Reproductive Traits, Growth Performance, and Economic Efficiency of *Archachatina marginata* Snail under Captive with Different Stocking Density

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***Abstract*—** The reproductive traits, growth performance, and economic efficiency of African giant land snails under captive fed *ad libitum* and reared under different stocking densities was investigated in a twelve weeks experiment. A total of 196 growing, medium – sized *Archachatina marginata* snails of the same age with an average mean weights of 150.39g were used for the study. The four groups (treatment) of different stocking density was made up of 4, 8, 12, and 16 snails, and they were represented as A, B, C and D respectively. The different stocking densities of the snails (4, 8, 12, and 16) was reared in wooden boxes (cage) measuring 25cm width x 35cm length x 21cm height or 0.25m width x 0.35m length x 0.21m height, placed inside the snailery unit. The four different groups (A, B, C and D) were replicated four times in a completely randomised design arrangement. The result showed that, growth performance of snails under treatments A and B were significantly ($P<0.05$) higher and similar compared with snails in other treatments. The reproductive traits were better ($P<0.05$) for treatments A and B while the economic efficiency with regards to revenue generated from snails produced and gross profit were highest ($P<0.05$) for treatments A and B compared with other treatments. However, we concluded that, for effective utilization of floor surface per snail, farmers are encouraged to adopt the floor space of 8 snails/0.25m × 0.35m (treatment B) for an improved growth performance and reproductive efficiency of breeding snails as well as for economic performance maximization of the enterprise. This seems to be a step towards biodiversity conservation, and its sustainability is very important in order to enhance our life support system.

***Key words*:** African giant land snails, biodiversity conservation, floor space, sustainability.

I. Introduction

The sustainability of policies and implementation on several programmes aimed at improving the production of animal protein has been lacking in developing countries for many decades [1]. This has led to the problem of inadequate protein intake in most African countries, hence, the need to shift research and production emphasis to the domestication of micro-livestock such as African giant land snail, rabbit, grasscutter (cane rat), guinea pig, quail and African giant rat [2], [3]. Micro-livestock have potentials of a good source of animal protein in human diet [4], [5]. African giant land snails is one of the micro livestock that could serve as ready source of inexpensive meat among the human population especially in the humid tropics where snails thrive widely [6], [7]. African giant land snails are widely distributed in the moist forest belt of West Africa (Ghana, Nigeria, Cameroon, Republic of Benin, Togo, Liberia, Sierra Leone and Côte d'Ivoire, etc) and they are gathered from the forest during the wet season [8]. Since the supply of snails (African giant land snail) depends mainly on the wild, the demand outstrips supply, resulting in constant rise in price of snails in the market. For example, the sale of full grown *Archachatina marginata* was at about $ 0.03 US dollar in 1991, $ 0.07 – 0.10 US dollar in 1994 [9], [10], $ 0.83 – 0.90 US dollar in 2008 [11], and $ 8 – 10 US dollars in 2020 [12]. According to Natalie [13] there is a flourishing International trade of snails in Europe and North America, and the annual requirement of snail in France is about 50,000 Tones, over 60% of which is imported. The estimated annual consumption in Italy is 450 million snails while 50% is imported and in Spain alone, more than 4,000 tones are demanded every year [14]. However, in spite of the considerable foreign and local demands, commercial snail farms such as those in Europe, South-East Asia and the America hardly exist in Africa [15].

Archachatina maginata snail has a crude protein of about 19% [16] and the low cholesterol level and high iron content of the meat makes it a good antidote for fat related diseases [17], [5]. It has been reported that, the high iron content of the meat is considered important in treating anaemia and it has been recommended for the treatment of ulcers, asthma, high blood pressure and other related ailments due to their relatively low cholesterol levels [18]. The shell which constitutes about 30 % of the live weight can be used as a good source of calcium for poultry [17], [19] and Orthocalcium phosphate extracted from the snails could cure kidney disease, tuberculosis, anaemia, diabetes and asthma [20], [21]. Meat of snail is palatable, nutritious and rich in essential amino acids such as lysine, leucine, isoleucine and phenylalanine as well as high iron contents [22]. In recent years, wild snail populations have declined considerably, primarily because of the impact of such human activities as deforestation; pesticide use; slash and-burn agriculture; spontaneous bush fires and the collection of

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immature snails [23], [5]. As the snail is going into extinction, there is need to conserve them in order to maintain our own life support system. This is in line with the worldwide campaign for biodiversity conservation [24], and there are two main ways to conserve biodiversity. These are termed ex situ (i.e. out of the natural habitat) and in situ (within the natural habitat).

It is therefore important to encourage snail farming (heliciculture) in order to conserve this important resource. Snail farming does not require much space for establishment, expenses on management is low compare with other conventional livestock and it is a good earner of foreign exchange [25], [26]. However, farmers are complaining of slow growth and high mortality rate [19]. Many factors are known to affect animal performance, they are quality of diet [27] - [31], breeds [32], disease control [33] and optimum density etc. In poultry, there is increased rate of cannibalism, disease spread and increased number of birds culled when birds are densely packed [34] – [36]. There is a decrease in egg production [37] – [39], depression in feed consumption, and decreased final body weight at higher stocking rate [40], [41]. Despite the growing popularity of African giant snail (*Archahcatina maginata*), there is a dearth of information on the economic efficiency, growth performance and reproductive traits of *Archachatina maginata* snails exposed to different stocking rates. Hence, this study was conducted to establish the appropriate stocking rate for the breeding and finishing snails.

