IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 15, Issue 3 Ser. II (March 2022), PP 18-26
www.iosrjournals.org

Effect of Dietary Protein Supplementation on the Reproductive Performance of Sexually Mature Snails (*Archachatina marginata*)

Ngwarh Perpetua Tuncha, Aziwo Tatanja Niba* Gueikep Nounamo J. A. and Ndzi Roger Banla

*Department of Animal Production Technology, College of Technology, University of Bamenda P.O. 39 Bambili, North West region Cameroon, *Tel.: 0023679498574, *Email.: at_niba@hotmail.com*

Abstract

Background: *This study was aimed at improving the reproductive performance of sexually matured snails (Archachatina marginata) fed different levels of protein in the supplemental diets.*

Materials and Methods: *This study was carried out between January to April 2020 at the Helvy Farms-WVED Cameroon located at Station Bamenda. 150 sexually matured adult breeding Archachatina marginata snails weighing between 43 and 58g, full shells free of any form of injury were acclimatized for four weeks during which time they would have to shed the eggs they came with before commencement of the study. These snails were randomly allotted to four treatments of different protein levels (16%CP, 18%CP, 20%CP, and 22%CP) and a control (natural plant feed) replicated three times with 10 snails each per replicate for a period of 16weeks during which data was collected. The number of egg clutches, clutch size, egg weight, duration of incubation, hatchlings weight were noted and the egg width and length were measured with a vernier caliper (0.02mm accuracy).*

Results: *The results showed that snails fed 20% and 22%CP were significantly higher (P<0.05) in the mean number of clutches (3.44±0.12 and 3.93±0.15), mean cutch size (13.07±0.43 and13.78±0.49), and mean egg weight (277.56±2.37 and 283±3.57). For the mean egg length and width, all eggs from snails fed the experimental diet were significantly higher (P<0.05) than those fed the control diet. Snail eggs from snails fed 22%CP hatched at 24days of the incubation period. Percentage survivability of snailets was also significantly higher (P<0.05) in snailets from parents fed 22%CP and hatchlings' weight was also significantly higher in snailets from parents fed 20% and 22%CP. There was an improvement in reproduction with the snails fed the experimental diet and especially with that fed 22%CP.*

Conclusion: *We can therefore recommend that 22%CP be included in the diet of Archachatina marginata breeding snails for better reproductive performance.*

Keywords: *Reproductive performance, snailets, Archachatina marginata, protein level, survivability.*

Date of Submission: 02-03-2022 Date of Acceptance: 16-03-2022

I. INTRODUCTION

Snails have been known to be an important and valuable source of animal protein in many countries of the world[1,2] and in many parts of West and Central Africa[3], having good quality protein of upto 60.56% [4] and rich in potassium, phosphorus, essential amino acids and vitamins C and B complex[5, 6].There is a flourishing international trade of snails in Europe and North America and that the annual requirement of snails in France is about 50,000 tonnes, over 60% of which is imported[7]. The estimated annual consumption in Italy is 450million snails of which 50% is imported and in Spain alone, more than 4000 tonnes are demanded every year[8]. However, despite the considerable foreign and local demands, commercial snail farming such as those in Europe, South-East Asia, and the United States have remained in their infancy in Africa [9].In Cameroon, Ghana, Nigeria, Côte d'Ivoire, and some other West African countries where snail meat is particularly popular, snails are gathered from the forest during the wet season[10]. The Giant African Land Snail (*Archachatina marginata),* is one of the micro-livestock that could serve as a readily available and cheap source of animal proteins for the human populations where snails thrive widely[11].

Success in snail production involves among other things proper nutrition. Nutrients such as protein, energy, and minerals should always be provided. According to [12], protein functions mainly in tissue growth, metabolic activities, reproduction, while calcium functions in shell growth [1]. Most snails are herbivores, feeding on green vegetation including fruits and vegetables on farms, although a few land species and many marine species may be omnivores or carnivores [13,14,15]. Snails conventional feed are mostly of plant origin including

pawpaw leaf, pawpaw fruit, watermelon, sweet potatoes, breadfruits, water leaves, leaves, and ripe fruits of banana and plantain, orange, mango fruits among others [16,17,15]. According to Kehinde *et al*. [13,] and Odunaiya *et al* [18] these feeds are seasonal, perishable, and cannot supply all the nutrients required for optimum performance of snails. Ibom[19] and Okon *et al*[20] observed that snails fed on sole forage as well as those fed on sole concentrate feed do not perform well compared to snails on mixed feeding regimes of forage and formulated diet. Such diets according to these authors contain varying combinations of ingredients for growth and reproduction. There is therefore the need to use supplemental diets for a timely and successful snail production venture since their performance is greatly influenced by what they feed on [21,13,16,15]. Feed formulated to meet the snail's specific nutritional requirement has the effect of enhancing the productive potential of these snails. Their maturity and market weight can equally be attained within a shorter time [22, 23, 24]. The use of diets that could meet the nutrient requirements of snails can increase their performance as a whole. The use of protein feed at different levels of incorporation in the diet of snails is of great importance towards this achievement. The objective of this study was to look at the effect of protein nutrition on the reproductive performance of snails.

