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Food and Feeding Habits of the African Rainbow Lizard (*Agama agama*, Linnaeus, 1758) in Selected Sites of a University Community

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Abstract

Various factors, including habitat, season, prey availability, body size, and evolutionary adaptations, influence lizard feeding preferences. In this study, we examined the dietary composition and morphometric characteristics of Rainbow Lizards (*Agama agama*) from four different sites. The collected specimens' guts were dissected longitudinally for food analysis based on sex and site. It was observed that Site 1 had the highest number of specimens (31.43%), followed by Site 2 (25.71%), Site 4 (22.86%), and Site 3 (20%). The sex distribution revealed that male specimens accounted for 54.29% of the population, while females comprised 45.71%. Morphometric measurements indicated maximum and minimum body lengths of 40.00 cm and 14.20 cm, respectively, with males exhibiting larger dimensions. Body weight ranged from 28.42 g to 73.10 g, and head and tail lengths varied between sexes. Gut analysis indicated that insects were the dominant food source, followed by plant matter and non-food items like stones and sand. Chi-square analysis revealed no significant association ($p > 0.05$) between food content and sex. Both ANOVA and Mann-Whitney U-tests indicated no significant differences ($p > 0.05$) in food content, sex distribution, and lizard abundance across sites. Correlation analysis showed a significant positive relationship ($p < 0.05$) between female body weight and female food content weight, as well as a stronger correlation ($p < 0.01$) between female body weight and plant food weight. These findings provide insights into the feeding patterns and body characteristics of A. agama across different environments, highlighting the lizards' exploration of various food items.

Keywords: feeding, habits, Agama agama, University Community

Introduction

With over 6,000 species spread across different ecosystems globally, lizards, which belong to the order Squamata, are a diverse group of reptiles (Villa & Delfino, 2019). They have been able to flourish in a variety of environments, including urban areas, deserts, and rainforests, due to their extraordinary adaptability (Leenders, 2019; Wilson, 2012). Their feeding behaviour, which includes a broad range of eating

habits, is an essential part of their ecological success (Abu Baker et al., 2021). An understanding of the ecology of lizard feeding is essential for environmental and evolutionary studies as well as for the preservation of biodiversity and habitat management (Biaggini & Corti, 2021). Lizards have a wide range of food preferences, from omnivory and specialised feeding to herbivory and insectivory (Herrel et al., 2004). A number of factors, including body size, habitat structure, food availability, and environmental seasonality, affect their diet and foraging tactics (Bijay-Singh & Craswell, 2021; Rabiu, 2020). Lizards' evolutionary adaptability and their function as significant ecological regulators in their environments are highlighted by their capacity to alter their food preferences in response to changing environmental conditions (Buckley & Kingsolver, 2021). Lizards' feeding activities are essential to preserving the equilibrium of the ecosystem. Their ability to control arthropod populations as insectivores aids in the management of pests (Monagan et al., 2017).

While herbivorous lizards aid in the dynamics of vegetation and seed dispersal, omnivorous and specialised feeders improve the cycling of resources in their environments (Valencia-Aguilar et al., 2013; Yang et al., 2021). Lizard population declines or losses can upset these ecological processes, emphasising the significance of conservation initiatives.

Agama agama, commonly known as the African rainbow lizard, is a diurnal lizard native to sub-Saharan Africa. Studying its food and feeding habits is crucial for understanding the species' ecology and reveals how the species interacts with its environment and the implications of these interactions for its survival (Kondrakiewicz et al., 2019). The common agama (*Agama agama*) serves as a significant source of protein for many communities in West Africa, particularly in Nigeria and Ghana. Agama meat is considered nutrient-dense, providing a good supply of protein, vitamins, minerals, and essential amino acids (Rabiu, 2019). Because it is low in fat and lean, it is a valuable dietary component, especially in areas where other protein sources may be limited. Its consumption has deep cultural roots and is believed to have therapeutic benefits in some cultures, including the treatment of coughs and asthma, as well as preventing strokes and epilepsy, going beyond its nutritional advantages (Solís & Casas, 2019; Valencia-Aguilar et al., 2013).