II. MATERIALS AND METHODS

A. Study site

The experiment was conducted at the snailery unit of the Department of Animal Science, University of Nigeria, Nsukka Nigeria. Nsukka lies within latitude 06^{o} 22^{1} North and longitude 07^{o} 24^{1} East. It has an annual rainfall range of 1567.05mm to 1846.98m. Natural day length is 12-13 hours and means minimum and maximum daily temperatures are 20.99^{o}C and 30.33^{o}C, respectively. Relative humidity ranges from 46.68% to 76.20% [42]. Nsukka belongs to the humid tropical rainforest zone of South-eastern Nigeria. The entire study lasted for twelve weeks.

B. Feeding

The snails were fed formulated ration (24% CP). However, the percentage and chemical compositions of the feed ingredients were presented in table1. Sample of the diet was analyzed for its proximate (chemical) compositions according to AOAC (2006) methods (table 1).

TABLE I: PERCENTAGE AND CHEMICAL COMPOSITION OF FEED FED TO THE EXPERIMENTAL SNAILS (24% CP)

Ingredient	**% Composition**
Maize	32.50
Wheat offal	28.40
Soybean meal	9.20
Groundnut cake	13.20
Fish meal	8.70
Bone meal	4.00
Oyster shell	3.50
Vitamin premix	0.50
Total	**100**
Chemical composition	**%**
Crude protein	23.20
Crude fiber	3.49
Moisture	8.25
Ash	7.25
Oil	2.30
Nitrogen free extract	55.51

C. Experimental snails and management

Ethical principles were taken into consideration during the study to adapt to the national and international standards governing research of this nature with regards to the use of research animals. A total of 196 growing, medium – sized *Archachatina marginata* snails of the same age with an average mean weights of 150.39 g were used for the study. The snails were randomly allocated to four different treatments (T_A. T_B, T_C and T_D). Treatments A, B, C and D contain 4, 8, 12 and 16 snails respectively and each treatment was replicated four times. Each of the four groups (treatment) of different stocking densities was reared in wooden boxes (cage) measuring 25cm width x 35cm length x 21cm height or 0.25m width x 0.35m length x 0.21m height, placed inside the snailery unit. The boxes stood 30 cm off the ground and the stands of each cage were put inside a container filled with used engine oil to prevent soldier ant infestation. The sides and top of the boxes were constructed with nylon net (mosquito netting) reinforced with wire mesh to facilitate ventilation, while the floor had holes for drainage when wetting the soil. The boxes were filled with garden soil up to 8 cm heights from the floor. The soil was thoroughly mixed before snails were introduced into the boxes. Trees were planted around the house at the snailry unit which made the environment cool. All snails were kept under the same environmental conditions and managed similarly.

D. Egg collection and handling

The snails started laying eggs after 3 weeks of housing in the boxes. Eggs were collected twice daily (early morning and late evening) for 5 days before incubation. Eggs waiting to be incubated were held or stored at 16-17°C (~61-63°F) in a refrigerator with the main objective to stop all embryonic development until the eggs can be set at normal incubation temperatures (37.5°C; 99.5°F) and a secondary objective of cool storage was to discourage bacterial growth [43]. At lower temperature the water loss of the eggs is reduced and the deterioration of albumen slowed down [44].

E. Economic efficiency and growth performance parameters measured

The economic efficiency traits determined are the cost of feed consumed, revenue generated and gross profit while the growth parameters measured include; Initial and final body weights (g): These were measured at the beginning and at the end of the experiment, respectively. Weight changes were measured on weekly basis.

Average body weight gain (g) = Final body weight – Initial body weight.

Average daily feed intake (ADFI) per bird was measured by subtracting the weight of the feed remaining from that of the feed initially supplied, and dividing the difference by the total number of snails in each pen (replicate). Average live-weight was measured weekly by weighing all the snails in each pen using a 10,100 g (10.1 kg) capacity precision weighing balance with model, A and D Weighing GF-10K industrial balance, made in Japan. The feed conversion ratio (FCR) was calculated as follows: = Feed intake / weight gain**,** it is the mathematical relationship between the input of the feed that has been fed to the snail and the weight gain of the snail**.** FCR can provide a good indication of how efficient a feed or a feeding strategy can be.

