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Relationship between External Morphology and Gonads in Rainbow Lizard (*Agama agama*) in Obafemi Awolowo University, Ile-Ife, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author AOB designed the study, performed the statistical analysis and wrote the protocol. Author EOM wrote the first draft of the manuscript, managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Background of the Study: The morphology of any reptile may be affected by different environmental factors such as climate change and habitat related features such as availability of food and other resources.
Objective: This study aimed at determining the morphology and sexual variation of Rainbow male and female lizards (*Agama.agama*) in Obafemi Awolowo University.
Study Design: Three locations in the University were selected (Student Hostels, Academic Area and Staff Quarters) and rainbow lizards were sampled from June to December 2019.
Results: A total of 93 lizards were sampled, body parameters were measured, and the gonads were weighed after dissection. There was a positive correlation (0.98 & 0.78) between the body weight and gonad weight of the male and female lizards in all the three locations. Also, the specimen from the academic area of the University had the least body and gonad weight, while the samples caught in the staff quarters had the highest body and gonad weight. The Principal Component Analysis (PCA) showed a relationship in the body and gonad weight with few differences from samples captured in the academic area.

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Conclusion: In summary, external morphology of the rainbow lizards from all the three locations were similar with little difference in body weight. There was a positive relationship between external morphology and gonads of rainbow lizards.

Keywords: Gonads; food; reproduction; bodyweight; reptiles.

1. INTRODUCTION

The morphology of any reptile may be affected by different environmental factors such as climate change and availability of food. Availability of food is directly linked to survival and fitness and consequently shapes the life history of reptiles. The choice of food can influence external morphology among species, abundance, reproduction and ultimately the transfer of energy and matter within ecosystems [1].

Morphometric techniques have proven to be useful in separating morphologically similar groups in the absence of any other diagnostic characters [2]. Among reptiles, this technique has been widely used to differentiate new species and subspecies in groups of closely related species [3]. Bamidele and Akinpelu [4,5] used cranial and body morphometric to determine if there was a new species of tree squirrel in some part of Southwest of Nigeria. They reported no new species of the tree squirrels in the area sampled.

Although many reptiles and most amphibians are generalized insectivores, the study conducted by Weterings [6] reported that the insectivorous gecko *Hemidactylus platyurus* fed on rice, cucumber, and egg in garbage bins, while anthropophilic and insectivorous gecko *Gehyramutilata* have been reported by Tanalgo and Hughes [7] to feed on nectar from flowers. Also, Weterings and Weterings [8] reported that insectivorous *Gekko monarchus* was observed feeding on white bread on a kitchen table in the house.

The West African rainbow lizard (*Agama agama* Linnaeus, 1758) has been recognized to have the geographic distribution that is wide and overlaps with human habitations [9] which can influence their diet and remove them from being only insectivorous reptiles based on the reports of other reptiles (Gecko). The report of Ofori et al [10] showed that rainbow lizards can feed on processed food which increases their adaptation to humans.

Feeding on processed foods by lizards (*A. agama*) may influence their population in human settlement and therefore affect their external morphology and reproductive organs (gonads). Porter and Tracy [11] reported that female rainbow lizards reach sexual maturity at age fourteen to eighteen months, while it takes two years for males and that they reproduced mainly during the wet season. They [11] (Porter and Tracy 1983) reported that rainbow lizards are capable of reproducing nearly year-round in areas of consistent rainfall.

Since rainbow lizards can reproduce all year round and can feed on processed foods, it is important to determine their external morphology and their gonads which may be responsible for their reproduction rate. Hence, the study determined the relationship between external morphology and gonads of rainbow lizards from three locations in Obafemi Awolowo University, Ile-Ife.

2. MATERIALS AND METHODS

2.1 Study Location

This research work was carried out in Obafemi Awolowo University students' hostels, academic area and staff quarters, Ile Ife. The University is located between Latitudes 7°26'N and 7°32'N and between Longitudes 4°31'E and 4°35'E. The landmass is 5506 hectares with an altitude of 300 m above sea level.