Their abundance can influence the predator-prey dynamics in local ecosystems, highlighting their ecological significance (Hawlena et al., 2010). The rainbow lizard is primarily insectivorous, with prey items depending on size, species, and location (Ofori et al., 2018; Vitt & Caldwell, 2014). Some agama lizards are omnivorous, consuming both plants and small animals (Rabiu, 2020). The dentition of lizards reflects their diverse diets, which can include carnivorous, insectivorous, omnivorous, herbivorous, and molluscivorous patterns (Melstrom, 2017; O'Grady et al., 2005). Seasonal variations in diet have been observed, with species consuming more insects during the rainy season when insect abundance is higher, while plant matter makes up a more significant portion of their diet during the dry season when insects are scarce (Znari & El Mouden, 1997). Competition with other species and reproductive status can also influence food and feeding habits (Gomides et al., 2013). Habitat fragmentation, destruction, and degradation caused by urbanisation lead to a decrease in the availability of food resources, contributing to potential population decline (Lal et al., 2021). Understanding the feeding habits of this species is essential as it provides insights into its ecological role and effective conservation mechanisms. Despite its prevalence in urban landscapes, there is limited research on its dietary preferences and how these diets vary across different landscapes within a university community. This study aims to bridge the knowledge gap by determining the feeding habits of the rainbow lizard (*Agama agama*), comparing food preferences across study sites, and analysing the relationship between body weight, sex of the specimens, weight, and food contents. This valuable information will aid in species management and conservation efforts, ensuring the sustainability of the population in its natural habitats.

Methodology

The study was carried out at Obafemi Awolowo University in Ile-Ife, Osun State, in the southwestern part of Nigeria. The study area lies between latitudes of 070º26'N and 070º32'N and longitudes of 004º031'E and 0040º35'E (Figure 1) and is characterised by two distinct seasons, which are rainy and dry (Obayemi and Komolafe, 2019). The rainy season runs from mid-March to October, and the dry season runs from November to March. The vegetation is part of the tropical savanna biome, characterised by a mixture of grasslands, woodlands, and pockets of forested areas. Four sampling sites were chosen: The Biological sciences area, the Cooperative Hall car park, the Medical sciences area and the Akintola Hall car park. These sites are hereafter referred to as sites 1, 2, 3 and 4, respectively. Specimens were captured between February and July 2023. Sweep nets were used to capture the lizards, and after that, they were secured in a bag with air holes to prevent suffocation, escape, or injury. The specimens were taken to the laboratory and anesthetised using chloroform. Morphometric parameters such as weight, body length, head length and tail length were

taken according to the methods of Ogundimu (2019). Stomach contents were obtained by excision of the stomach through dissection according to the process of (Christel et al., 2007; Srichairat et al., 2018). We used a pair of fine forceps to remove the stomach contents, and the food types were identified. Collected materials were weighed using the Monobloc inside the weighing machine Mettler Toledo PB153 model, recorded, and analysed. The quantity of food consumed by each specimen, the types of food items and the amounts found in the stomachs were recorded. The composition of food content was determined using frequency and percentage. Chi square analysed the association between the diets of male and female Agama, while cluster analysis determined the dietary allocation among the various sites. Statistical analyses were carried out using PAST Version 4.13 (Hammer et al., 2001) and Microsoft Excel 2016.