F. Reproductive performance traits measured

Total number of eggs laid by the snails was determined and recorded. All eggs that did not hatch after the 30th day were collected and opened to determine the ones with dead embryos and those that were not fertile *ab initio*. These were counted and recorded. From these, the following parameters were calculated.

$$\text{Fertility (\%)} = \frac{No.\text{ of fertile eggs (w)}}{Total\text{ no. of eggs incubated (x)}} \times \frac{100}{1}$$

Where, w = No. of eggs that hatched + No. of dead-in-shell

$$\text{Embryo mortality (\%)} = \frac{No.\text{ of dead-in-shell (y)}}{Total\text{ no. of fertile eggs (w)}} \times \frac{100}{1}$$

$$\text{Hatchability (\%)} = \frac{No.\text{ of eggs that hatched (z)}}{Total\text{ no. of fertile eggs (w)}} \times \frac{100}{1}$$

G. Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) for Completely Randomized Design (CRD) [45] using Statistical Package for the Social Sciences [46], windows version 17.0. Significantly different means were separated using Duncan's New Multiple Range Test [47] as outlined by Obi [48].

III. RESULTS

A. Growth performance

Mean values obtained for growth traits in table 2 showed that all the parameters (final body weight, average weight gain, total feed intake, Daily feed intake and feed conversion ratio) were significantly (P<0.05) affected except for initial body weight that does not differ (P>0.05) significantly. The final body weight (FBW) was highest (P<0.05) for snails under treatment A (570.42g) but they are statistically similar with snails under treatment B (561.81g), while, snails under treatments C (497.16g) and D (482.37g) were the same (P>0.05) with lowest FBW. Average weight gain (AWG) and daily weight gain (DWG) were significantly (P<0.05) higher for snails under treatments A and B while snails in treatment D recorded the lowest AWG and DWG. The feed conversion ratio was best (P<0.05) for snails under treatment B (0.33), although, they are statistically similar with snails in other treatments (A = 0.38; C = 0.37 and D = 0.36). Snails under treatment A had the highest (P<0.05) total feed intake (TFI) and Daily feed intake (DFI) when compared with other treatment means while treatment D snails had the lowest TFI and DFI.

TABLE II: EFFECT OF STOCKING DENSITY ON THE GROWTH PERFORMANCE OF SNAIL

Parameters	T_A	T_B	T_C	T_D	**SEM**	**P-value**
IW (g)	150.46	150.96	149.04	151.11	2.28	0.62
FW (g)	750.42^{a}	561.81^{ab}	497.16^{c}	482.37^{c}	2.62	0.04
AWG (g)	419.96^{a}	410.85^{a}	348.12^{c}	331.26^{d}	1.28	0.01
DWG (g)	4.99^{a}	4.89^{a}	4.14^{bc}	3.94^{c}	0.12	0.01
TFI (g)	161.28^{a}	137.94^{a}	130.53^{c}	106.01^{d}	1.78	0.04
DFI (g)	1.92^{a}	1.64^{b}	1.55^{c}	1.26^{cd}	0.11	0.02
FCR	0.38^{a}	0.33^{ab}	0.37^{a}	0.36^{a}	0.03	0.03

a,b,c,d; Row means with different superscripts differ significantly at *P* <0.05. IW = Initial weight. FW = Final weight. AWG = Average weight gain. DWG = Daily weight gain. TFI = Total feed intake. DFI = Daily feed intake. FCR = feed conversion ratio.

B. Reproductive traits

The reproductive traits of snails under four different stocking rates (T_A T_B T_C and T_D) is presented in table 3. Results showed that, total number of eggs laid (TNE), percentage hatchability of eggs (HE), fertility of eggs (FE), embryo mortality (EM), and average weights of hatchlings at day old (AWHD) were significantly (P<0.05) affected. Snails under treatment A (76.00) and B (69.00) laid more (P<0.05) eggs when compared with snails in other treatments (T_C = 49.00 and T_D = 38.00). Percentage hatchability and fertility of eggs were higher and better (P<0.05) for T_A and T_B. Snails under Treatment D recorded the highest embryo mortality percentage of 19.00% while, that of T_A, T_B and T_C were 2.70%, 3.12% and 10.89% respectively. It is obvious from the data that, snail eggs under treatments A and B had the lowest (P<0.05) percentage embryo mortality. Average weights of hatchlings was better (P<0.05) under treatments A (2.90g) and B (2.87g) when compared with other treatment means (2.52g and 1.77g for, T_C and T_D respectively).

TABLE III: REPRODUCTIVE PERFORMANCE OF SNAILS UNDER DIFFERENT STOCKING RATES

Parameters	T_A	T_B	T_C	T_D	SEM	P-value
TNE	76.00^a	69.00^a	49.00^b	38.00^c	0.97	0.03
HE (%)	97.30^a	93.88^a	86.11^{ab}	75.00^b	1.06	0.04
FE (%)	97.37^a	96.08^a	81.82^b	73.68^c	1.10	0.04
EM (%)	2.70^d	3.12^d	10.89^b	19.00^a	0.05	0.01
AWHD (g)	4.02^a	3.97^a	2.72^b	2.07^c	0.02	0.05

a,b,c,d; Row means with different superscripts differ significantly at P <0.05. TNE = Total number of eggs laid. HE = Hatchability of eggs (%). FE = Fertility of eggs. EM = Embryo mortality. AWHD = Average of weight of hatchability at day old (g).