II. MATERIALS AND METHODS

Study period and area

This study was carried out from January to April 2020 (4months) under experimental conditions at the snailery unit of Helvy farms upskill Research at Station Bamenda of the Western Highlands of Cameroon situated on latitude 5°57'5.98" N and longitude 10o10'10o04" E, at an altitude of 1,258 m above sea level [25]. It is characterized by a tropical climate consisting of two distinct seasons; a wet season from March to October and a dry season from November to February. The mean annual rainfall is about 2,145 mm and a mean annual temperature of 21.5 °C with the highest temperatures recorded in March (23 °C) and the lowest temperatures recorded in July and August (18°C). The average relative humidity stands at about 75%, with February recording the lowest mean relative humidity and July being the most humid month[26]

Experimental design and Diet

150 sexually mature adult breeding *Archachatina marginata* snails weighing between 43 and 58g, full shelled, free of any form of injury gotten from the extensive system of the Helvy Farms Upskill Research Station Bamenda, were acclimatized for four weeks in the pens to enable them to shed the eggs they came with before commencement of the study. The snails were weighed 10snails each of similar weights and randomly distributed to 15 pens. There were four (4) treatments corresponding to the supplemental diets (Table 1) and a basal control diet. Each treatment T0, T1, T2, T3, and T4 had 3 replicates; R1, R2, and R3 (Figure 1). The supplemental diets (Table 1) were produced with ingredients gotten from BELGOCAM Bamenda Branch meanwhile; the basal diets (T0) (waterleaf, pawpaw leaf, cabbage, lettuce, pawpaw fruit, watermelon, and ripe banana) came from the local markets in Bamenda. A mixture of equal proportions of the basal diets (T0) gave a Mean Crude Protein content of 1.4%.

Table 1: Feed formula and calculated composition of supplemental diets

Ingredients	**Proportion of ingredients (%)**			
	***T1 (16 %)**	**T2 (18 %)**	**T3 (20 %)**	**T4 (22 %)**
Corn flour	55.00	55.00	55.00	55.00
Soybean cake	16.8	18.9	20.7	22.8
Palm kernel cake	3.75	2.65	2.75	1.01
Fish meal	4.35	3.35	1.65	1.09
Limestone (CaCO3)	20.0	20.0	20.0	20.0
Iodizedsalt	0.1	0.1	0.1	0.1
Total	**100**	**100**	**100**	**100**
	Calculated Composition			
CrudeProtein (%DM)	16.03	18.01	20.04	22.05
Calcium	8.12	8.14	8.12	8.13
ME (Kcal/KgDM)	2500.03	2500.01	2500.05	2500.05
Fat	3.04	3.03	3.04	3.02

*T= Treatment

Animal management

The methodology used in snail management, egg collection, and incubation was as described by Okon *et al*.,[20,] and Agbelusi *et al*.,[27,]. 150 sexually mature adult breeding *Archachatina marginata* snails weighing between 43 and 58g, full shelled, free of any form of injury were acclimatized for four weeks during which time they would have to shed the eggs they came with before commencement of the study. The *Archachatina marginata* snails were managed intensively in built-up surface trench pens of 1m×0.5m×0.5m in dimension under a shade made of aluminum roofing sheets in an open space with adequate cross ventilation. To prevent potential attacks on the snails from soil organisms, the soil introduced into the pens was heat-treated using boiled water and allowed for 24hrs before the introduction of the snails. Also, dry banana leaves (*Musa paradisiaca*) were heat-treated by steeping into boiled water to kill ants and other insects before placing in the pens to serve for covering, moisture absorber, and food. Heat treatment of the soil in the pens was also repeated every 3 months necessarily to eliminate any potential pests and microbes that could be a nuisance to snail growth and development. Shallow feeding and drinking trays were placed in all pens to prevent the drowning of snails.

10 breeding snails each were randomly allotted to treatments following a completely randomized design into 4 treatment groups with 30 snails of homogenous weight per treatment. Each pen of T1 T2 T3 and T4 received 30g of supplemental diets containing different levels of protein (16%, 18%, 20%, and 22%) + 30g of the basal plant diet while the snails in the Control pen (T0) received only the basal plant diet daily (60g) which had a mean crude protein content of 1.4% (on DM basis). The basal diet was analyzed at the Food Technology Laboratory of the Catholic University of Cameroon-Bamenda on both a fresh and dry matter basis. The basal plant diet was weighed (60g) and served which was made of waterleaf, pawpaw leaf, cabbage, lettuce, pawpaw fruit, watermelon, and ripe banana used throughout the experiment. Water was provided *ad libitum*, snails were fed each day between 4-5 pm following their nocturnal feeding habit [28]. The snail pens were watered every day to maintain the relative humidity (70-80%) level for snail production [29].

The snails were allowed to breed naturally following the method described by Ibom[19] and Ibom *et al*.[30]. Data were collected on reproductive performance characteristics which were; number of clutches, number of eggs per clutch, the weight of an egg, duration of incubation, hatchability, survivability, and weight of snailets.

Trial management

The eggs considered for this study were collected after four weeks of acclimatization and adaptation of the breeding snails to the different treatments in the rearing pens. Eggs were collected from clutches daily and after collection, all the eggs for incubation were sorted against cracks and morphological deformities before measurements began. Egg weights were measured at lay using a KA8-AM digital LCD electronic scale balance of 0.01g sensitivity. The number of egg clutches, number of eggs per clutch were noted while egg lengths and breadths were measured with a Focket-Carbon Steel vernier caliper of 0.02mm accuracy.

