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ABSTRACT

A 10-weeks study was conducted to determine the effect of varying dietary protein and energy levels on performance of growing giant African land snail (GALS), *Archachatina marginata.* One hundred and forty-four snails with mean weight of 138.48g were used for this study. The snails were randomly divided into 12 groups of 12 snails each, assigned to 12 diet treatments in a 3 x 4 factorial arrangement involving three crude protein levels (25%, 27.5%, and 30%) and four energy levels (300, 320, 340 and 360 kcal/100g). Each treatment was replicated 3 times with 4 snails per replicate giving a total of 12 snails per treatment. Results showed that the diets were different from one another due to the variation in the protein to energy ratio. Snails fed the treatment 3 diet had the highest protein to energy ratio (99.7) while snails fed the treatment 10 diet had the lowest (69.4). The final and weekly body weight gain (BWG), was highest ($P < 0.05$) for snails (207.84g and 8.75g respectively) fed diet 3 at 30% protein and 300kcal/100g energy levels while the final body weight gain was lowest for snails fed diet 5 (121.08g) and weekly weight gain was lowest for snails fed diet 2 (0.89g). In addition, snails on diet 3 had better ($P<0.05$) FCR (15.01) compared to snails fed with other diets. Diet with high protein and low energy resulted in better weight gains. Shell width increase was positively affected ($p<0.05$) by protein and energy levels with highest values corresponding with the highest protein and energy levels. In conclusion, diets with protein and energy levels of 30% and 300 kcal/100kg seems adequate for the optimum performance of GALS (*Archachatina marginata*) in the humid tropics.

Keywords: Protein-energy ratio, weight gain, shell length, Shell width, Feed conversion efficiency, *Archachatina marginata, GALS.*

INTRODUCTION

Snail meat is gaining worldwide attention as source of protein food for man while snail farming has received much popularity with micro livestock farmers all over the African continent, due to its numerous benefits (Klapwijk *et al.,* 2020). The high-quality protein and essential amino acids in snail meat could adequately supplement the present protein requirement being sought from conventional livestock resources such as pork, poultry and beef. (Nyoagbe *et al*., 2016). Snails also play an important role in traditional medicine in the manufacture of treatments for whooping cough, asthma, diabetes, and other diseases in several parts of Africa (Offiong *et al.,* 2013). Because of their low cholesterol levels, snails have been advised for the treatment of anemia, asthma, high blood pressure, and other related disorders (Kalio and Etela, 2011).

The effect of nutrition on growth performance of livestock is highly important, as studies have shown that nutritional effects are reflected in areas such as body weight changes, systems and organs functions, various aspects of reproductive performance, and body condition score (Meza-Herrera and Tena-Sempere, 2012; Ibtisham *et al.*, 2018; Cordova-Izquierdo, 2016). However, the need to feed suitable feed stuffs, depending on the physiological state of the snails, and at the appropriate digestible protein and energy level, is of great importance (Kirkpinar and Acikgoz, 2018).

Earlier studies by Lee and Lim, (2005); Omole *et al.* (2000); Oluokun *et al.* (2005); Sika *et al.* (2015) and Ani *et al.* (2013) showed that growth characteristics improve with increase in the level of protein and energy in the diet of growing snails. Physiological functions can be compromised as a consequence of nutrient shortages (Gernand *et al.,* 2016). The need for adequate information on protein, energy and mineral requirement for snails is essential since more snail farmers are opting for formulated ration in snail production. However, there is shortage of information on standard nutrient requirements for snail optimum growth. Therefore, the aim of this experiment is to discover the responses of *Achachatina marginata* to compounded rations of varying protein and energy levels during the growing phase.

MATERIALS AND METHODS

The study was conducted at the Snail Unit of the Department of Animal Science, Teaching and Research Farm, Landmark University. One hundred and forty-four (144) growing African giant land snails (*Archachatina marginata*) with average weight of 100 – 150g were purchased from reputable snail farms, and housed in plastic baskets in a completely randomized design (CRD). Each basket is of dimension 30 cm by 40 cm by 24 cm. Each basket base was drilled with holes and covered with sandy loam soil, which was moistened regularly to prevent aestivation. Granulated feed and water were given to snails' *ad libitium*. Shallow plastic troughs were used for feeding and watering. The snails were fed in the evenings, between 5pm and 6 pm and fresh feed and clean water were given to the snails daily while left over feed and water were removed daily. The housing units, feeding and watering troughs were cleaned daily before serving a fresh feed and water. Feces were scooped out of the basket daily to prevent disease outbreak. Twelve (12) diets made up of different combinations of crude protein (22.5, 25, 27.5, and 30%) and energy levels (300, 320, 340, and 360 kcal/100kg) were used. The composition of the diets with the different combinations of protein and energy was represented by treatments 1 to 12 respectively.