C. *Economic efficiency*

The cost of total feed consumed, revenue from snail produced, gross profit and market weight are presented in table 4. All the economic traits recorded in the present study were affected (P<0.05) by different levels of population density. Total body weight was significantly (P<0.05) higher for snails under treatment A, though they are statistically similar with snails under treatment B. Hence, total body weight tends to decrease across the treatments. Total feed intake followed the same trend where the highest (P<0.05) feed consumed was recorded for snails under treatment A, while the lowest (P<0.05) feed consumed was found in snails under treatment D. The cost of total feed intake was highest (P<0.05) for snails under treatments A, B, and C.

TABLE IV: ECONOMIC EFFICIENCY OF *ARCHACHATINA MAGINATA* SNAILS REARED UNDER DIFFERENT STOCKING DENSITY

Parameters	T_A	T_B	T_C	T_D	SEM	P-value
FC per kg ($)	2.46	2.46	2.46	2.46	-	-
TBW (g)	570.42^a	561.81^{ab}	497.16^c	482.37^c	2.62	0.04
TFI (g)	161.28^a	137.94^b	130.53^c	106.01^d	1.72	0.04
SC per kg ($)	10.53	10.53	10.53	10.53	-	-
CTFI ($)	0.40^a	0.34^{ab}	0.32^{ab}	0.27^b	0.02	0.08
RSP ($)	6.00^a	5.90^a	5.27^b	5.05^b	0.11	0.02
GP ($)	5.60^a	5.56^a	4.95^b	4.78^b	0.09	0.03

a,b,c,d; Row means with different superscripts differ significantly at P <0.05. US dollar, $ = ₦364.25.00 (as at the time of the study). FC = Feed cost per kg ($). TBW = Total body weight (g). TFI = Total feed intake (g). SC = Snail cost per kg ($). CTFI = Cost of total feed intake ($). RSP = Revenue from snail produced ($). GP = Gross profit ($).

The revenue from snail produced was highest (P<0.05) for snails under treatments A (6.00 US dollar) and B (5.90 US dollar) while snails under treatments C (5.27 US dollar) and D (5.05 US dollar) had the least revenue generated. Again, snails under treatments A (5.60 US dollar) and B (5.56 US dollar) were able to generate the highest (P<0.05) gross profit followed by snails in treatment C (4.95 US dollar) and lastly snails under treatment D (4.78 US dollar).

IV. DISCUSSION

A. *Growth performance*

The result showed that, feed intake of snail decreases with increase in the stocking rate. It was also noticed from the study that, as the feed intake of snails decreases with increase in the stocking rate, the body weight also decreases with the same trend. This finding seems to agree with earlier research works from Agunbiade and Benyi [49]; Omole *et al* [19] that higher stocking density depresses feed consumption and final body weights. The decreased feed intake recorded at higher stocking rate could be attributed to over population which did not allow the snails' free access to feed. Omole *et al* [19] opined that the performance of snails in captivity is suppressed when their social structures and environments are altered. Similar result of low feed intake when broilers were stocked at high stocking rate was observed [50], [51], it was attributed to high environmental temperature and the reduced airflow at bird level. The better growth performance recorded for snails under stocking rate of 4 snails per 0.25m × 0.35m space (treatment A) and 8 snails per 0.25m × 0.35m space (treatment B) may be due to sufficient space and easy access to feed and water. This is in line with the broiler study reports of Bilgili and Hess [52], Simitzis *et al* [51] and Gabanakgosi *et al* [41], that, broiler performance was possible as they are exposed to sufficient space. FAO [53] and Aboosadi *et al* [54] as cited by Oyeagu *et al* [30] also had a similar experience with broilers. However, the current finding did not agree with the reports of El-Deek and Ai-Harthi [55] and Tayeb *et al* [56], they found no influence of stocking density on body weight of broilers. Currently, consumers perceive stocking density to be one of the most important factors that influence animal wellbeing and the application of optimal welfare standards (i.e. normal stocking density) which is believed to result in a higher product quality [57]. This study upholds the fact that, low feed intake recorded at higher stocking rates could be attributed to over population which did not allow the snails' free access to feed. There seems to be an inverse relationship between feed intake and stocking density. This is in tandem with the study of Sorensen [58] who stated that the reduction in final body weight can be connected to decrease in food consumption because of difficult access to feeding space in condition of higher stocking density. Irwin *et al* [59] also reported that, stocking density affects growth rate and mean weight. Similar results of low feed intake when broilers were stocked at a higher stocking rate were documented [60], [34], [61], [62].

B. *Reproductive traits*

The contrast between the higher number of eggs laid for snails under treatments A and B and the lowest number of eggs laid for snails under treatment D may be attributed to the number of snails per unit of floor space (m^2). The study of Ayodele and Asimalowo [63] and Omole *et al* [19] showed that, the amount of eggs laid and the frequency of laying is reduced at higher stocking rate. Ademolu *et al* [21] and Mogbo *et al* [64] implicated overcrowding for poor growth and sexual development of snails. Similarly, Akegbejo-Samson and Akinnusi [65] pointed out that egg-laying capacity of snails and growth were adversely affected under a very high population density. The improved percentage hatchability, fertility and embryo mortality as well as average weights of hatchlings for treatments A and B may be due to the conducive housing (floor) space that allow snails easy access to feed and water. Irwin *et al.* [59] had stated that, in densely populated pens, snails become smaller adults, lay few clutch of egg, and have few eggs per clutch with lower egg hatchability, meanwhile hatchability seems to have a positive correlation with fertility [5]. The lowest mortality recorded in treatments A and B could be due to proper ventilation, less competition for feed, water and space while poor ventilation, cannibalism and increase in disease spread as a result of overcrowding could have resulted in higher mortality recorded at higher stocking rate [66], [19]. In this study, the average live weight of the hatchlings (3.20g) were lower than that (3.94g) reported by Omole *et al* [19] and higher than the average live weight (2.37g) recorded by Oyeagu *et al* [5]. This could be attributed to the size of the snails used in this study. It was reported that the size of the hatchlings produced has positive correlation with the size of the snails [67].