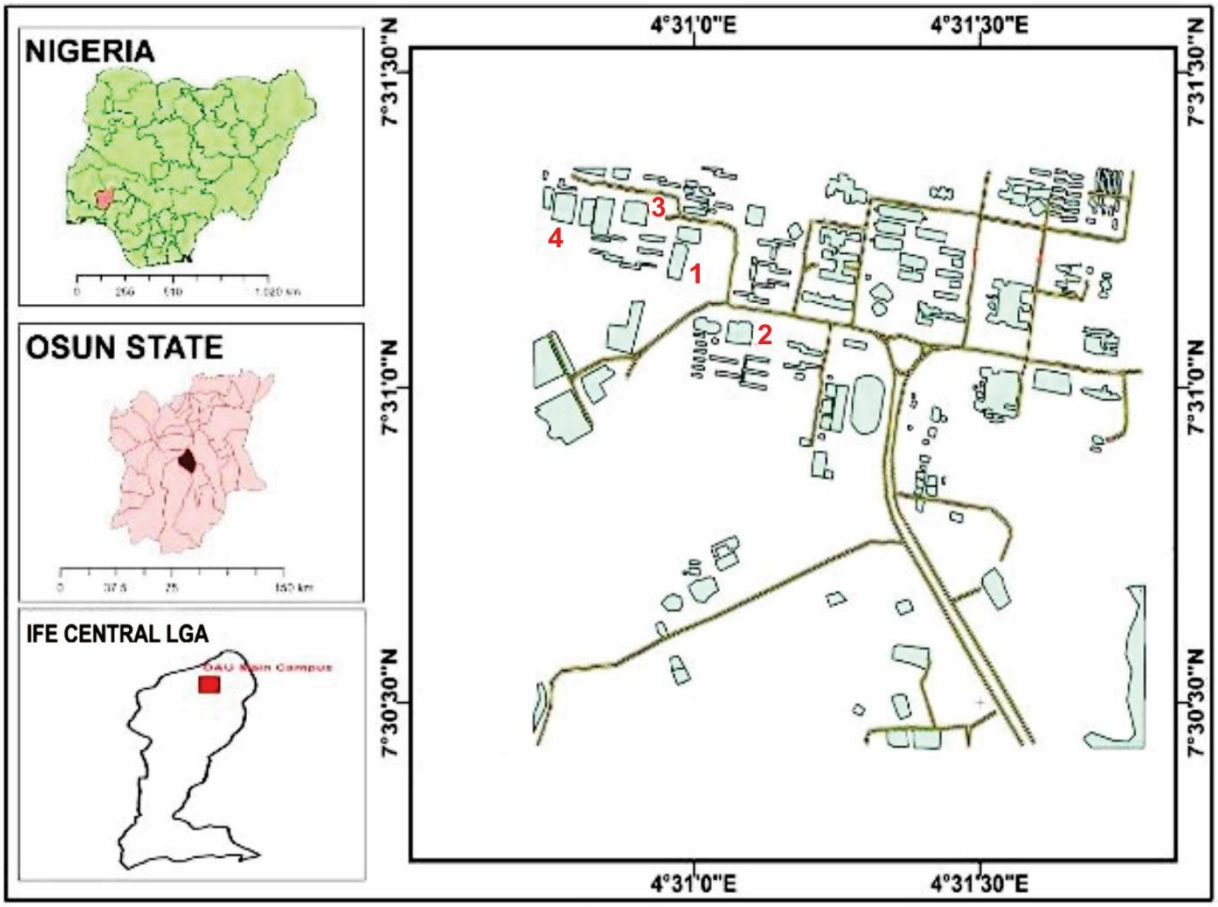

Figure 1: Map of the study areas

Results

In this study, 35 specimens of *Rainbow lizard* were collected from 4 different sites over the sampling period. A total of 11 lizards were obtained from Site 1, 9 lizards from Site 2, 7 lizards from Site 3, and 8 lizards from Site 4, with 31.43%, 25.71%, 20%, and 22.86%, respectively, as shown in Supplementary 1. Also, 54.29% of the specimens collected from all sampling sites were males, while 45.71% were females. Of the 35 dissected digestive guts, all except two had no food present. Therefore, food contents were found in 33 lizards. Based on the analysis of gut contents, insects were the primary food source. Plant matter was also found, along with other non-food materials, such as small stones and sand grains. Generally, 17 (51.52%) male lizards and 16 (48.49%) female lizards had food content, as shown in Supplementary 2. Supplementary 3 shows that plant food was found in 28 lizards while insect food was found in 27 lizards; 15 (53.57%) of the male lizards had plant food compared to 13 (46.43%) of the female lizards while 15 (55.56%) of the male lizards had insect food compared to 12 (44.44%) of the female lizards.

In Site 1, plant food was found in 44.44% of lizards, including 27.77% males and 16.67% females, while insect food was found in 55.56% of lizards, with 38.89% males and 16.67% females. In Site 2, plant food appeared in 66.67% of lizards, 41.67% males, and 25% females, while insect food was found in 33.33% of

lizards, 25% males, and 8.33% females. Site 3 had plant food in 58.33% of lizards, 25% males, and 33.3% females, while insect food was found in 41.67% of lizards. In Site 4, plant food was in 38.46% of lizards and insect food in 61.54% of them (Table 1).