Data Collection

The initial body weight of the snails was measured on the first day and subsequent weights were taken every week till the end of the experiment using sensitive weighing balance. The shell length and shell width of the snails were measured with Venier Caliper on weekly basis.

Feed Intake

The total feed intake was measured by weighing out a given quantity of feed, using sensitive scale, for each replicate every week. The snails were fed from this given quantity on daily basis and the left over collected was subtracted from the measured quantity to obtain the total feed intake per week.

Feed Conversion Ratio

Feed conversion ratio was calculated as the ratio of feed intake to weight gain.

Proximate Analysis

Proximate analysis of experimental diets was carried out according to AOAC (1990).

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) as described by Steel and Torrie (1980). Significantly different means were separated using Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

The composition and proximate analysis of the experimental diets (Table 1) shows that the diets were different from one another due to the variation in the protein to energy ratio. Snails fed the treatment 3 diet had the highest protein to energy ratio (99.7) while snails fed the treatment 10 diet had the lowest (69.4). The active feeding by the snails on all the experimental diets with some resultant levels of weight increase indicated that the diets are well accepted by the snails and able to support snail growth, though the capacity of each diet to support snail growth varies. This observation is corroborated by Anigbogu *et al*. (2011), who reported that both nutrient quality and level in the diet is important for animal production to be effective. However, Reece (2004) indicated that feed intake depends on nutrient composition of feed and other factors such as palatability, texture, taste mechanism etc. The present study shows that dietary energy and protein levels both had significant effects on body weight gains, feed intake, shell width and shell length increases. There were differences ($P<0.05$) among the dietary treatments in the final weight gains with snails in treatment 3 (30% CP and 300 kcal/100g) having higher gains when compared with others. The weekly body weight gain was also highest in diet 3 and lowest in diet 2 (27.50% CP and 300 kcal/100g). The average daily, weekly, and total feed intake were highest ($P<0.05$) for snails fed diet 11 (27.50%CP and 360 kcal/100g) and lowest for snails fed diet 2 (27.50%CP and 300 kcal/100g). There were significant differences ($P<0.05$) among treatments in feed conversion ratio (FCR). The highest value for feed conversion ratio was observed for snails in treatment 12 (29.92). While, the best FCR was observed for snails in treatment 3 (15.01), these variations may be due to imbalance in the protein to energy ratio of the diets. This finding is supported by Ogunyemi (2021) who observed similar trends when feeding snails with varied protein and energy. Although snails fed diet 11 at 27.50%CP and 360 kcal/100g, had a higher feed intake, however the weight gain was not commensurate with the feed intake, hence the higher feed to gain ratio. Snails fed diet 2, at 27.50%CP and 300 kcal/100g, had the lowest feed intake but similar weight gains with snails on other diets except those on diet 3. This suggests that the weight gained could have increased if the intake was higher. Earlier studies have shown that snails eat more when the feed is low in energy and palatable (Kehinde *et al.,*2019) also, Beski (2015), reported that high protein products are highly digestible.