2.2 Materials

2.2.1 Materials used in the research field

Sweep net: For trapping the specimens, chloroform: to anesthetize the specimens, killing jar: where the specimens are kept immediately after collection, cotton wool: Placed inside the killing jar for a smooth landing for the anesthetized specimens, measuring ruler, thread, rubber gloves, Harvard trip balance, camera.

2.2.2 Method of collection

Rainbow lizards (*Agama agama*) were collected by using a sweep net to cover them and they

were put inside killing jar containing chloroform. The chloroform was used to anesthetize the specimens until they were taken into the laboratory for identification and other laboratory procedures.

2.3 Identification of Specimens

The Agama lizard (*Agama agama*) was identified by the descriptions given by Harris [12]. External features include white underside, brown back limbs and a tail with a light stripe down the middle. Breeding males have brilliant orange heads, and an indigo blue or black body and legs. Their tail is bluish at the base and has an orange middle area and black tail tip. The non-breeding male is pale in colour and might not have the orange on the head. Females are brown and have olive green colour on their backs with some barring marks.

2.4 Data Collection

The specimen was collected from June to December 2019.The captured specimens were taken into the laboratory and were anesthetized in chloroform jars. The sex of each lizard was determined and measurements of the morphometric parameters were taken. The specimens were dissected to reveal their gonads before measurement. Different parameters were measured according to the report of Bamidele and Olutunji [13], the gonads were also examined (Fig. 1). The body weight and gonad weight were measured with Harvard trip weighing balance.

1. **Bodyweight (BW):** The measurement of the entire body in gram.
2. **Snout-vent length (SVL):** From the tip of snout to anterior end of the cloaca.
3. **Head height (HH):** Height of the head.
4. **Head length (HL):** Ventral measurement from the tip of the lower jaw to immediately posterior to the jaw.
5. **Head width (HW):** The widest portion of the head anterior to the ear.
6. **Tail length (TL):** From the anterior end of the cloaca to the tip of the tail.
7. **Tail width (TW):** Measured at the base of the tail from one side to another.
8. **Trunk length (TRL):** From where the forelimb originates to where the hind limb originates.
9. **Mouth opening (MO):** From snout to posterior.
10. Testes weight.
11. Ovaries weight.

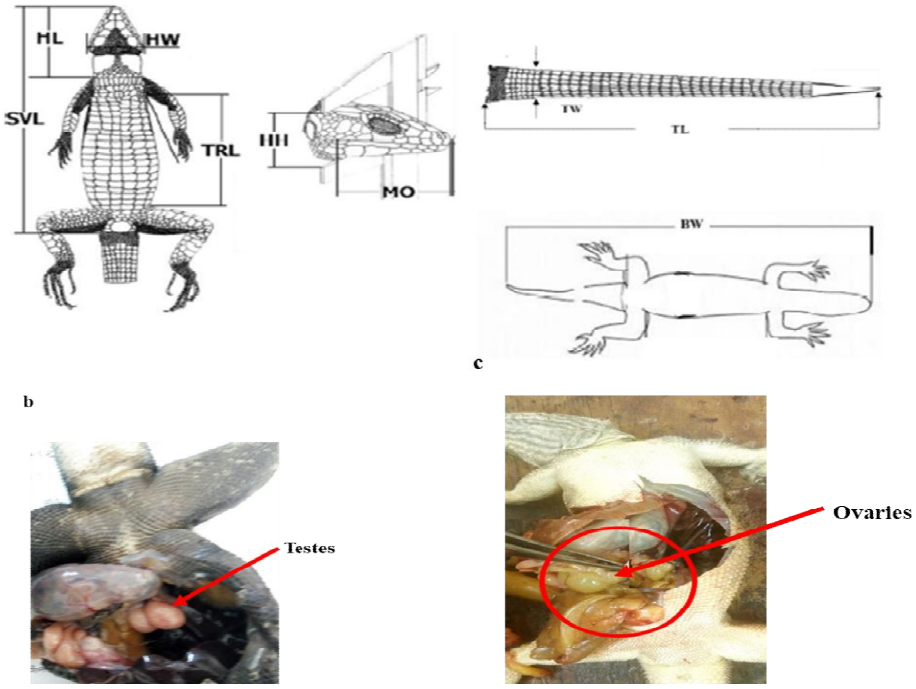

Fig. 1. Diagram showing some measured parameters on the lizard *(A. agama*) (13) (b) the testes (c) the ovaries