C. *Economic efficiency*

The increase in feed intake of snails under treatments A and B showed their unrestricted access to feed and water which has resulted in their better weight gain. Again, the increased feed intake may be the reason for the higher cost of total feed consumed. However, the better revenue generated as well as the gross profit may be due to their improved total body weight. According to Gabanakgosi *et al* [41], they recorded a similar result with broiler birds. The floor surface per snail is a very important welfare factor which directly and indirectly influences and determines the level of snail body weight [68]. Profitability can be realized by efficient management of floor space. Estevez [61] and Verspecht *et al* [69] pointed out that, economic profit may be threatened as a result of reduced animal performance, health, and welfare if stocking density is high. In this study, stocking density of 4 snails per 0.25m × 0.35m (treatment A) floor space and 8 snails per 0.25m × 0.35m (treatment B) floor space showed a better performance in achieving the final market weight and higher gross profit margin due to their exposure to sufficient floor space that guarantee unrestricted access to feed and water. Mehmood *et al* [70] argued that, economic use of floor space is a strategy used for increasing the amount of meat produced per unit area. However, its effects on snail's health and productivity need to be considered as well.

V. CONCLUSION

The study showed a better growth performance, reproduction and economic efficiency for 4 snails per 0.25m × 0.35m (treatment A) floor space and 8 snails per 0.25m × 0.35m (treatment B) floor space. However, for effective utilization of floor surface per snail, farmers are encouraged to adopt the floor space of 8 snails per 0.25m × 0.35m (treatment B) for an improved growth performance, reproductive efficiency and state of health of the breeding snails as well as for economic performance maximization of the enterprise. This is a big step towards biodiversity conservation, and its sustainability is important in order to enhance our life support system.

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REFERENCES

[1] A. Hamilton-Amochree, H. D. Mepha and C. U. Ogunk Nnoka. (2009). Comparative value of kola testa, corn-bran and rice-bran with maize for mature African giant land snail (*Archachatina marginata*). *Nigerian Journal of Animal Production*, 34 (2), 265-276.

[2] L. A. Ibom, B. Okon and A. Essien. (2008) Morphometric analysis of eggs laid by two ectotypes of *Archachatina marginata* raized in captivity. *Proceedings of the 33rd Annual conference of Nigeria Society for Animal production (NSAP)*. March 16th – 20th 2008. Ago-Iwoye, Nigeria. Pp. 28 – 30.

[3] B. Okon, L. A. Ibom and E. E. Odido. (2011). Reproductive performance and egg quality traits of crossbreeding between two strains of snails. *Archivos De Zootecnia* 60 (229): 153 – 156. https://doi.org/10.4321/S0004-05922011000100020

[4] Merkramer (1992). Golden Snail as food and feed. Proceedings of seminar on invertebrate ECC Philippines. Pp. 244.

[5] C. E. Oyeagu, U. Udeh Fredrick, E. Uzochukwu Ifeanyi, O. Osita Charles, S. O. C. Ugwu and H. Agugom Obinna (2018). Effect of dietary Centrosema Pubscens leaves on growth and reproductive traits of *Archachatina maginata* Snails. *Journal of Applied Animal Research*. VOL. 46, NO. 1, 947–952. https://doi.org/10.1080/09712119.2018.1434528.

[6] D. Ngoupayon (1992). Guinea pig raising for meat production. Proceedings of Seminar Research on feed and feeding Summary. 15-19.

[7] S. S. Ajayi, O. O. Tewe, C. Morianty and M. O. Awesu (2008). Observation on the biology and Nutritive value of the African giant land snail, *Archachatina marginata*. *J. of East Afri. Wildlife*. 16: 85 – 95 https://doi.org/10.1111/j.1365-2028.1978.tb00430.x

[8] CADEV (Community Action for Development) 2006. From a taboo to a delicacy: the evolution of eating snail meat in Bakossi (Cameroon). Non-wood news No. 15. FAO.

[9] A. A. Awah, (1994). Snail farming in mature rubber plantation: 2. Evaluation of some methods of reducing field mortality during the dry season. Snail Farming Research, 4, 43-47.

[10] A. A. Awah, Obehi Edeoghon, B. C. Clara Lalabe and Omo-Erigbe Patience (2001). Snail farming in mature rubber plantation: 4. Studies on some artificial method of hatching of snails egg and protection of young snails during the dry season. *Tropicultura*, 19 (4): 194-198.