The protein-energy (P/E) ratio in snail diets is of great importance for the determination of their dietary protein and energy requirements. In the present study, it was observed that diets with high protein (30%) and low energy (300kcal/100g) resulted in better weight gains. However, an increase in the energy at high protein level could not produce an appreciable increase in weight gain and this may be due to the fact that the energy of the diet dictates the intake of the feed, Albuquerque *et al.* (2003) reported that feed intake increases or decrease as dietary energy intake decreases or increases, respectively. Earlier studies have recommended contrasting protein levels for growth of snails ranging between 19.5 to 26% (Babalola and Akinsoyinu, 2009; Eneruvie *et al.,* 2018; Ani and Ugwuowo, 2011; Tchowan *et al.,* 2018) and while others reported energy levels of 2200 to 3000kcalME/kg (Mayaki and Daramola, 2013, Omole, 2003; Tchowan *et al.,* 2018) and adequate for snail growth. Dietary protein provides the essential amino acids, which are used for protein synthesis in the growth and repair of tissue, and it is principal source of nitrogen (Linda *et al.,* 2011). Earlier reports had shown that at inadequate energy levels, dietary protein in animals would be used as an energy source (Bowen *et al.,* 1995; Drummen *et al.,* 2018) and that the more protein is used for energy, the more ammonia is produced, and the more energy is lost as heat (Cho and Kaushik, 1985, Kohlmeier, 2003, Tomé, 2021) which consequently, should result in less protein being retained in the animal body. The reverse seems to be the case for snails in this experiment, whereby at high protein and low energy the snails gained more weight; the snails utilized the available proteins to produce energy essential for their growth. Proteins are necessary for building and maintenance of living cells in order to increase muscle mass and production. Proteins are important for the renewal of muscle tissue, bone matrix and many physiological processes in the form of digestive enzymes, hemoglobin, hormones, receptors or immunoglobulins (Tchowan *et al.,* 2018). Protein deficiency can cause fatigue in animals, susceptibility to infections, and decreased muscle mass (Jurgens, 2002). The best snail weight gain was achieved on a diet containing 30% and 300 kcal/ 100 g protein and energy, respectively. This diet presumably contained the most appropriate P/E ratio (99.7 mg protein/kcal). An excessive energy intake at moderate protein levels would lead to fat deposition (Hill *et al.,* 2012), however, at an adequate energy level, dietary protein will be spared for growth (Millward, 2016; El-Sayed, 1987). The proper balance between dietary protein and energy is, therefore, essential in snail feed formulation. The present study revealed that at a low energy level (300 kcal/ 100 g), growth rates were significantly high at all protein levels indicating that this energy level is adequate for snail growth. Increasing dietary energy beyond this level did not further improve snail growth and feed utilization efficiency. Ogunyemi (2021) had similar finding when snails fed with varying protein-calorie diets had a decline in growth responses after an optimum protein level was reached.

The total shell width increase was not affected ($P>0.05$) by variations in the protein to energy ratio in the diets. However, the shell width gained per week from week 1 to 4 differed ($P<0.05$) across the dietary treatments, while the shell width gains per week from week 5 to 9 did not differ ($P>0.05$) across the dietary treatments. The shell length increase was affected ($P<0.05$) by variations in the protein to energy ratio in the diets throughout the feeding experiment.

The total shell length increase was highest ($P<0.05$) for snails on treatment 12 and lowest for snails on treatment 2. Further observations showed that snail-shell width increase was constant throughout the experimental period. However, the rate of shell length increase was lower for the first four weeks of the experiment compared with the rate of increase from week 5 to 9 for most of the experimental snails across the dietary treatment. The shell width increase was positively affected ($p<0.05$) by protein and energy levels with highest values from snails fed with highest protein and energy levels while shell length increase was positively affected ($p<0.05$) only by increasing protein level but not by increase in energy.

These observations were similar to reports by other authors (Tuncha *et al.,* 2021; Tchowan *et al.,* 2018).

These studies demonstrated that over an appropriate range of dietary protein and energy, the diet with the optimum P/E ratio produced the best growth and feed utilization. Furthermore, increasing protein and energy levels in snail diets results in corresponding increase in shell width and length.

Table 1: Composition and proximate analysis of the experimental diets with varied protein and energy levels

Parameters (%)	1	2	3	4	5	6	7	8	9	10	11	12
Maize	46.7	40	34.2	46.7	40	34.2	46.7	40	34.2	46.7	40	34.2
SBM	38.4	45	51.2	38.4	45	51.2	38.4	45	51.2	38.4	45	51.2
Fish meal	1.9	1.8	1.8	1.9	1.8	1.8	1.9	1.8	1.8	1.9	1.8	1.8
Palm oil	3.2	2.2	2.6	3.2	4.1	4.7	5.4	6.3	6.9	7.6	8.5	9.1
Oyster shell	9	9	9	9	9	9	9	9	9	9	9	9
Limestone	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin premix	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Proximate												
Crude protein (%)	25.3	27.51	30.00	24.50	27.45	29.87	25.25	27.54	30.09	24.80	27.50	30.07
Crude fibre (%)	2.20	2.80	3.15	2.30	2.75	2.70	2.22	2.80	2.90	3.20	3.11	3.80
Moisture (%)	8.25	9.50	7.25	7.75	8.00	8.50	8.75	8.05	8.25	8.50	9.00	9.07
Ether extract (%)	9.50	8.05	8.90	8.00	9.15	8.00	8.00	9.50	9.56	9.00	9.45	9.07
Ash (%)	16.25	15.75	15.70	17.50	17.25	17.23	17.75	16.00	16.65	16.75	16.50	13.74
NFE (%)	38.50	36.39	35.00	36.55	35.4	33.70	38.03	36.11	32.55	37.75	34.44	34.25
GE kcal/100g	301	303	301	320	320	320	340	340	340	361	361	361
P/E ratio (%)	83	91	99.7	78	85.9	93.8	73.5	81	88	69.4	76.4	83

