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Association Between Body Weight and Dimensional Shell Traits of Snails (*Archachatina marginata* and *Achatina achatina*)

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Target Audience: Researchers, Snail breeders, Snail farmers, Animal Scientists

Abstract

This study evaluated the association between the body weights and dimensional shell parameters of two snail breeds (Archachatina marginata and Achatina achatina). Two hundred (200) sexually mature snails, one hundred (100) each of A. marginata and A. achatina sorted out of a base population purchased from snail vendors in Calabar were used for the study. Their weights ranged from 127.6 – 443.4 g for A. marginata and 85.43 – 249.08 g for A. achatina. Each of the snail breed constituted a treatment and was replicated ten (10) times with ten (10) snails per replicate in a completely randomized design (CRD) for ease of data collection. Traits measured on each snail included shell length (cm), shell width (cm), aperture length (cm), aperture width (cm), spiral length (cm), spiral width (cm), diagonal length (cm), length between aperture and first spiral (cm) and body weight (g). Data collected were subjected to correlation and regression analyses to establish relevant associations among the traits. Results of correlation among traits showed that all the pairs of traits investigated in A. marginata expressed medium to high positive and significant ($P<0.05$) correlation values. Whereas some pairs of traits investigated on A. achatina expressed low to high positive and significant ($P<0.05$) correlation values, other pairs expressed negative correlation values. The two snail breeds had high coefficient of determination (r^2) values, ranging from 69 to 84 % for A. achatina and 95 to 98 % for A. marginata. The results of regression models revealed that live weight of A. achatina was best predicted with multiple linear regression models, while with live weight of A. marginata was best predicted with simple linear regression model and multiple linear regression models. A test of accuracy of the linear regression models showed that the models with three, four, six and seven traits best predicted body weight in A. achatina, whereas the models with one and models with two and six traits best predicted bodyweight in A. marginata. This implies that snails body weight and dimensional shell traits are positively correlated and the variability in live weight of these snail breeds can be explained by changes in other phenotypic traits.

Key words: Association, *A. achatina*, *A. marginata*, body weight, shell traits

Description of Problem

Snail farming and research are fast growing areas of animal agriculture in Nigeria. Undoubtedly, snails play important roles in the economy of rural poor families of the rainforest and riparian savanna zones of the country.

Important snails' morphometric variables such as shell length, shell width, shell thickness, aperture length, aperture width, spiral length, spiral width, diagonal length, length between aperture and first spiral, and number of whorls on the shell are quantitative traits that show continuous variation and thus can be used to estimate body weight and by extension age. It has been established that the weight of a snail has direct proportion with the dimensional shell traits (1). This proportionality varies significantly between breeds and/or strains of snails and between snail species.

Genetic improvement of snails is important in order to increase the contribution of snails to the much needed animal protein in Nigeria (2). A prerequisite for this improvement is the knowledge of genetic parameters of economic traits (3, 4).

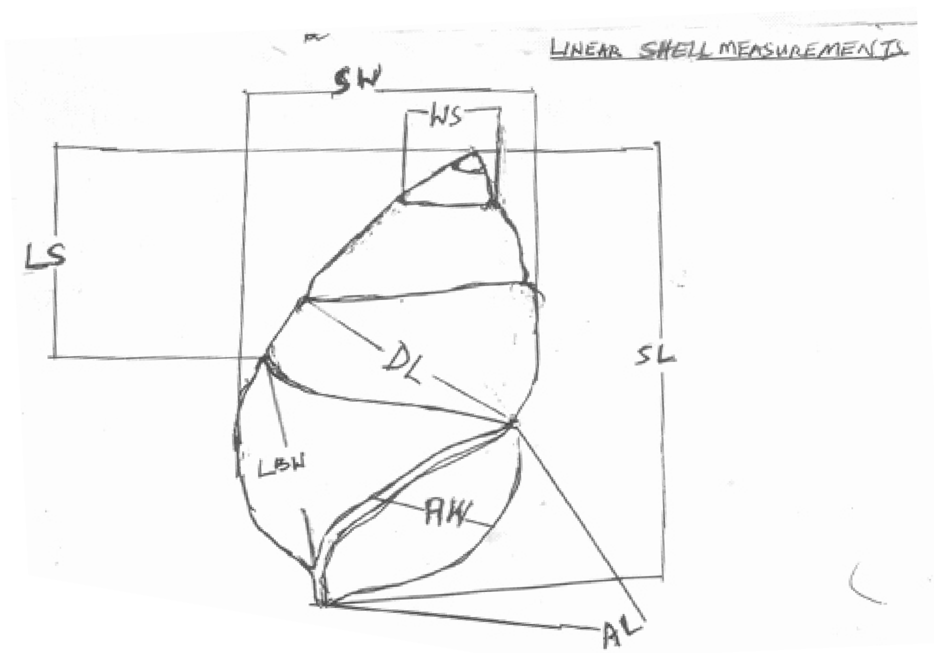
Rearing snails in confinement under farm conditions results in variable performances and sometimes below expectations. It is also known that different snail strains respond differently to environmental stresses, thus producing different and specific reactions due to genotype by environment interaction as a result of different sensitivities of genotype(s) to environment(s) (5). These necessitated the evaluation of the association between the body weight and dimensional shell parameters of two snail breeds (*Archachatina marginata* and *Achatina achatina*) to provide further information for commercial snail production in Calabar and its environs.