2.5 Data Analysis

One-way analysis of variance (ANOVA) was used to determine the significant difference between the means, while the significant mean was separated at $p \leq 0.05$ using Least Significant Difference (LSD) test from System Analysis Software [14] (SAS Institute, 1997). Principal Component Analysis (PCA) was carried out with PAST version.

3. RESULTS

The total number of Rainbow lizards caught in the three locations were 93 (56 females and 38 males) (Table 1). The ratio of female to male in every location (1.3: 1 in Student hostels, 1.6:1 in academic area and 1.5:1 in Staff quarters) showed that female Rainbow lizards were more than male. The least number of the specimens were caught in the student hostels (32.26%), while the highest number of specimens were caught in the University Staff Quarters (34.41%). Female rainbow lizards were consistently more abundant than males in the University. Table 2 and 3 shows the morphometric parameters measured on female and male rainbow lizards respectively. The bodyweight of the female rainbow lizard specimens in the academic area. ranged between 34.4 to 38.6 g and the mean body weight was 36.32 g.

This weight (female rainbow lizards from the academic area) was the least when compared with the bodyweight range and mean weight of female rainbow lizards from other locations (Student hostels and Staff quarters). The body weight range of female rainbow lizards from student hostel was 36.4-40.2 g, with the mean weight of 38.64 g. Also, the bodyweight of female rainbow lizards from Staff quarters ranged between 39.4 – 42.6 g with the mean body weight of 40.62 g.

The mean snout-vent length (SVL) of specimens from student hostels and that of staff quarters showed no significant difference ($p>0.05$) however, mean SVL of the specimens from both locations was significantly different from that of specimen from the academic area. This trend was similar for the Height of the Head (HH) and Trunk length (TRL). There were no significant differences among the specimens caught in the three locations for measured morphometric parameters such as Head length (HL), Head width (HW), and Mouth opening (MO). The Tail length (TL) of all the specimens from different locations showed a significant difference at $p < 0.05$. The significant difference in the TL may be due to accidents that occur during fighting or running from predators.

The Bodyweight (BW) of the specimen from the three locations showed significant differences ($p<0.05$). Male rainbow lizards from Staff quarters had the highest range of bodyweight (68.2-75.2 g) and mean bodyweight (72.40 g). This was followed by the specimens from the student hostel (range 62.4-67.6 g; the mean value of 65.43 g). The specimen from the academic area had the least range of bodyweight (57.2-64.2 g) and the mean bodyweight of 60.24 g.

There was no significant difference ($p>0.05$) in Height of Head (HH), Tail width (TW) and mouth opening (MO) among the specimen from the three locations, while there was a significant difference ($p<0.05$) among the specimen from all the location in measured Tail length (TL), and Snout-vent length (SVL). Specimens from student hostel and Staff quarters showed no significant difference ($p<0.05$) in measured Trunk length (TRL), Head width (HW) and Head length (HL).