[11] A. A. Awah, B. C. Lalabe, I. Nasiru and Patience Omo-Erigbe (2009). Comparative studies on the composition and purchase costs of some edible land snails in Nigeria. *Tropicultura*, 27 (1): 54-47.

[12] IEP (Import Export Platform) (2020). Snail International Market Price. http://www.importexportplatform.com/207_snail_sellers.html

[13] Natalie Huet (2014). Snail production and trade in France. www.frenchkpi.com/snails-production-and-trade-in-france/ Jul 23, 2014. Retrieved on the 16th of September, 2015.

[14] Lun Oscar (2013). Snail farming: A great business opportunity for everyone. Vivirmas.org/…/snail-farming-great-business-opportunity. Oct, 14, 2013. Retrieved on 1st November, 2015.

[15] O. A. Duah and K. A. Monney (2001). Snail farming: snail collection and small-scale production in Africa and Europe. In: *African Jouenal of Ecology*. Vol. 37 (3): 550 – 559.

[16] O. Fagbuaro, J. A. Oso, J. B. Edward, and R. F. Ogunleye (2006). Nutritional status of four species of giant land snail in Nigeria. *J. Zhejiang Univ. Sci. B*. 7: 686 – 689. Doi:10.1631/JZUS.2009.B0686.

[17] S. O. Bright (1996). Prospects and problems associated with snail farming. *Heritage printers Nig. Ltd, Lagos Nigeria*. P. 96.

[18] F. A. O. Akinnusi (2002). Comparative Evaluation of fresh fruits leaves and concentrate feed on the growth and reproductive performance of the African land snail (*Archachatina marginata). Proceedings of the 27th Annual Conference of the Nigerian Society for Animal Production* (NSAP), Federal University of Technology, Akure (FUTA), March 17-21, 2002: 328-320.

[19] A. J. Omole, O. O. Obi, K. O. Soetan and T. O. Olaseinde (2010). Influence of stocking rate on growth and reproductive performance of breeding snails (*Archachatina marginata*). *Journal of cell and Animal biology*. vol. 4 (4), pp. 064-067, April, 2010.

[20] A. R. Mead (1981). The Giant African Snail. Chicago University Press, USA pp. 310 – 315

[21] K. O. Ademolu, A. B. Idowu and O. M. Agbelusi (2006). Effect of stocking density on the growth and haemolymph biochemical value of

Archachatina marginata snail. *African journal of biotechnology*.Vol. 8 (12), pp. 2908-2910. 17 June, 2006.

[22] C. I. Ebenebe (2000). Mini-livestock production in Nigeria. The present and the future. proc., 5th ann., conf., asan, Port harcourt, Nigeria, sept. 19-22, 2000

[23] Monney K A, 1994. Notable notes on giant African snails. In: Snail Farming Research, Vol 5, p. 1-13.

[24] Barbara Corker (2003). Biodiversity and Conservation. http://www.countrysideinfo.co.uk/biodvy.htm. Retrieved on the 16th September, 2015

[25] FAO (1986). Farming snails by FAO. Better farming series, 3; 33. Rome Italy.

[26] U. Gerhard (2017). Snail farming: making good use of a small space. https://www.farmersweekly.co.za/agri-business/agribusinesses/snail-farming-making-good-use-of-a-small-space/

[27] K. U. Amaefule and O. C. Onwudike (2000) Evaluation of processing methods of, pigean pea seeds (Cajanuscajan) as protein source for broiler starter. *J. Sustainable Agriculture and Environment* 2(I): I34-138.

[28] A. O. Ani and G. C. Okeke (2003). The substitution of pigeon pea (Cajanuscajan) seed meal for soyabean in broiler finisher ration. *Proc. 8th Ann. Conf. of ASAN*,pp 10-12.

[29] B. O. Esonu, F. C. Lheukwumere T. C. Lwuji, N. Akanu and O. H. Nwugo (2003). Evaluation of microdermispuberula leaf meal as feed ingredient in broiler starter diets. *Nigerian J. Anim. Prod*. 30 (1); 3 – 8. https://doi.org/10.4314/njap.v30i1.3306

[30] C. E. Oyeagu, A. O. Ani, C. F. Egbu, E. S. Akpolu, J. C. Iwuchukwu and J. N. Omumuabuike (2015). Performance of Broiler Finisher birds fed toasted bambara nut (*vigna subterranean* (L) verdc) offal with supplementary Enzyme. *Asian Journal of Science and Technology*. Volume 6, Issue 01, pp. 934-939, January, 2015.

[31] C. E. Oyeagu, A. O. Ani, C. F. Egbu, F. U. Udeh, J. N. Omumuabuike, and J. C. Iwuchukwu (2016). The effect of feeding toasted Bambara nut (*Vignasubterranea* (L) verdc) Offal and supplementary Enzyme on Performance of broiler chicks. *Tropical Agriculture*, volume 93 no 4, pp. 271 - 283

[32] B. Okon, L. A. Ibom, H. E. Ettah and I. E. Ukpuho (2012). Effect of gynotype, dietary protein and energy on the reproductive and growth traits of parents and F1 hatchlings of *Achatina achatina* (L) snails in Nigeria. International science of applied science and technology, vol. 2 No. 1, pp. 150 – 158

[33] Nwogwugwu Chiemela Peter, Nwakpu Emeka Petrus, Oyeagu Chika Ethelbert and Obi Chidimma Lynda 2015. Effect of *Vernonia Amygdalina* (bitter leaf) extract on growth performance, carcass quality and economics of production of broiler chickens. *International Journal of Agriculture and Earth Science*. Vol. 1 No. 5 2015.www.iiardonline.org.