Materials and Methods

Two hundred (200) sexually mature snails, one hundred (100) each of *Archachatina marginata* and *Achatina achatina* sorted out of a base population purchased from snail vendors in Calabar were used for this study. Their weights ranged from 127.6 – 443.4 g for *A. marginata* and 85.43 – 249.08 g for *A. achatina*. The snails were selected based on active appearance and lack of injury on the foot and on the shell. Each of the snail breeds constituted a treatment and was replicated ten (10) times with ten (10) snails per replicate in a completely randomized design (CRD) for ease of data collection.

Data were collected according to the procedures of (2) and (6) (Figure 1). The data collected on each snail included shell length (cm), shell width (cm), aperture length (cm), aperture width (cm), spiral length (cm), spiral width (cm), diagonal length (cm), length between aperture and first spiral (cm) and body weight (g). Body weight was measured using a Metier® electronic scale to the nearest 0.01 g, while the shell dimensional parameters were measured using vernier caliper. The data collected were analyzed to estimate phenotypic correlations (r_p) between pairs of traits using (7) statistical programme. The stepwise variable selection procedure of the same software package was used to determine the most appropriate model for predicting body weight, using dimensional shell measurements. The general prediction model used is:

$Y = a + b_iX_i = E$
where:
Y = body weight
a = constant
b_i = regression coefficient of i^{th} independent variable
X_i = the value of independent variable
E = error term
$X_i = X_1 + \text{- - - -} + X_8$ (X_1 = shell length, X_2 = shell width, X_3 = aperture length, X_4 = aperture width, X_5 = spiral length, X_6 = spiral width, X_7 = diagonal length and X_8 = length between aperture and first spiral)



SL = Shell length, SW = Shell width, AL = Aperture length, AW = Aperture width, LS = Spiral length, WS = Spiral width, DL = Diagonal length, LBW = Length between aperture and first spiral.
Sources: Ibom (2) and El Zaffir *et al*. (6)

Results and Discussion

The results of correlation analyses between body weight and dimensional shell measurements and between the dimensional shell measurements of two snail breeds (*Achatina achatina* and *Archachatina marginata*) are presented in Table 1. The upper part of the diagonal shows the correlation/association values between body weight and dimensional shell parameters/measurements and between the dimensional shell measurements of *A. achatina*, while the lower part of the diagonal shows the correlation/association values between body weight and dimensional shell

Table 1: Correlations between body weight and dimensional shell measurements of *Archachatina marginata* and *Achatina achatina* snails.

	Achatina achatina								
	BW	**SL**	**SW**	**APL**	**APW**	**SPL**	**SPW**	**DL**	**LBW**
BW	1.00	0.83**	0.77**	0.79**	0.19	0.58*	– 0.09	0.26	0.43
SL	0.98**	1.00	0.86**	0.69*	0.16	0.61*	– 0.17	0.12	0.53*
SW	0.96**	0.96**	1.00	0.62*	0.19	0.49	– 0.50	– 0.02	0.36
APL	0.90**	0.94**	0.92**	1.00	1.00	0.54*	– 0.23	0.34	0.30
APW	0.83**	0.77**	0.75**	0.67*	1.00	– 0.40	0.48	– 0.51	0.30
SPL	0.94**	0.96**	0.90**	0.86**	0.75**	1.00	– 0.58	0.78**	0.55*
SPW	0.62*	0.63*	0.60*	0.57*	0.60*	0.59*	1.00	– 0.68	0.41
DL	0.90**	0.91**	0.87**	0.84**	0.74*	0.90**	0.68*	1.00	– 0.40
LBW	0.82**	0.85**	0.78**	0.79**	0.59*	0.84**	0.51*	0.81**	1.00
	BW	**SL**	**SW**	**APL**	**APW**	**SPL**	**SPW**	**DL**	**LBW**
	Archachatina marginata								