Table 4 shows the gonad weight of the specimens\ from all three locations (Student hostel, Academic area and Staff quarters). There was no significant difference ($p>0.05$) in the weight of the ovaries of all the specimens from different locations. The ovary weight of all the specimens from all the different locations ranged between 0.02-0.13 g with the specimen from Staff quarters having the highest value (0.10 g). The mean ovaries weight of the specimen from the Student hostel and academic area were the same (0.09 g). There was a significant difference

Table 1. The abundance of female and male lizard (*A. agama*) from three different locations in the university (student hostel, academic area and staff quarter)

Locations	Female	Male	Total	Percentage (%)
Students Hostel	17	13	30	32.26
Academic area	19	12	31	33.33
Staff quarters	20	13	32	34.41
Total	56	38	93	100

Table 2. The morphometric parameters of female rainbow lizard (*A. agama*) caught at three different locations in the university (student hostel, academic area and staff quarter)

Locations	Statistic	BW (g)	SVL (cm)	HH (cm)	HL (cm)	HW (cm)	TL (cm)	TW (cm)	TRL (cm)	MO (cm)
Student	Mean	38.64^{b}±0.8	10.48^{b}±0.5	0.48^{b}±0.1	2.86^{a}±0.3	2.22^{a}±0.3	14.80^{b}±0.5	0.44^{a}±0.1	4.21^{b}±0.2	1.49^{a}±0.1
Hostels	Range	36.4-40.20	8.96-11.41	0.10-1.01	0.6-1.40	1.2-3.6	12.4-15.4	0.12-0.96	2.3-6.6	0.9-2.14
Academic	Mean	36.32^{a}±0.5	9.46^{a}±0.3	0.36^{a}±0.1	2.56^{a}±0.1	2.05^{a}±0.1	13.20^{a}±0.4	0.32^{a}±0.1	3.94^{a}±0.2	1.42^{a}±0.1
Area	Range	34.4-38.6	8.22-10.2	0.1-0.4	1.2-4.8	1.2-3.9	10.2-15.8	0.1-0.49	2.1-5.9	0.98-2.56
Staff	Mean	40.62^{c}±0.6	10.96^{b}±0.3	0.52^{b}±0.1	2.94^{a}±0.1	2.42^{a}±0.2	15.20^{c}±0.3	0.82^{b}±0.1	4.86^{b}±0.2	1.62^{a}±0.2
Quarters	Range	39.4-42.6	9.4-12.2	0.2-1.2	1.8-3.6	1.5-3.7	13.1-17.3	0.2-1.0	3.2-5.8	1.1-2.89

**Means within column with different Superscript are significantly different (P≤0.05) from each other*

Footnote: BW is the Body weight, HH is the Height of the head, HL is the Head length, HW is the Head width, TL is the Tail length, TW is the Tail width, TRL is the Trunk length, MO is the Mouth opening and SVL is the Snout-vent length

Table 3. The morphometric parameters of male rainbow lizard (*A. agama*) caught at three different locations in the university (student hostel, academic area and staff quarter)

Locations	Statistic	BW (g)	SVL (cm)	HH (cm)	HL (cm)	HW (cm)	TL (cm)	TW (cm)	TRL (cm)	MO (cm)
Student	Mean	65.43^{b}±0.8	11.99^{b}±0.4	1.56^{a}±0.1	3.56^{b}±0.3	3.72^{b}±0.3	17.04^{b}±0.5	0.92^{a}±0.1	5.29^{b}±0.2	1.92^{a}±0.1
Hostels	Range	62.4-67.6	10.2-13.2	0.61-1.8	2.42-5.01	2.2-4.9	12.2-18.89	0.32-1.7	2.96-7.25	1.3-2.98
Academic	Mean	60.24^{a}±0.5	10.94^{a}±0.3	1.46^{a}±0.1	2.92^{a}±0.1	3.02^{a}±0.1	16.42^{a}±0.4	0.82^{a}±0.1	4.39^{a}±0.2	1.82^{a}±0.1
Area	Range	57.2-64.23	9.4-12.9	0.52-1.56	2.01-4.20	2.2-4.60	11.4-17.86	0.21-1.50	2.2-6.51	1.01-2.04
Staff	Mean	72.40^{c}±0.6	12.46^{c}±0.3	1.72^{a}±0.1	3.97^{b}±0.1	3.88^{b}±0.2	18.01^{c}±0.3	1.02^{a}±0.1	5.67^{b}±0.2	1.98^{a}±0.2
Quarters	Range	68.2-75.2	11.01-13.6	0.72-1.8	2.6-5.8	2.8-4.9	14.0-19.8	0.52-1.82	2.89-7.59	1.40-3.01