SBM= Soya bean meal, NFE=Nitrogen free extract, GE= Gross energy, calculated on the basis of 5.65, 4. I and 9.5 kcal GE/g protein, NFE and lipid, respectively. P/E (Protein-to-energy) ratio= mg crude protein/kcal.

f Varying Dietary Crude Protein and Energy Levels on Growth Performance of *Archachatina marginata*

				Treatments						
3	4	5	6	7	8	9	10	11	12	SEM
133.00	125.5	112.25	128.84	115.84	131.08	119.25	120.42	136.59	152.59	6.68
149.94^{a}	137.67^{ab}	121.08^{c}	138.08^{ab}	126.00^{c}	141.25^{ab}	129.83^{abc}	131.00^{ab}	147.50^{b}	161.17^{ab}	6.68
.27	0.19	0.14	0.15	0.16	0.16	0.17	0.17	0.17	0.14	0.08
1.88^{a}	1.35^{b}	0.98^{b}	1.03^{b}	1.13^{b}	1.13^{b}	1.18^{b}	1.18^{b}	1.21^{b}	0.95^{b}	0.59
16.94	12.17	8.84	9.25	10.17	10.17	10.58	10.58	10.92	8.58	5.38
.63^{abc}	3.49^{abc}	3.74^{ab}	3.69^{abc}	3.53^{bcd}	3.70^{abc}	3.73^{ab}	3.40^{de}	3.75^{a}	3.67^{abc}	0.02
5.43^{abc}	24.45^{cde}	26.18^{ab}	25.80^{abc}	24.73^{bcd}	25.88^{abc}	26.13^{ab}	23.78^{de}	26.28^{a}	25.68^{abc}	0.17
54.25^{abc}	244.50^{cde}	261.75^{ab}	258^{abc}	247.25^{bcd}	258.75^{abc}	261.25^{ab}	237.75^{de}	262.75^{a}	256.75^{abc}	1.77
5.01^{c}	20.09^{ab}	29.61^{a}	27.89^{a}	24.31^{ab}	25.44^{ab}	24.69^{ab}	22.47^{ab}	24.06^{ab}	29.92^{a}	1.41

ifferent superscripts on the same row are significantly different ($P<0.05$). PM=Parameter, FCR=Fee
dard error of mean. BW= Body weight, WI= Weight increase, FI= Feed increase.

TABLE 3: Treatment Effects of Varying Dietary Crude Protein and Energy Levels on Shell Parameters of *Archachatina marginata*

PM	1	2	3	4	5	6	7	8	9	10	11	12	SEM
Initial SSW (cm)	4.45	4.55	4.9	4.55	4.65	4.83	4.4	4.73	4.7	4.63	4.55	4.2	0.07
Final SSW (cm)	5.23	5.55	5.75	5.45	5.38	5.9	5.53	5.9	5.93	5.65	5.6	5.4	0.08
Daily SWI (cm)	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00
Weekly SWI (cm)	0.09	0.11	0.09	0.1	0.08	0.12	0.12	0.13	0.14	0.11	0.12	0.13	0.00
Total	0.78	1	0.85	0.9	0.73	1.08	1.13	1.18	1.23	1.03	1.05	1.2	0.04
Week 1-4	0.28^{c}	0.50^{a}	0.33^{bc}	0.55^{a}	0.48^{ab}	0.45^{ab}	0.58^{a}	0.58^{a}	0.53^{a}	0.53^{a}	0.45^{ab}	0.60^{a}	0.01
Week 5-9	0.5	0.53	0.55	0.58	0.55	0.58	0.6	0.63	0.7	0.6	0.6	0.73	0.02
Initial SSL (cm)	9.20^{abc}	9.60^{abc}	10.05^{a}	8.68^{c}	9.28^{abc}	9.43^{abc}	9.38^{abc}	9.55^{abc}	8.98^{bc}	9.33^{abc}	9.78^{ab}	9.15^{abc}	0.09
Final SSL (cm)	10	10.2	10.8	9.68	10.18	10.5	10.53	10.7	10.03	10.25	10.65	10.38	0.09
Daily SLI (cm)	0.01^{abc}	0.01^{c}	0.01^{bc}	0.02^{abc}	0.01^{abc}	0.02^{ab}	0.02^{ab}	0.02^{ab}	0.02^{ab}	0.01^{abc}	0.01^{abc}	0.02^{a}	0.00
Weekly SLI (cm)	0.09^{abc}	0.07^{a}	0.08^{ab}	0.11^{abc}	0.10^{abc}	0.12^{bc}	0.13^{bc}	0.13^{bc}	0.12^{bc}	0.10^{abc}	0.10^{abc}	0.14^{a}	0.00
Total SLI (cm)	0.80^{abc}	0.60^{c}	0.75^{bc}	1^{abc}	0.90^{abc}	1.08^{ab}	1.15^{ab}	1.15^{ab}	1.05^{ab}	0.93^{abc}	0.88^{abc}	1.23^{a}	0.04
Week 1-4	0.33^{d}	0.38^{bcd}	0.35^{cd}	0.43^{abcd}	0.50^{abcd}	0.58^{a}	0.55^{ab}	0.45^{abcd}	0.53^{abc}	0.48^{abcd}	0.48^{abcd}	0.58^{a}	0.01
Week 5-9	0.50^{ab}	0.43^{b}	0.43^{b}	0.58^{ab}	0.53^{ab}	0.60^{ab}	0.60^{ab}	0.58^{ab}	0.63^{a}	0.53^{ab}	0.48^{ab}	0.65^{a}	0.01