BW = Body weight, SL = Shell length, SW = Shell width, APL = Aperture length, APW = Aperture width, SPL = Spiral length, SPW = Spiral width, DL = Diagonal length, LBW = Length between aperture and first spiral.
* = p<0.05, ** = p<0.01

parameters/measurements and between the dimensional shell measurements of *A. marginata*.

The results showed that whereas most of the pairs of traits investigated on *Achatina achatina* snails expressed low through medium to high positive correlation values, all the pairs of traits investigated on *Archachatina marginata* snails expressed medium to high positive correlation values (Table 1). The correlation values of traits investigated on *A. achatina* snails ranged from $r_p = – 0.02$ to $r_p = 0.86$, while the correlation values of *A. marginata* snails ranged from $r_p = 0.51$ to $r_p = 0.98$. The pairs of *A. achatina* traits that expressed negative correlation values were: shell width (SW) and diagonal length (DL) ($r_p = – 0.02$), aperture width (APW) and DL ($r_p = – 0.51$), spiral width (SPW) and DL ($r_p = – 0.68$), body weight (BW) and SPW ($r_p = – 0.09$), shell length (SL) and SPW ($r_p = – 0.17$), SW and SPW ($r_p = – 0.50$), aperture length (APL) and SPW ($r_p = – 0.23$), spiral length (SPL) and SPW ($r_p = – 0.58$) and the duo of APW and SPL, and DL and length between aperture and first spiral (LBW) ($r_p = – 0.40$). The pair of APL and APW expressed perfect positive correlation ($r_p = 1.00$) in *A. achatina* snails. However, some other pairs of traits expressed highly significant (P<0.01) positive correlation values. These included SL and SW ($r_p = 0.86$), BW and SL ($r_p = 0.83$), BW and APL ($r_p = 0.79$), SPL and DL ($r_p = 0.78$) and BW and SW ($r_p = 0.77$) (Table 1). Other pairs of traits (SL and APL, SW and APL, SL and SPL, BW and SPL, SPL and LBW, APL and SPL, and SL and LBW) expressed medium positive and significant (P<0.05) values of $r_p = 0.69$, $r_p = 0.62$, $r_p = 0.61$, $r_p = 0.58$, $r_p = 0.55$, $r_p = 0.54$ and $r_p = 0.53$ respectively. Traits such as SW and SPL, APW and SPW, BW and LBW, SPW and LBW, SW and LBW, APL and DL, the duo of (APL and LBW and APW and LBW), BW and DL, the duo of (BW and APW and SW and APW), SL and APW, and SL and DL expressed low positive correlation values ($r_p = 0.49$, $r_p = 0.48$, $r_p = 0.43$, $r_p = 0.41$, $r_p = 0.36$, $r_p = 0.34$, $r_p = 0.30$, $r_p = 0.26$, $r_p = 0.19$, $r_p = 0.16$ and $r_p = 0.12$ respectively) that were not significant (P>0.05).