The eggs were weighed in incubation batches of ten (10) with a KA8-AM digital LCD electronic scale balance of 0.01g sensitivity. Each incubation batch was tied in a mesh net and randomly placed in an incubation medium to a depth of 3 to 5 cm and covered sparingly with the incubation substrate which was a moist mixture of sawdust/soil. This procedure continued until a total of three hundred (300) eggs were incubated in the various incubation boxes lined with impermeable plastic film and filled with moist soil/sawdust mixture at the same temperature (25-28^{o}C) and humidity (70-80%) watered twice every week to maintain the humidity level for proper development of snail eggs.

Measurement of humidity of the incubation media was taken using a ROBU-IN 3 way soil probe, whereas the temperature of the incubation media was recorded at 09:00 and 16:00 daily with the help of a DURAC® Plus^{TM} Pocket mercury-in-glass thermometer throughout the incubation period. Eggs in all incubation boxes were checked every 3 to 4 days for any possible hatchlings. After 45 days unhatched eggs were broken to reveal their contents. At hatching, the weights of the snailets were also recorded. Incubation duration, hatchability, and survivability were also calculated.

Data collection

Data collected for reproductive performance included the egg characteristics (weight, length, breadth), number of egg clutches, number of eggs per clutch, incubation duration, and weight of snailets. The eggs were observed and checked for snailets and turned every five (5) days from day fifteen (15) in incubation. The snailets that emerged were removed, counted, and transferred to growing pens according to the various treatment diets (T0, T1, T2, T3, and T4) to prevent them from consuming the other eggs

still in incubation. Unhatched eggs were allowed in incubation for up to 45 days [27], after which the eggs were gently cracked to reveal their contents.

The number of egg clutches, numbers of eggs per clutch were counted, and incubation duration (in days) was recorded as the number of days eggs took to hatch from the date of incubation. The numbers of eggs hatched were counted as snailets emerged from the eggs. The snailets were weighed to determine their weight at hatching. Hatchability and survivability were also calculated and expressed as a percentage. The reproductive parameters under study were calculated using the following formulae as described by Ibom *et al.* [30] and Oyeagu *et al.* [31].

Reproductive performance characteristics measured:

- Egg weight and weight of snailets were measured using KA8-AM digital LCD electronic scale balance of 0.01sensitivity and a Focket Carbon Steel vernier caliper of 0.02sensitivity were used to measure egg breadth and egg length respectively.
- Number of clutches and clutch size (counted and recorded)

- Eggs counted clutch by clutch to obtain the total number of clutches and also the total number of eggs per clutch

- Duration of incubation (DI)

- Interval between incubation and hatching and the various means calculated.

DI= Date of incubation to Date of hatching

$$\%\, Hatc\square ability = \frac{number\ of\ \square atc\square ed\ eggs}{numberofeggsincubated} \times 100$$

$$\%\ \text{Survivability} = \frac{Numberoflivesnailets}{totalsnailets\square atc\square ed} \times 100$$

Data analysis

Data collected were subjected to a one-way Analysis of Variance-ANOVA (variable being protein level) following the general linear model (GLM), according to the following statistical model :

$\mathbf{X_{ij} = \mu + \alpha_i + e_{ij}}$

X_{ij} = Observation on the animal having received treatment or ration i

μ = general mean

α_i = Effect of protein level (i)

e_{ij} = residual error caused by animal j having received the treatment or ration i

Separation of significant means was done using Duncan's test at 5% level of significance [32]. Correlation and regression coefficients were used to evaluate the relationship between protein level and the weight of the snailets. Statistical analyses were done using SPSS 18.0 software.

III. RESULTS

Influence of protein level on the egg characteristics of sexually mature *A. marginata* snails

Table 2 shows the effect of protein level on the egg characteristics. Protein supplementation was observed to influence the reproductive performance of mature snails. Results show that there was an increase in all the egg characteristics as the protein level in the diet increased. This was the case for the number of clutches (2-4 clutches), clutch size (9-14 eggs), egg weight (255-283mg) for the basal diet (T0) compared with the 22% (T4) protein supplemental diet respectively. The highest in number of clutches, clutch size, egg weight, egg breadth, and egg length were obtained in snails fed the supplemental diet containing 22% crude protein and the lowest values were obtained in snails receiving the control diet (T0). There were significant differences ($P<0.05$) between the snails fed different levels of the supplemental diet and those fed solely the basal diet. The snails fed supplemental diets containing 20% and 22% protein levels respectively were significantly higher ($P<0.05$) in the number of clutches, clutch size, egg weight, egg breadth, and egg length compared to the snails fed supplemental diets containing 16%, 18% proteins levels as well as the control group.

Table 2: Influence of protein levels on egg characteristics of sexually mature *A. marginata* snails

Egg characteristics	**Treatments**				
	T0 (1.4%)	**T1 (16%)**	**T2 (18%)**	**T3 (20%)**	**T4 (22%)**
Number of egg clutches	1.56±0.51[a]	2.89±0.11[b]	3.04±0.11[b]	3.44±0.12[c]	3.93±0.15[c]
Clutch size	9.26±0.13[a]	10.63±0.26[b]	10.30±0.28[b]	13.07±0.43[c]	13.78±0.49[c]
Weight of an egg (mg)	255.74±1.29[a]	265.70±1.78[b]	269.48±1.78[b]	277.56±2.37[c]	283.07±3.57[c]