[34] W. A. Dozier, J. P. Thaxton, S. L. Branton, G. W. Morgan, D. M. Miles, W. B. Roush, B. D. Lott and Y. Vizzier-Thaxton (2005). Stocking density effects on growth performance and processing yields of heavy broilers. Poultry Science 84: 1332 – 1338. https://doi.org/10.1093/ps/84.8.1332

[35] S. Guardia, B. Konsak, S. Combes, F. Levenez, L. Cauquil, J. F. Guillot, C. Moreau-Vauzelle, M. Lessire, H. Juin and I. Gabriel (2011). Effects of stocking density on the growth performance and digestive microbiota of broiler chickens. Poultry Science 90:1878–1889 doi: 10.3382/ps.2010-01311

[36] A. Sekeroglu, M. Sarica, S. M. Gulay and M. Duman (2011). Effect of stocking density on chick performance, internal organ weights and blood parameters in broilers. *Journal of Animal and Veterinary Advances*, 10 (2): 246-250. https://doi.org/10.3923/javaa.2011.246.250

[37] K. Benyi, D. Norris and P. M. Tsatsinyane (2006). Effects of stocking density and group size on the performance of white and brown hyline layers in semi-arid conditions. *Tropical animal health and production*. Volume 38, issue 7, pp 619–624. https://doi.org/10.1007/s11250-006-4417-1

[38] Asghar Saki, P. Zamani, M. Rahmati and H. Mahmoudi (2012). The effect of cage density on laying hen performance, egg quality, and excreta minerals. *Journal of Applied Poultry Research* 21:467–475. http://dx.doi.org/ 10.3382/japr.2010-00318.

[39] Y. Y. Guo, Z. G. Song, H. C. Jiao, Q. Q. Song and H. Lin (2012). The effect of group size and stocking density on the welfare and performance of hens housed in furnished cages during summer. *Animal Welfare* 2012, 21: 41-49 ISSN 0962-7286. https://doi.org/10.7120/096272812799129501

[40] H. B. Tong, J. Lu, J. M. Zou, Q. Wang and S. R. Shi (2012). Effects of stocking density on growth performance, carcass yield, and immune status of a local chicken breed. *Poultry Science* 91:667–673 http://dx.doi.org/ 10.3382/ps.2011-01597.

[41] Gabanakgosi Kenaleone, John Cassius Moreki, Shalaulani James Nsoso and Christopher Mareledi Tsopito (2014) Influence of stocking density on growth performance of family chicks reared up to 18 weeks of age in under an intensive system. *International Journal of Current Microbiology and Applied Sciences* (2014) 3(3): 291-302.

[42] S. O. C. Ugwu, C. C. Ogbu and C. C. Amaechi (2011). Effect of soil type and soil depth on the reproductive performance of two species of Giant African land snails in the Humid Tropics. International journal of Science and Nature (I.J.S.N). Vol. 2(2) 2011: 176-182.

[43] Gaylene M Fasenko (2006). Optimal egg storage conditions. *World Poultry Science* 01 October, volume 62 pp. 1218-1224

[44] T. J. Walsh, R. H. Rizk and J. Brake (1995). Effects of storage for 7 or 14 days at two temperatures in the presence or absence of carbon dioxide on albumen characteristics, weight loss and early embryonic mortality of broiler hatching eggs. *Poultry Science* 74: 1403–1410. https://doi.org/10.3382/ps.0741403

[45] R. G. D. Steel and J. H. Torrie (1980). Principles and procedures of statistics. A biometric approach (2nd ed). McGraw-Hill Publishers, New York.

[46] SPSS 2003 Statistical Package for Social Sciences, Windows Version 8. SPSS Inc. USA.

[47] D. B. Duncan (1955). New multiple range test. Biometrics, 11: 1 – 42. https://doi.org/10.2307/3001478

[48] I. U. Obi (2002). Statistical methods of detecting differences between treatment means and research methodology issues in laboratory and field experiments.*2nd Ed. Express Publ. Ltd. Enugu*. Pp13-21.

[49] J. A. Agunbiade and K. Benyi (1988). Effects of stocking rate on the performance of two hybrids. *Nig. J. Anim. Prod*. 13: 112-118.

[50] J. J. R. Feddes, E. J. Emmanuel and M. J. Zuidhof (2002). Broiler performance, body weight variance, feed and water intake, and carcass quality at different stocking densities. *Poultry Science*. 81: 774 – 779. https://doi.org/10.1093/ps/81.6.774

[51] P. E. Simitzis, E. Kalogeraki, M. Goliomytis and M. A. Charismiadou (2012). Impact of stocking density on broiler growth performance, meat characteristics, behavioural components and indicators of physiological and oxidative stress. *British Poultry Science.* 53, number 6, pp. 721-730. Doi: 10.1080/00071668.2012.745930.