On the other hand, most of the pairs of traits in *Archachatina marginata* expressed highly significant (P<0.01) correlation values. The high correlation values were BW and SL (r_p= 0.98), the trio of BW and SW, SL and SPL, SL and SW (r_p= 0.96), the duo of BW and SPL, SL and APL (r_p= 0.94), SW and APL (r_p= 0.92), SL and DL (r_p= 0.91), the quartet of BW and APL, SW and SPL, BW and DL, SPL and DL (r_p= 0.90), SW and DL (r_p= 0.87), APL and SPL (r_p= 0.86), SL and LBW (r_p= 0.85), the duo of APL and DL, SPL and LBW (r_p= 0.84), BW and APW (r_p= 0.83), BW and LBW (r_p= 0.82), DL and LBW (r_p= 0.81), APL and LBW (r_p= 0.79), SW and LBW (r_p= 0.78), SL and APW (r_p= 0.77), and the duo of SW and APW, APW and SPL (r_p= 0.75) (Table 1). The other pairs of traits [APW and DL (r_p= 0.74), SPW and DL (r_p= 0.68), APL and APW (r_p= 0.67), SL and SPW (r_p= 0.63), BW and SPW (r_p= 0.62), the duo of SW and SPW, APW and SPW (r_p= 0.60), also the duo of SPL and SPW, APW and LBW (r_p= 0.59), APL and SPW (r_p= 0.57) and SPW and LBW (r_p= 0.51)] expressed medium positive and significant (P<0.05) correlation values (Table 1). The positive correlation values recorded in this study for all the pairs of traits investigated in *A. marginata* snails and some in *A. achatina* snails could mean that the traits are influenced by the same genes in the same direction. This corroborated the position of (2). Besides, the author opined that the positive correlation could also suggest that there are direct relationships between the traits, and that weight increment in snails is as a result of increase in the size of corresponding traits.

The highly significant (P<0.01) positive correlation values recorded by some pairs of traits in this study compared favourably with the reports of (2) and (8) who reported $r_p = 0.98$ to $r_p = 1.00$ as the range of phenotypic correlation values for sexually mature *A. marginata var. saturalis*, (9) and (4) who reported correlation values of $r_p = 0.89$ and $r_p = 0.774$ respectively for F_1 hatchlings of purebred white-skinned and crossbred of the same snail breed. The results of this study also compared favourably with (10) report of $r_p = 0.134$ to $r_p = 0.722$ as correlation range values for the pairs of traits evaluated in *A. marginata* and *A. fulica* snail breeds. The results of this study also compared with the range values of 0.360 – 0.977, 0.537 – 0.970 and 0.586 – 0.988 reported by (11) as correlation values of offspring of BO X BO, BS X BS and BO X BS mating groups respectively.

The positive significant correlations obtained for some traits in this study indicated that the pairs of traits are controlled by the same genes in the same direction, thus selection and improvement for one trait will lead to improvement of the other. This is in accordance with the position of (2) who stated that positive significant correlations denoted that the pairs of traits have direct relationships and are controlled by the same genes in the same direction. Besides, it could be applied for selection and crossbreeding to improve genetic traits in line with (12) who stated that correlated responses of qualitative traits can be used for selection and crossbreeding to improve genetic traits.

The negative correlation values recorded by some pairs of traits investigated in *A. achatina* snails in this study agreed with the report of (13) that snails of different age groups expressed negative or no significant difference amongst some pairs of their traits. The negative correlation values could also signified that the genes controlling their expression are working in opposite direction, and improvement in one trait will lead to reduction in the other. This corroborated the position of (2) who stated that negative correlations denoted that such pairs of traits have indirect relationship and are at least controlled by the same genes in different direction. Thus, selection for one trait will lead to the reduction of the other.

The results of correlation values obtained in this study agreed with the positions of (14) and (15) that correlation can be high or low and/or positive or negative between traits. Variations in correlation values among evaluated traits according to (2) revealed that the influence of genes on these different traits differ from one to another.

The differences in correlation values between this study and those previously reported could be attributed to breed effects, ages and sizes of snails used, number of traits involved and the prevailing environmental conditions.

Table 2 shows the results of regression equations, correlation coefficients and coefficients of determination relating the body weight and dimensional shell parameters of *A. achatina* snails. The regression estimates of parameters and coefficients of determination for the simple linear function ($Y = -323.430 + 41.580X_1$) showed a slightly high and strong interrelationship ($r_p = 0.83$) between body weight and a dimensional shell trait (i.e. shell length). The multiple linear functions for predicting body weight using three, four and five dimensional shell traits (shell length, shell width, aperture length, aperture width and spiral length) showed highly significant ($p<0.01$) and strong interrelationship ($r_p = 0.88$). However, when seven and eight dimensional shell traits were fitted into the multiple linear regression function, a highly significant ($P<0.01$) and very strong interrelationship ($r_p = 0.92$) was obtained between body weight and the dimensional shell traits (Table 2).

The coefficient of determination (r^2) results of this study for *Achatina achatina* varied from 0.69 to 0.84. This range of coefficient of determination values indicated that weight can be predicted using the dimensional shell parameters. Besides, it revealed that 69 % to 84 % of the variability in *A. achatina* snails body weight can be explained by changes in other considered dimensional shell traits.