Egg breadth (cm)	0.78±0.27[a]	1.13±0.28[b]	1.15±0.26[b]	1.27±0.32[c]	1.32±0.26[c]
Egg length (cm)	1.22±0.27[a]	1.81±0.27[b]	2.11±0.26[c]	2.21±0.32[c]	2.37±0.27[c]

Means within the same row with different superscript letters differ significantly (P<0.05) T0=1.4% T1= 16%, T2=18%, T3=20% & T4=22% of dietary protein levels respectively

Influence of protein level on duration of incubation for *A. marginata* eggs

From the results (Table 3), the duration of incubation of eggs decreased as the protein level in the diet increased. The longest (42days) incubation duration was observed in eggs from the control group while the shortest (24days) was observed in eggs from snails receiving 22% protein level in supplemental diet giving a numerical difference of 17days. This showed that the protein level in the supplemental diet may have affected the metabolic activities involved in the incubation process within the snail eggs. The number of days of incubation of eggs from snails fed supplemental diet at 22% protein level was significantly shorter (P<0.05)than for eggs from all the other experimental groups (including the control group).

Table3: Influence of protein levels on the duration of incubation for *A. marginata* eggs

Treatments	Duration of Incubation (days)
T0 (1.4%)	41.97±0.60[a]
T1 (16%)	26.97±0.14[b]
T2 (18%)	26.17±0.13[bc]
T3 (20%)	25.57±0.12[c]
T4 (22%)	24.07±0.14[d]

Means with different superscript letters differ significantly (P<0.05) T0=1.4% T1= 16%, T2=18%, T3=20% & T4=22% of dietary protein levels respectively

Influence of protein levels on hatchability of eggs and survivability of snailets

The results in Table 4 show that there was a gradual increase in hatchability of eggs and survivability of snailets as the level of protein supplementation increased in the diet. The eggs from Snails fed the diet containing 22% protein showed significantly (p<0.05) higher hatchability and survivability rates compared to all the other treatments. The lowest hatchability (70.61%) and survivability (45.39%) rates were observed in the control group. In comparison to the control group, a 22% protein level in the supplemental diet increased the hatchability of eggs by 16% and doubled the survivability of snailets.

Table4: Influence of protein level on hatchability of eggs and survivability of snailets

Treatments	% Hatchability	% Survivability
T0 (1.4%)	70.61±6.11[a]	45.39±7.21[a]
T1 (16%)	73.85±9.32[b]	90.92±9.31[b]
T2 (18%)	75.42±6.71[b]	91.73±8.81[b]
T3 (20%)	79.21±7.38[c]	93.64±9.26[c]
T4 (22%)	86.23±6.02[d]	96.88±8.75[d]

Means within the same column with different superscript letters differ significantly (P<0.05). T0=1.4% T1= 16%, T2=18%, T3=20% & T4=22% of dietary protein levels respectively

Influence of protein level on snailets weight in *A. marginata*

The results (Table 5) show that there was an increase in snailets weights as the protein levels increased, with the highest (1.86g) weight obtained from snails fed 22% protein level in supplemental diets and the lowest (0.95g) in snails fed solely the basal diet. The snailets weight was significantly (P<0.05) higher in snails fed 22% protein levels and differed significantly from the other treatment levels and the control group.

Table 5: Influence of protein levels on snailets weight (g) in *A. marginata*

Treatments	Snailets weight (g)
T0 (1.4%)	0.95±0.24[a]
T1 (16%)	1.36±0.25[b]
T2 (18%)	1.47±0.33[b]
T3 (20%)	1.77±0.37[c]
T4 (22%)	1.86±0.41[d]

Means with different superscript letters differ significantly (P<0.05). T0=1.4% T1= 16%, T2=18%, T3=20% & T4=22% of dietary protein levels respectively

IV. DISCUSSION

Reproductive performance of mature snails

Egg characteristics

The reproductive performance of mature snails in this study has been clearly affected by the protein level of the supplemental diets. This is so for the mean number of clutches which increased from 2 in snails fed the basal plant diet to 4 in snails fed 22% protein level in supplemental diet. The mean clutch size increased from 9 eggs in snails fed the basal plant diet to 14 eggs in snails fed 22% protein level in supplemental diet. These results corroborate with those of Omole *et al.*,[33],whose mean number of clutches and clutch size ranged from 2-5 and 7-12eggs respectively for *Achatina achatina* and also with Okon *et al.*[34] for *Archachatina marginata* on both formulated and natural plant feed material. These results are at variance with those of Okon and Ibom[35] who obtained a mean clutch size of 20 -28 eggs for black-skinned purebred cross, 12-18eggs for white-skinned purebred cross, and 12-20eggs for the black-skinned crossbred cross. The differences in the number of clutches and clutch sizes may be due to the effect of the diet on the reproductive snails. Dietary protein interferes with all metabolic activities including digestion, absorption, and egg formation.

The egg weights (0.95-1.86g) recorded in this research, however, fall below the range recorded by Okon *et al.*[36] who showed that snail egg weights at laying ranged from 0.54 - 2.45g (mean of 2.00g).The average egg weights of the black and white-skinned ecotypes of *A. marginata* to be 1.80g and 1.05g respectively[37]. However, Giant African Land Snail egg weight of 2.3–5.1g with a length of 2.1-3.2cm and breadth of 1.5-2.6 cm have been reported[38,39,22,40]. The huge variation in the average egg weight ranges reported could be linked to the effect of improved nutrition as related to the protein level in the supplemental diet. Nutrition itself has been reported by several authors [41,42,43,44,45,31,46] to provide hormones responsible for embryonic growth and development because the most important factor influencing the performance of animals under captivity is the quality of the diet offered to the animals. This performance might be because available nutrients of the supplemental diets originate from different feedstuffs which could complement each other in the deficiency to specific nutrients.