Supplementary 4 shows a bar chart of food content in lizards, with plant food found in 28 lizards (15 males, 13 females) and insect food in 27 lizards (15 males, 12 females). Supplementary 5-8 present food content across sites. Supplementary 5 indicates higher male frequencies for plant and insect food (5 and 7) at Biological Sciences, while females show lower frequencies (3 each). Supplementary 6 shows similar trends at the Cooperative Hall car park. Supplementary 7 at Site C reveals higher plant food frequencies for females and insect food for males. Supplementary 8 shows females dominating both food types at the Akintola Hall car park.

Chi-square was used to determine if the observed food contents were significantly associated with the rainbow lizard's sex. It indicated that there was no significant association ($p>0.05$) between the food content ingested by both sexes at each studied site and overall (Table 2).

The morphometric data of the *Rainbow lizard* were also measured and recorded in terms of the body length, weight, head length, and tail length. Generally, the maximum body length, weight, head length, and tail length of all the *Rainbow lizard* sampled were 40.00 cm, 73.10 g, 3.50 cm, and 22.00 cm respectively while the minimum body length, weight, head length, and tail length were 14.20 cm, 28.42 g, 1.10 cm, and 4.70 cm respectively as shown in Table 5.

Supplementary 9 shows the body measurements of male and female Rainbow lizards. The maximum body length for males was 40.00 cm and 34.10 cm for females, while the minimum was 22.10 cm for males and 14.20 cm for females. The maximum weights were 73.10 g for males and 51.20 g for females, while the minimums were 32.10 g and 28.42 g, respectively. The maximum head lengths were 3.50 cm for males and 3.40 cm for females, with minimums of 1.10 cm and 1.20 cm. Tail lengths ranged from 22.00 cm (maximum) to 8.40 cm (minimum) in males and 18.40 cm to 4.70 cm in females.

The hierarchical cluster analysis of *Agama agama* diets, based on stomach content analysis across four sites, reveals two distinct dietary clusters: Sites 1 and 4 group together, indicating similar diets likely due to comparable prey availability in their respective environments. Similarly, Sites 2 and 3 cluster together, suggesting their diets are alike, possibly due to ecological similarities in their habitats.

Table 1: Frequency and Percentage composition of food content of *A. agama* based on sexes from study sites

Location	Food content	Males (%)	Females (%)	Total (%)
Site 1	Plant food	5(27.78)	3(16.67)	8(44.44)
	Insect food	7(38.89)	3(16.67)	10(55.56)
	Total	12(66.67)	6(44.44)	18(100)
Site 2	Plant food	5(41.67)	3(25)	8(66.67)
	Insect food	3(25)	1(8.33)	4(33.33)
	Total	8(66.67)	4(33.33)	12(100)
Site 3	Plant food	3(25)	4(33.33)	7(58.33)
	Insect food	3(25)	2(16.67)	5(41.67)
	Total	6(50)	6(50)	12(100)
Site 4	Plant food	2(15.38)	3(23.08)	5(38.46)
	Insect food	2(15.38)	6(46.15)	8(61.54)
	Total	4(30.77)	9(69.23)	13(100)
Total	Plant food	15(50)	13(52)	28(50.91)
	Insect food	15(50)	12(48)	27(49.09)
	Total	30(100)	25(100)	55(100)

Table 2: Chi-square analysis of the food content of *Agama agama* across sexes

	Food content	Males	Females	Total	Chi-Square	Degree of freedom	p-value
Site 1	Plant food	5	3	8	0.1125	1	0.73732
	Insect food	7	3	10			
	Total	12	6	18			
Site 2	Plant food	5	3	8	0.1875	1	0.665
	Insect food	3	1	4			
	Total	8	4	12			
Site 3	Plant food	3	4	7	0.3429	1	0.5582
	Insect food	3	2	5			
	Total	6	6	12			
Site 4	Plant food	2	3	5	0.325	1	0.5686
	Insect food	2	6	8			
	Total	4	9	13			
Overall Study Area	Plant food	15	13	28	0.0218	1	0.8825
	Insect food	15	12	27			
	Total	30	25	55			