**Means within column with different Superscript are significantly different (P≤0.05) from each other*

Footnote: BW is the Body weight, HH is the Height of the head, HL is the Head length, HW is the Head width, TL is the Tail length, TW is the Tail width, TRL is the Trunk length, MO is the Mouth opening and SVL is the Snout-vent length

(p<0.05) in the testes weight of all the specimens from the three different locations. The mean testes weight of the specimen from the academic area was the least (0.12 g) while the mean weight of the testes from the specimen from Staff quarters was the highest (0.17 g). The Testes from all the locations ranged between 0.07-0.19 g with the specimens from the academic area having the least range (0.06-0.14 g). The Principal Component Analysis (PCA) (jollief cut of 0.7) showed that the measured gonads were similar with little difference from the specimen from the academic area (Fig. 2). The specimen from student hostels and that of academic area showed 95% similarity in the gonads measured. The gonads of the specimen from the academic area showed that few of the specimen is outside the staff quarters circle but still integrated to that of the student hostel circle. There was a positive correlation (0.99 for male and 0.75 for female) between the gonad weight and SVL of the specimen from all the study area.

4. DISCUSSION

The higher abundance of the female rainbow lizards than male recorded in this study may be due to search for food by the female rainbow lizard which may expose them to easy capture. This finding is in line with the report of Bamidele and Olutunji [13], on abundance and morphometric study of some lizards. They reported a higher number of female (*A. agama*) lizards than males in the University hostels and University staff quarters than the University library. The variation in some of the measured morphometric may be due to effect of habitat related environmental conditions that impact on

Table 4. The gonad weight of the specimen (male and female lizard) caught at three different locations in the university (student hostel, academic area and staff quarter)

Locations	Statistic	Ovaries weight (g)	Testes weight (g)
Student Hostels	Mean	0.09^{a}±0.0	0.15^{b}±0.1
	Range	0.03-0.12	0.07-0.18
Academic Area	Mean	0.09^{a}±0.0	0.12^{a}±0.1
	Range	0.02-0.11	0.06-0.14
Staff Quarters	Mean	0.10^{a}±0.0	0.17^{c}±0.1
	Range	0.03-0.13	0.09-0.19

**Means within column with different Superscript are significantly different (P≤0.05) from each other*

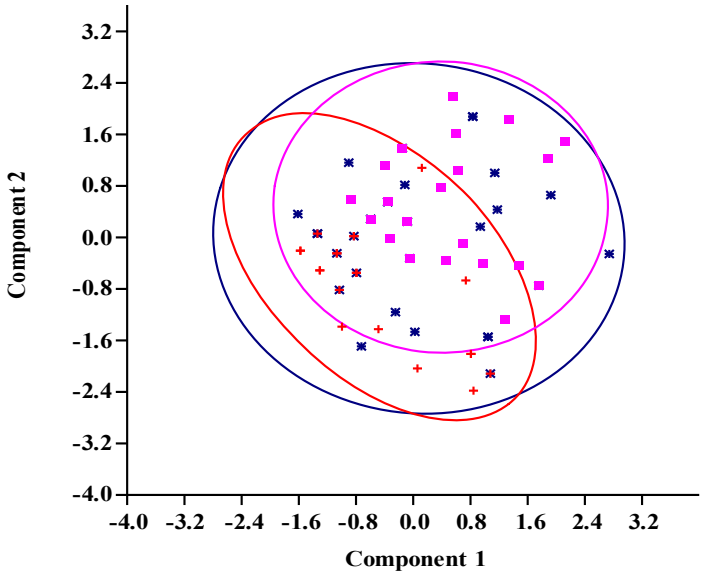

Fig. 2. Principal component analysis (PCA) scatter plot showing relationship in body and gonad weight of the specimen (lizard) caught in three different locations (students' hostels (SH), academic area (AA) and staff quarters (SQ)

Keys: Blue colour represent student hostels, Red colour represent academic area, Pink colour represent staff quarters

the morphology of these lizards. It has been reported that lizard phenotypes are easily modified in nature and under semi-natural conditions [15].