The mean egg breadth obtained in this study increased from 0.89cm in snails fed the natural plant feed to 1.32cm in snails fed supplemental diet at 22% protein level. Meanwhile, the mean egg length obtained ranged from 1.22cm in snails fed the basal diet to 2.37cm in snails fed supplemental diet at 22% protein level. These results obtained are slightly different from those obtained by Ibom *et al.*[37] who observed that the mean egg lengths for black-skinned and white-skinned ecotypes of *Archachatina marginata* were 1.61cm and 1.43cm respectively. Lower egg breadth values of 1.29 cm and 1.05cm for the black-skinned and white-skinned ecotypes of *Archachatina marginata* respectively obtained by Ibom *et al* [37], are similar to the mean values obtained in this study. Egg length and breadth observed in this study differ from the egg length range of 13.00-16.00 mm (mean of 14.88 mm) and breadths from 9.00-11.00 mm (mean of 10.80mm) reported in literature[36]. The supplemental diet improved the egg characteristics which in turn influenced the reproductive performance of the snail. The higher the number of egg clutches and clutch size, the greater the number of eggs to be incubated for possible hatching and a probable increase in the number of snailets and of course subsequent increase in productivity of mature snail. The egg weight, length, and breadth are directly proportional to the weight of the snailets.

Duration of incubation

Protein nutrition in supplemental diets influenced the incubation duration of the mature *A. marginata* snails. The duration of incubation observed in this study varied from 24-26days in snails fed the supplemental diet and 42 days in snails fed the basal plant diet. The findings corroborate with those of Omole *et al*[33] who reported an incubation period range of 25-32days. Also, Okon *et al.*[36] stated that snails hatched between 28 and 30days with a mean incubation period of 29 days while Ibom *et al.*[30] observed the incubation period to range from 24-29days. The values obtained in this study are also similar to those obtained by Ibom[19] and Okon *et al*[47] but lower than the values reported by other authors [48,49,50]. Their values corroborate with those obtained for the control experiment in this study. The disparity in incubation period may be attributed to variation in genetic factors like breed, strain, age and size of the snail, egg size, and environmental factors like temperature and relative humidity as opined [36].Besides, Ibom *et al.* [30]observed that exposure of eggs to fluctuating environmental conditions which differed from their near-constant uterine environment may influence the incubation period. In addition, they noted that incubation conditions such as uptake and loss of moisture, increased transpiration, and water loss resulting from increased heat produced by the developing embryo canal so cause this variation in the incubation period. This difference in incubation duration between snails fed 22% CP in supplemental diet and those fed the basal diet is up to 17days. Time is a

very important factor in agriculture, which implies there will be higher productivity in snails fed the supplemental diet compared to those fed solely on the basal diet. These snails fed a supplemental diet of 22%CP probably acquired more of the nutrients necessary for embryo development. Therefore, the protein level has been demonstrated to have a far-reaching influence on the reduction in the duration of incubation. Apart from other factors which have already been elaborated upon, protein nutrition as one of the contributors to improvement in duration of incubation may have ensured adequate nutrient content and embryo development in a way that brought about efficient and timely hatching of the eggs from the mature snails in the protein supplemented diets.

Hatchability and survivability of snailets

The rate of hatchability obtained across the study for all the snails fed both supplemental protein diet and basal plant diet ranged from 70%-86%. These findings fall within the range of 67%-82% reported by Okon *et al.* [27,] and Ukpong *et al.*[51] who worked on different incubation media. However, several authors reported a 0-100% hatchability range for purebred white-skinned ecotype of the same snail species [39,52,53,54,19,30] used in this study. The values obtained in this study agree with the findings of several other authors [55,16,56,33,19,30]. The results of this study are higher than those obtained for *Archachatina marginata* snails raised in South-Eastern Nigeria[52,57,58,34]. Snail egg's hatchability is highly affected by the incubation media conditions (temperature, relative humidity, dryness, and water-logging)[19]. Snail egg hatchability depends on environmental conditions and whether or not they were fertilized before laying [30].

The findings for survivability obtained in this study (Table 4) in snails fed the supplemental diet at different protein levels of 16%, 18%, 20%, and 22% agree with those obtained by some authors who reported survivability range of 86%-97%[19,59,30]. However, these results are higher than those obtained by Adegbaju[55] who observed a survivability range of 60%-76%. The significant difference in survivability observed between the snails fed the supplemental diet and those fed the basal plant diet indicates that supplemental protein diets exposed the snails to essential nutrients especially protein required for their maintenance, growth, and survival.

3.4.4. Weight of snailets

The mean weights of snailets were seen to be influenced by the protein level in the supplemental diets. There was an increase in snailets weights with increasing protein levels in the supplemental diets. The snailets weights in the supplemental diets were significantly higher than those of the basal diets. The snailets weights increased from 0.95g in snails fed the basal diet to 1.86g in snails fed 22% protein level in the supplemental diet. These results are higher than those obtained by many authors [52,54,55,37,60,61,19,62,34,30]for crossbred *Archachatina marginata var. saturalis* snails.