The results of regression equations, correlation coefficients and coefficients of determination relating *Archachatina marginata* snails' body weights and dimensional shell traits are presented in

Table 2: Regression analysis of body weight on other phenotypic traits of *Achatina achatina*.

Traits	Prediction equation	R	r^2
BW/SL	$Y = -323.430 + 41.580X_1$	0.83	0.69
BW/SL,SW	$Y = -295.183 + 33.100X_1 + 12.854X_2$	0.84	0.70
BW/SL,SW,APL	$Y = -397.267 + 20.824X_1 + 10.114X_2 + 40.120X_3$	0.88**	0.79
BW/SL,SW,APL,APW	$Y = -399.583 + 20.884X_1 + 9.926X_2 + 39.896X_3 + 1.166X_4$	0.88**	0.79
BW/SL,SW,APL,APW, SPL	$Y = -403.213 + 17.488X_1 + 10.339X_2 - 36.180X_3 + 5.845X_4 + 7.963X_5$	0.89**	0.79
BW/SL,SW,APL,APW,SPL,SPW	$Y = -436.006 + 17.689X_1 + 7.363X_2 + 38.702X_3 + 3.207X_4 + 13.316X_5 + 5.976X_6$	0.90**	0.81
BW/SL,SW,APL,APW,SPL,SPW, DL	$Y = -487.912 + 29.627X_1 + 19.302X_2 + 24.956X_3 + 0.159X_4 - 22.081X_5 + 9.209X_6 + 35.217X_7$	0.91**	0.84
BW/SL, SW, APL, APW, SPL, SPW, DL, LBW	$Y = -475.959 + 24.240X_1 + 25.669X_2 + 23.142X_3 - 2.457X_4 - 26.496X_5 + 7.931X_6 + 40.605X_7 + 14.160X_8$	0.92**	0.84

Y = BW = Body weight, X_1 = SL = shell length, X_2 = SW = shell width, X_3 = APL = Aperture length, X_4 = APW = Aperture width, X_5 = SPL = spiral length, X_6 = SPW = spiral width, X_7 = DL = diagonal length, X_8 = LBW = length between aperture and first spiral, R = correlation coefficient, r^2 = coefficient of determination, ** = significant ($p<0.01$)

Table 3. The regression estimates of parameters and coefficients of determination for the simple linear function ($Y = -484.884 + 60.569X_1$) showed very strong relationship (r_p = 0.97) between body weight and a phenotypic or dimensional shell trait (i.e. shell length). Similarly, the regression estimates of parameters and coefficients of determination for the multiple linear functions showed very strong relationship (r_p = 0.98) between body weight and other phenotypic or dimensional shell traits evaluated.

The coefficient of determination (r^2) results obtained for *A. marginata* snails in this study were very high and ranged from 0.95 to 0.98. This range of coefficient of determination values revealed that weight can be predicted using the dimensional shell parameters. Live weight of *A. marginata* snails was more closely predicted when one to eight shell traits were used, an indication that 95 % to 98 % of the variability in *A. marginata* snails body weight can be explained by changes in other considered dimensional shell traits.

The r^2 results recorded for *A. achatina* snails in this study were higher than the low r^2% values (2.12% to 50.20%) reported by (2011) for the same breed of snails. On the contrary, the r^2 results recorded for *A. marginata* snails in this study were in agreement with the results of high r^2% value (88%) reported by (9 and 16) and (4) for the same breed of snails. The variations in the results of this study with those in available literature could be attributed to effects of age, sizes of snails used, and the number of quantitative traits used in the prediction.

Table 4 shows the results of predicted and actual body weights of *A. achatina* snails. The actual mean body weight of snails measured was 182.47 g, while the predicted body weights ranged from 182.47 g to 182.48 g. A comparison between the actual body weight and the predicted body weights revealed that there was no significant difference. This could be due to the strong, positive and closely correlated responses between body weight and other phenotypic traits investigated. The predicted body weight values in Table 4 showed that 182.67 g best tally with the live weight. This means that the multiple linear regression models with three, four, six and seven phenotypic traits best predicted live weight of *A. achatina* snails.

