vol. 12 (3): 137-143. https://doi.org/10.1080/21580103.20150.1135827

University of Georgia Extension News, (2022). Maximizing poultry manure use through nutrient management planning. Bulletin 1245, Georgia Extension Publication. Extension.uga.edu

Yousaf, Ayub.,Aamir, Mehmood., Jingzheng, Ren, Carmank, M. Lee (2022). Sustainable recycling of poultry litter to value added products in developing countries of South Asia. Journal of Cleaner Production. Vol.357,132029. . https://doi.org/10.1016/j.jclepr.2022.132029

World Bank, (2021).World Bank Open data. Worldbank.org