V. CONCLUSION

It can be concluded that feeding snails with diets containing 22% protein level in a supplemental diet can greatly improve the reproductive performance of snails. The number of egg clutches, clutch size egg weight, egg length, egg breadth, duration of incubation, hatchability, and snailets weight were all improved and consequently had an impact on the reproductive performance and productivity of mature *A. marginata* snails in this study.

REFERENCES

[1]. Akinnusi, O., 1998. A practical approach to backyard snail farming. Nigerian Journal of Animal Production. 25, 193–197.
[2]. Jennifer, V., 2009. Snails more protein, less expensive than beef;[accessed2015Nov1].News.discovery.com//snails-more-protein-less-ex.
[3]. Blay, E.T., Ofori, B.D.,Heloo, J.,Ofori, J.B.,Nartey, E., 2004. Agro diversity within and without conserved forests for enhancing rural livelihoods.In:Gyasi, E.A.,Kranjac- Beris, avljevic, G.,Baly, E.T.,Oduro, W. (eds.) Managing Agrodiversity The Traditional Way: Lessons from West Africa in Sustainable Use of Biodiversity and related natural Resources. Tokyo: United Nations University Press. Pp.203-214.
[4]. Essein, E.A.,Ubong, J.E.,Ndifreke, E.W., Harrison, O.T., 2016. Nutritional assessment of giant land snail (Archachatina marginata) from a shellfish producing area in AkwaIbom state, Nigeria. African Journal of Science and Research, 3,(5):11-15.ISSN: 2306-5877. http://ajsr.rstpublishers.com/
[5]. Baba, K.M., Adeleke, M.T., 2006. Profitability of snail production in Osun State, Nigeria. Journal of Agricultural and Food Sciences. 4, 147-155.
[6]. Okpeze, C.N.,Omole, A.J.,Ajayi, F.T.,Adebowale, E.A., 2007. Effects of feeding adult snails Stylosanthes guianensisor Lablab purpureusas substitute for pawpaw leaf. African Journal of Biotechnology. 6, 1959-1962.
[7]. Huet, N., 2014 Snail production and trade in France; [accessed 2015 Sep 16]. www.frenchkpi.com/snails- production-and-trade-in-france/.
[8]. Oscar ,2013. Snail farming: a great business opportunity for everyone; [accessed 2015Nov1].Vivirmas.org//snail-farming-great-business opportunity

[9]. Duah, O.A., Monney, K.A., 2001. Snail farming: snail collection and small-scale production in Africa and Europe. African Journal of Ecology. 37, (3):36-43.

[10]. [CADEV] Community Action for Development 2006. From a taboo to a delicacy: the evolution of eating snail meat in Bakossi (Cameroon).Nonwood Newsno.15. FAO.

[11]. Ngoupayou, D., 1992. Guinea pig raising for meat production. Proceedings of Seminar Research on Feed and Feeding Summary, Pp.15–19.

[12]. Olomu, J.M., 1995. Monogastric animal nutrition. Principles and practice. Benin, Edo, Nigeria: A Jachem Pub. P. 54.

[13]. Kehinde, A. S., Omole, A.J., Odidi, S.E., Muraina, G., Ayoola, O.A., Adeyinka, A., Oriowo, B.F., 2004. Effect of different protein levels on the performance of growing snails. Journal of agriculture, Forestry and the Social Sciences, 2, (2): 78-83.

[14]. Hamilton-Amachree, A., H.D..Mepha and C.U. Ogunka-Nnoka, 2009. Mineral contents of tissues and body fluids and heavy metal contaminants of four predominant snail species in the Niger Delta. Journal of Food, Agriculture & Environment, 7(2): 163-168.

[15]. Okon, B., Ibom, L.A., 2012. Snail breeding and snailery management.Fresh dew Productions, Calabar, Pp. 1-70.

[16]. Akinnusi, O., 2004.Introduction to snail farming. (2nd ed). Abeokuta: b Triolas Esquisite Ventures, 42-44.

[17]. Okon, B.,Ibom, L.A., Williams, M.E., Etukudo, O.M., 2010. Effects of parity on breeding and morphometric traits of eggs and hatchlings of F1 crossbred of snails (Archachatina marginata var. saturalis). Journal of Agriculture, Biotechnology and Ecology.3, (1):36-43.

[18]. Odunaiya, O., Akinyemi, F.A.O., 2008. Effect of some cheap locally available feeding material on the growth performance of edible land snail. Proc 33rd Ann. Conf. of Nig. Soc. for Anim. Prod. (NSAP).March 16th – 20th, 2008, College of Agricultural Sciences, Olabisi Onabanjo University, Yewa Campus, Ayetoro, Ogun State Nigeria. Pp. 126-128.

[19]. Ibom, L.A., 2009. Variations in reproductive and growth performance trait of white- skinned x black-skinned African giant snail hatchlings [Archachatina marginata(Swainson)] in Obubra, Nigeria. Ph.D. Thesis, Department of Animal Science, University of Calabar, Calabar, 166p.

[20]. Okon, I. B., Ibom, L.A., Ekpo, E. and Ewa, O. (2009). Evaluation of reproductive and some egg quality parameters of Albino snails (Archachatina marginata saturalis Swainson). Journal of Applied Science, 12(1): 8234-8240.

[21]. Okonkwo, A.C., Isaac, L.J., Nkanga, I., Usoro, O.O., 2000.Effect of various feeding regimes on the performance of snails (Archachatinamarginata).Proc 25th Ann. Conf. Nig. Soc. For Anim. Prod. (NSAP), March 19-23,2000. Michael Okpara Univ. of Agric. Umudike, Nigeria.Pp314-315.