The results of predicted and actual body weights of *A. marginata* snails are presented in Table 5. The results showed that the actual mean body weight of snails measured was 306.62 g, while the predicted body weights ranged from 306.62 g to 306.64 g. A comparison between the actual body weight and the predicted body weights showed that there was no significant difference. This could be as a result of the strong, positive and closely correlated responses between body weight and other phenotypic traits investigated. The predicted body weight values in Table 5 showed that 306.62 g best matched with the live weight. This means that both the simple linear regression model and the multiple regression models with one and two to six phenotypic traits respectively best predicted live weight of *A.*

Table 3: Regression analysis of body weight on other phenotypic traits of *Archachatina marginata*.

Traits	Prediction equation	R	r^2
BW/SL	$Y = -484.884 + 60.569X_1$	0.97	0.95
BW/SL,SW	$Y = -455.387 + 46.459X_1 + 23.849X_2$	0.98	0.96
BW/SL,SW,APL	$Y = -460.238 + 56.601X_1 + 29.862X_2 - 22.093X_3$	0.98**	0.97
BW/SL,SW,APL,APW	$Y = -509.313 + 45.862X_1 + 25.746X_2 - 13.297X_3 + 33.678X_4$	0.98**	0.98
BW/SL,SW,APL,APW, SPL	$Y = -509.433 + 45.568X_1 + 25.815X_2 - 13.190X_3 + 33.708X_4 + 0.410X_5$	0.98**	0.98
BW/SL,SW,APL,APW,SPL,SPW	$Y = -513.531 + 47.385X_1 + 25.525X_2 - 13.762X_3 + 34.953X_4 - 1.067X_5 - 5.597X_6$	0.98**	0.98
BW/SL,SW,APL,APW,SPL,SPW, DL	$Y = -520.381 + 46.634X_1 + 25.374X_2 - 13.806X_3 + 34.712X_4 - 2.958X_5 - 7.033X_6 + 6.678X_7$	0.98**	0.98
BW/SL, SW, APL, APW, SPL, SPW, DL, LBW	$Y = -520.935 + 45.260X_1 + 26.026X_2 - 13.665X_3 - 35.403X_4 - 2.998X_5 - 6.868X_6 + 5.838X_7 + 4.507X_8$	0.98**	0.98

Y = BW = Body weight, X_1 = SL = shell length, X_2 = SW = shell width, X_3 = APL = Aperture length, X_4 = APW = Aperture width, X_5 = SPL = spiral length, X_6 = SPW = spiral width, X_7 = DL = diagonal length, X_8 = LBW = length between aperture and first spiral, R = correlation coefficient, r^2 = coefficient of determination, ** = significant ($p<0.01$)

marginata snails. The results in Tables 4 and 5 contrasted the positions of (17) and (8) that a single trait and two traits respectively best predicted body weight. Rather, the use of multiple traits gave better and more reliable live body weight prediction (Tables 4 and 5).

Table 4: Comparison between actual and predicted weights of *Achatina achatina* as derived from regression equations.

Actual body weight (g)	Predicted body weight (g)
182.47	182.48
182.47	182.48
182.47	182.47*
182.47	182.47*
182.47	182.48
182.47	182.47*
182.47	182.47*
182.47	182.47*

* = Values that best predicted live weight

Table 5: Comparison between actual and predicted weights of *Archachatina marginata* as derived from regression equations.

Actual body weight (g)	Predicted body weight (g)
306.62	306.62*
306.62	306.62*
306.62	306.64
306.62	306.63
306.62	306.63
306.62	306.62*
306.62	306.63
306.62	306.63

* = Values that best predicted live weight

Conclusion and Application

It was concluded that:

1. Most of the pairs of traits investigated on *Achatina achatina* snails expressed low through medium to high positive correlation values, while all the pairs of traits investigated on *Archachatina marginata* snails expressed medium to high positive correlation values.
2. The correlation values of traits investigated on *A. achatina* snails ranged from $r_p = -0.02$ to $r_p = 0.86$, while the correlation values of *A. marginata* snails ranged from $r_p = 0.51$ to $r_p = 0.98$.
3. Multiple regression models using multiple traits (between three to seven) best predicted live body weight in *A. achatina* snails, while both simple and multiple linear regression models with one trait and two to six traits respectively best predicted live body weight in *A.*

marginata snails.

4. About 69 % to 84 % and 95 % to 98 % of the variability in *A. achatina* and *A. marginata* snails body weights respectively can be explained by changes in other considered dimensional shell traits.

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