The availability of food in student hostels and staff quarters may be responsible for the increase in body weight of rainbow lizards from these two locations when compared to the body weight of specimen from the academic area. Although rainbow lizards are known to feed on fruits and insects [16], the report of Ofori et al. [10] showed that rainbow lizards can feed on processed food which may be abundant in student hostels and staff quarters based on leftover foods. Taborsky [17] reported a relationship between food abundance and morphometric parameters measured in lizards. The abundance of food in the two locations may be good for higher body weight, but it may also have an adverse effect by attracting predators to such locations where the lizards are more [18].

The male bodyweight of the rainbow lizard was higher than that of females in this study and it varied from a different location with the least bodyweight or both male and female rainbow lizards found in the academic area of the University. This may be attributed to different habitats and the genetic modification of rainbow lizard. Harding and Mifsud [19] reported that the habitat in which the lizards are living may affect their body weight. For adaptation purposes, lizards living in the warm temperate region, but find herself in the cold region may develop some adaptation features to survive such conditions. Also, the male rainbow lizard has a higher body weight than females [20]. The difference in the morphometric parameters measured in the specimen from all the locations may be attributed to their use of the body part. The tail of the male rainbow lizard is used to fight for food or territory, and this may cut during the fight which may be responsible for difference recorded in Tail length (TL) among male rainbow lizards.

The gonads weight of the specimen showed a direct relationship to the bodyweight of the specimens with 0.98 and 0.78 correlation between the bodyweight and gonads weight for male and female specimens. There was no significant difference($p \geq 0.05$) in the ovaries weight of the specimen from the three locations (Student hostels, Academic area and Staff quarters). This observation may be due to the age of the female lizard caught in these locations. Although age was not taken into consideration in this study the similarity in the ovaries suggests that the specimen maybe of the same age range. Ortiz et al. [21] reported that the ovaries size of viviparous lizard increases during the wet season. The report of Ejere and Adegoke. [22] showed that food availability was of importance to female rainbow lizards for reproduction behaviour and hatching. Although the ovary size of the specimen from the Student hostels and academic area were the same (0.09 g) and that of staff quarters was 0.10 g, there was no statistical difference in their ovary's weights.

The testes of the specimen from the three locations differ and this may be attributed to the abundance of food and maturity of the specimen. The report of Mugads et al. [23] showed that an abundance of food is one of the major factors that are responsible for how different species will allocate energy among competing demands and maturity. Ejere and Adegoke [21] reported that the mean weight of the testes of rainbow lizard was 0.20 g and that the testes weight varied from season to season. It is expected that the weight of the testes of the older rainbow lizard will be higher than that of the younger ones.

The Principal Component Analysis (PCA) loading of the gonads measured showed similarities in the specimens from the three locations with very little difference from the gonads of the specimens from the academic area. The little difference may be attributed to the higher values of the male testes when compared to female ovaries which may be in line with the body weight.

The food availability in the different sample location may be responsible for differences in body weight of rainbow lizards caught in three different locations in Obafemi Awolowo University. It is important to note that food remnants from the students living in the hostels and that of staff living in the quarters may contribute to the body weight and the gonads weight of the rainbow lizards. The absence of processed foods in the academic area may be responsible for the reduction in body weight of the specimen from the location. The food availability in such locations and the abundance of the rainbow lizard may be of great danger to the students and staff because predators like snake may come around looking for lizard as food source.

5. CONCLUSION

The external morphology of the rainbow lizards from this study is similar despite the difference in

sampling area. There is positive relationship in the external morphology and the gonads of the specimen, although the ovary's weight of the female rainbow lizard is smaller and that of the male rainbow lizards is bigger depending on the locations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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