[52] S. F. Bilgili and J. B. Hess (1995). Placement density influences of broiler carcass grade and meat yields. *Journal of Applied Poultry Research*. 4: 384 – 389. https://doi.org/10.1093/japr/4.4.384

[53] FAO (2014). Family poultry development issues, opportunities and health working paper No. 12. Rome.

[54] J. Aboosadi, R. Scaife, I. Murray and M. Bedford (1996). Effect of supplementation with cell wall degradation enzymes on the growth performance of broiler chickens fed diets containing rice bran. *British Poultry Science*, 37: S41- 83.

[55] A. A. El-Deek and M. A. Al-Harthi (2004). Responses of modern broiler chicks to stocking density, green tea, commercial multi enzymes and their interactions on productive performance, carcass characteristics, liver composition and plasma constituents. *Int. J. Poult. Sci*. 3: 635 – 645. https://doi.org/10.3923/ijps.2004.635.645

[56] I. T. Tayeb, S. N. Hassan, M. M. Mustafa, S. A. M. Sadeq, G. I. Ameen and A. M. Hassan (2011). Effect of various stocking density on productive performance, carcass yield and immune status of a local chicken breed. *Poultry Science*, 90: 667-673 https://doi.org/10.3382/ps.2011-01597

[57] F. Vanhonacker, W. Verbeke, E. Van Poucke, S. Buijs and F. A. M. Tuyttens (2008). Societal concern related to stocking density, pen size and group size in farm animal production. Livestock Science, 113: 123-132. https://doi.org/10.1016/j.livsci.2008.09.023

[58] P. Sorensen, G. Su and S. C. Kestin (2000). Effect of age and stocking density on leg weakness in broiler chickens. Poultry Science 79: 864-870. https://doi.org/10.1093/ps/79.6.864

[59] S. Irwin, J. O. Halloran and R. O. FitzGerald (2005). Stocking density, growth and growth variation in juvenile turbot (*Scophthalmus maximus*). *Aquaculture*, 178: 77-88. https://doi.org/10.1016/S0044-8486(99)00122-2

[60] M. S. Dawkins, S. Donelly, and T. A. Jones (2004). Chicken welfare is influenced more by housing conditions than by stocking density. *Nature*. 427: 342 – 344. https://doi.org/10.1038/nature02226

[61] I. Estevez (2007). Density allowances for broiler: where to set the limits? *Poultry Science*. 86: 1265 – 1272. https://doi.org/10.1093/ps/86.6.1265

[62] S. Buijs, L. Keeling, S. Rettenbacher, E. Van-Poucke, and F. A. M. Tuyttens (2009). Stocking density effects on broiler welfare: identifying sensitive ranges for different indicators. *Poultry Science*. 88: 1536 – 1543. https://doi.org/10.3382/ps.2009-00007

[63] I. A. Ayodele and A. A. Asimalowo (1999). Essentials of snail farming. *Agape Printers, Ibadan* pp. 7-37.

[64] Mogbo Tochukwu Chinedu, Okeke John Joseph, Ufele Angela Nwogor, Nwosu Moses Chukwuemeka and Ibemenuga Keziah Nwamaka (2013). Preliminary investigation of the influence of housing types on reproductive characteristics of snail (Achatina achatina). *American Journal of BioScience*, Vol. 1, No. 4, 2013, pp. 54-58. doi: 10.11648/j.ajbio.20130104.11.

[65] Y. Akegbejo-Samson and O. Akinnusi (2000). Effect of population on the growth and egg laying capacity of the African giant land snail *Archachatina marginata* raised in captivity. *Nigerian J. of Anim. Production*. 27 (1): 99 – 105.

[66] R. S. Hansen and A. N. Becker (1980). Feeding space, Population Density and Growth of Young Chickens. *Poultry Science*. 39: 654-661. https://doi.org/10.3382/ps.0390654

[67] J. A. Amusan and M. O. Omidiji (1999). Edible Land Snail: A Technical Guide to Snail Farming in the Tropics. *Verity Printer Limited, Ibadan* pp. 5 - 50.

[68] Z. Skrbic, Z. Pavlovski and M. Lukic (2009). Stocking density – factors of production performance, quality and broiler welfare. *Biotechnology in Animal Husbandry*, 25(5-6): 359-372. https://doi.org/10.2298/BAH0906359S

[69] I. F. Verspecht, W. Vanhonacker Verbeke, J. Zoons, and G. Van Huylenbroeck (2011). Economic impact of decreasing stocking densities in broiler production in Belgium. *Poultry Science*. 90:1844–1851 doi: 10.3382/ps.2010-01277.

[70] S. Mehmood, A. W. Sahota, M. Akram, K. Javed, J. Hussain, M. S. Shaheen, Y. Abbas, A. S. Jatoi and A. Iqbal (2014). Growth performance and economic appraisal of phase feeding at different stocking densities in sexed broilers. *The Journal of Animal and Plant Sciences*, 24(3): 2014, Page: 714-721.

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