[22]. Stievenart, C., 1996. Shell morphology, growth, reproduction and aestivation by African snails: laboratory observation on Archachatina marginata Saturalis, Achatina achatina and Achatina fulica. Ph.D Thesis Institute of Tropical Medicine, Antwerp, Belgium. 240p.

[23]. Omole, A.J., Tewe, O.O., Makinde, G.O., Adetoro, F.O., Saka, J.O., Ogundola, F.I., 2000. Preliminary studies on the response of growing snails (A. marginata) to compounded feed as a supplementary ration. Tropical Animal, 3, 35-40.

[24]. Ejidike, B.N., 2009. Assessments on the Performance of snails Reared on Plant leaves or Supplemented plant leaves, Applied Tropical Agriculture. 14,(1&2):124-128.

[25]. Kande, L.H., Kamguia, J., Yap, L and Foyang, L. (2016).Reference Ellipsoid Parameters of Cameroon from GPS Data. International Journal of Geosciences, 7,1049-1056. http//dx.doi.org/10.4236/ijg.2016.78079

[26]. Kamguia, J., Tabod, C.T., Nouayou, R., Tadjou, J.M., Manguelle-Dicoum, E. and Kande, H.L. (2007).The Local Geoid Model of Cameroon, CGM05. Nordic Journal of Surveying and Real Estate Research, 4, 7-23.

[27]. Agbelusi, E., Adeparusi, E.O., 1999. Eggs incubation period and hatching success of the African Giant land snail (Archachatina marginata) Swains on indifferent incubation media. Journal of Applied Animal Research, 15, 57-62. DOI:10.1080/09712119.1999.9706231

[28]. Ademolu, K.O., Jayeola, O.A., Idowu, A.B. and Elemide, I.O. (2011).Circadian variation in locomotor and feeding periods of two land snail species. Arch Zootec, 60, 1323-1326.

[29]. Malaisse, F. (1997). Se nourrir en forêt claire africaine. Approche écologique et nutritionnelle. Les Presses Agronomiques de Gembloux, CTA Wageningen.

[30]. [30]Ibom, L.A.,Okon, B., Bassey, B.E.E., 2012. Egg traits, hatchability and survivability of black skinned, white skinned and crossbred Archachatina marginata snails. International Journal of Agricultural Science and Bioresource Engineering Research, 1, 10-18.

[31]. Oyeagu, C. E., Udeh, U. F., Uzochukwu, I. E., Osita, C.O., Simeon, O.C. U. and Obinna, H. A. (2018).Effect of dietary Centrosema pubescens leaf meal on growth and reproductive traits of Archachatina marginata snails. Journal of Applied Animal Research. Vol. 46, 2018- Issue 1.

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

[33]. Omole, A.J., Kehinde, A.S., 2005. Backyard snail farming at a glance. Back to Agricultural Series (1) Ibadan Technovisor Agricultural Publications.

[34]. Okon, B.,Ibom, L.A., Williams, M.E., Eyoh, G.D., Afangideh, U.P., 2011a.Reproductive and egg quality traits of African Giant Snails (Archachatina marginata var. saturalis) under mixed feeding with graded levels of seamp taro cocoyam (Cytosperma chamissonis) and forages.Journal of agriculture, Biotechnology and Ecology.4, (1):29-40.

[35]. Okon, B.and Ibom, L. A.(2012) Snail breeding and snailery management. Freshdew Productions, Calabar, 1-70.

[36]. Okon, B. L.A., Ibom, I.E., Ebenso, A.E., Bassey, 2013. Developmental stages and quality traits of giant African land snails [Archachatinamarginata(swainson)]eggs. Journal of Natural Science. 5, (10): 1121-1126. http://dx.doi.org/10.4236/ns.2013.510137

[37]. Ibom, L. A., Okon, B., Essien, A., 2008.Morphometric analysis of eggs laid by two ecotypes of snails Archachatina marginata (Swainson) raised in captivity. Global Journal of Agricultural Sciences, 7, 119-121.

[38]. Plummer, J.M., 1975.Observationsonthereproduction, growth, and longevity of a laboratory colony of Archachatina marginata (Swainson) subspecies Ovum.Proc. Malac. SOC. of London, 41, 395-413.

[39]. Awesu, M.O., 1980. The biology and management of the African giant land snail, Archachatina marginata. M.Phil. Dissertation, University of Ibadan, 198p.

[40]. Ejidike,B.N.(2009)Assessments on the Performance of Reared on Plant leaves or Supplemented plant leaves, Applied Tropical Agriculture. 14 (1&2) 124-128.