abcd: Means bearing the different superscripts on the same row are significantly different (P<0.05). PM – Parameter, SEM – Standard error of mean. SSW= Snail shell width, SWI=Shell width increase, SSL= Snail shell length, SLI=Shell length increase.

TABLE 4: Effects of Crude Protein and Energy Levels Interaction on Shell Width of *Archachatina marginata*

Parameter	ISW	FSW	ADG	AWG	TG	SWG 1-4	SWG 5-9
Protein (%)							
25	4.61	5.49	0.014	0.10	0.88	0.41^b	0.54
27.5	4.65	5.68	0.016	0.11	1.03	0.52^a	0.59
30	4.31	5.57	0.367	0.12	1.06	0.56^a	0.64
Energy (kcal/100g)							
300	4.06	5.51	0.01	0.10	0.91	0.43^b	0.58
320	4.67	5.70	0.02	0.12	1.03	0.49^b	0.57
340	4.62	5.63	0.02	0.11	1.01	0.45^b	0.58
360	4.21	5.48	0.48	0.11	1.00	0.63^a	0.63
P values							
Protein (%)	0.34	0.74	0.37	0.28	0.29	0.00	0.15
Energy (kcal/100g)	0.38	0.84	0.40	0.81	0.81	0.00	0.81
_PxE	0.25	0.49	0.44	0.44	0.44	0.08	0.96

a,b: Means bearing the different superscripts on the same row are significantly different ($P<0.05$). ISW = Initial shell width, FSW = Final shell width, ADG= Average daily gain, AWG = Average weekly gain, TG= Total gain, SWG 1-4=Shell width gained from week 1-4, SWG 5-9 = Shell width gained from week 5-9, PxE=Protein-Energy interaction

TABLE 5: Effects of Protein and Energy Levels Interaction on Shell Length of *Archachatina marginata*

Parameter	ISL	FSLI	ADI	AWSL	TI	SLI1-4	SLI 5-9
Protein (%)							
25	9.38	10.17	0.01	0.09[b]	0.79[b]	0.41[b]	0.54
27.5	9.41	10.48	0.02	0.12[a]	1.07[a]	0.52[a]	0.59
30	8.81	10.26	0.66	0.11[ab]	0.96[ab]	0.56[a]	0.64
Energy(kcal/ 100g)							
300	9.15[ab]	10.07	0.02	0.10	0.92	0.45	0.55
320	9.45[ab]	10.32	0.01	0.10	0.87	0.48	0.52
340	9.73[a]	10.66	0.02	0.10	0.93	0.47	0.50
360	8.46[b]	10.16	0.88	0.12	1.04	0.50	0.58
P values							
Protein (%)	0.35	0.45	0.38	0.04	0.05	0.00	0.05
Energy(kcal/ 100g)	0.12	0.20	0.40	0.53	0.55	0.68	0.23
_PxE	0.50	0.73	0.44	0.71	0.08	0.21	0.38

a,b: Means bearing the different superscripts on the same row are significantly different (P<0.05). ISL = Initial shell length, FSLI = Final shell length increase, ADI= Average daily increase, AWI = Average weekly increase, TI= Total increase, SLG 1-4=Shell length increase from week 1-4, SLG 5-9 = Shell length increase from week 5-9, PxE=Protein-Energy interaction

CONCLUSION

This study demonstrated the importance of the ratio between dietary protein and energy for the determination of protein and energy requirements of the giant African land snail (*A. marginata)*. It further demonstrated that a diet containing 30% protein and 300 kcal/ 100 g GE with a P/E ratio of 99.7 mg protein/kcal GE produced the best growth rates and feed conversion efficiency.

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