[41]. Amaefule, K.U and Onwudike, O.C. (2000). Evaluation of processing methods of, pigeon pea seeds (Cajanus cajan) as protein source for broiler starters. Journal of Sustainable Agriculture and Environment 2(1): 134-138

[42]. Ani, A.O. and Okeke, G.C. (2003).The substitution of pigeon pea (Cajanus cajan) seed meal for soybean in broiler finisher ration. Proceedings of the 8th Annual Conference of Animal Science Association of Nigeria, p. 10-12

[43]. Esonu, B.O., Lheukwumere, F.C., Lwuji, T.C., Akanu, N. and Nwugo, O.H. (2003).Evaluation of Micro dermis puberula leaf meal as feed ingredient in broiler starter diet. Nigeria Journal of Animal Production 30 (1): 3-8.
[44]. Nyameasem, J.K. and Borketey-La, E.B. (2014).Effect of formulated diets on growth and reproductive performance of the West African giant snail (Achatina achatina). J. Agric. Biol. Sci 9(1):1-6.
[45]. Oyeagu, C. E., Udeh, U. F., Uzochukwu, I. E., Osita, C.O., Simeon, O.C. U. and Obinna, H. A. (2018). Effect of dietary Centrosema pubescens leaf meal on growth and reproductive traits of Archachatina marginata snails. Journal of Applied Animal Research. Vol. 46, 2018- Issue 1.
[46]. Jimoh, O.A., Akinola, M.O., Ayedun, E.S., Oloruntola, O.D., Daramola, O.T., Ayodele, S.O. & Omoniyi, I.S. (2020). Effects of differen protein sources on growth and carcass characteristics of African Giant Land Snail (Archachatina marginata) in captivity. Animal Research International, 17(2): 3682-3690.
[47]. Okon, B., Ibom, L.A., Odido, E.E., 2011b. Reproductive performance and egg quality traits of cross breeding between two strains of snails. Archivos de zootecnia. 60, (229):153-156.
[48]. Payne, W. J. A., and Wilson, R. T. (1999).An Introduction to Animal Husbandry in the Tropics.5th ed. Osney Mead, UK. Blackwell Publishing Company Pp. 702-704.
[49]. Ejidike, B.N., Afolanyan,T.A., Alokan, J.A., 2002. Influence of food and season on egg production of African giant land snail (Archachatina marginata). Proceedings of the 27thAnnual Conference of NSAP; March 17–21; Akure, Nigeria: Federal University of Technology. Pp. 309-311
[50]. Ubua, J.A., 2004.Reproductive potentials of two snails –Archachatina marginata ovum and Archachatina marginata saturalis in the swamp Forest Zone of Nigeria MSc Thesis. Department of Animal Science. University of Calabar. Calabar, Nigeria.
[51]. Ukpong, E.E., Jacob, D.E.,Ekpa, N.E.,Nelson, I.U., 2013. Hatchability and Morphometric Growth Rate of African Giant Land Snail (Archachatina marginata) under Three Feeding Treatments. The Journal of Bioprocess Technology Photon 97,189-192.
[52]. Ogogo, A.U., 1989. The replacement of cassava flour with groundnut cake in the nutrition of the giant African snail A. marginata. MSc Thesis University of Ibadan, Ibadan, Nigeria.
[53]. Odido, E.E. (2007).Evaluation of reproductive, performance and some egg quality parameters of black-white (Albino snails) stained snails (Archachatina marginata saturalis) in Cross River State B. Agric Project, Department of Animal Science University of Calabar, Calabar (unpublished).
[54]. Ewa, E.C., 2007.Evaluation of reproductive performance and some egg quality parameters of albino snail (Archachatina marginata var. saturalis) in Cross rivers state. B. Agric. Project, Animal Science Department, University of Calabar, Calabar.
[55]. Adegbaju, S.W., 2000.A Guide to a Successful Poultry and Snailery Business. Agrocare Series. Pp. 22-29
[56]. Akintomide, T.O., 2004.Tropical Snail Farming. (1sted) Abeokuta: Oak Ventures, 185p.
[57]. Amubode, F.O., 1994.Growth and Reproductive Performance of two species of African Giant Snail (Achatina achatina and Archachatina marginata) Journal of Forestry Resources. 9 and 10:68-74.
[58]. Ibom, L.A.,Okon, B., 2010 Variations in morphometric traits of eggs produced from the cross of two ectotype snails [Archachatina marginata (swainson)] in a humid tropical environment. Proceedings, 35th Annual Conference of the Nigerian Society for Animal production. (NSAP). March 14-17, 2010. University of Ibadan, Nigeria. Pp. 28-31.
[59]. Fapohunda, J.B., Omole, A.J., Obi, O.O., Adebowale, E.A., 2007. Nutritional value of chicken offal as a replacement for local fish meal in growing snail. Proceedings of the 32nd Annual Conference of Nigerian Society for Animal Production (NSAP). March 18-21, 2007. Calabar, Nigeria. Pp. 363-364.
[60]. Okon, B. and Ibom, L. A., Williams, M. E. and Etukudo, O. M. (2010). Effects of parity on breeding and morphometric traits of eggs and hatchlings of F1 crossbred of snails (Archachatina marginata var. saturalis). Journal of Agriculture, Biotechnology and Ecology.3(1):36-43.
[61]. Ibom, L. A. and Okon, B. (2010). Variations in morphometric traits of eggs produced from the cross of two ectotype snails [Archachatina marginata (swainson)] in a humid tropical environment. Proceedings, 35th Annual Conference of the Nigerian Society for Animal Production. (NSAP). March 14-17, 2010. University of Ibadan, Nigeria. Pp. 28-31
[62]. Okon, B. and Ibom, L. A., Williams, M. E., Eyoh, G. D. and Afangideh, U. P. (2011a). Reproductive and egg quality traits of African Giant Snails (Archachatina marginata var. saturalis) under mixed feeding with graded levels of seamp taro cocoyam (Cytosperma chamissonis) and forages. Journal of agriculture, Biotechnology and Ecology.4(1):29-40.