Table 3: Descriptive statistics of the 35 Rainbow lizards captured

	Range	Minimum	Maximum	Mean	Std. Deviation
Body length(cm)	25.80	14.20	40.00	28.3743	6.83040
Weight(g)	44.68	28.42	73.10	45.3940	11.82466
Head length(cm)	2.40	1.10	3.50	2.4629	0.83845
Tail length(cm)	17.30	4.70	22.00	13.7286	4.78611

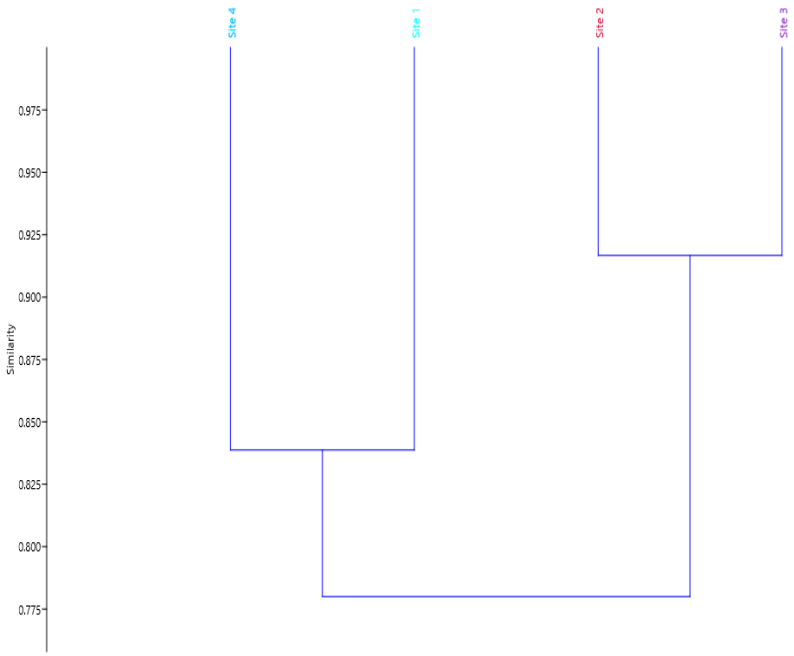

Figure 2: Cluster Analysis of *Agama agama* diets based on the various sites

Discussion

This study was conducted from March to June 2023 across four distinct study areas, during which thirty-five rainbow lizards (*Agama agama*) were collected and examined for their dietary preferences. Our findings confirmed that these lizards are diurnal, aligning with the observations of Murphy & Hanken (2018) & Mediannikov et al. (2012). However, recent research has indicated that lizards may also consume food at night, as noted by Mediannikov et al. (2012), who observed that *A. agama* primarily engages in nocturnal hunting activities. Additionally, Rabiu (2019) and Tan et al. (2020) reported that A. agama often hunts during daylight hours, a behavior that aligns with our field observations.

We observed that the rainbow lizard (*Agama agama*) typically hunts alone but tends to stay within the vicinity of other group members. This solitary hunting behavior within a group suggests a complex social structure where lizards maintain individual hunting territories while foraging closely together. A. agama is renowned for its remarkable foraging abilities, likely attributable to its speed and agility (Verwaijen & Van Damme, 2007). Furthermore, these lizards rely on their acute vision to detect potential prey, using their sharp eyesight to spot movement and identify suitable food sources. Their foraging habitats are diverse, encompassing the ground, trees, and various surfaces within their environment (Rabiu, 2020). This adaptability allows them to exploit a wide range of prey, including insects and other small animals (Tan et al., 2020; Znari & El Mouden, 1997).

In this study, the rainbow lizard (*Agama agama*) exhibited opportunistic feeding behavior, allowing it to adjust to various environmental resources. It has been observed that lizards regularly consumed non-natural, human-made foods, showing a diverse preference for a particular type of food (Enge et al., 2000). Also, a study by Rabiu (2019) analysed the dietary habits of *A. agama* across different age and sex classes in Nigeria. The study found that while arthropods constituted the primary food sources of the animal, the proportions of various prey items varied significantly by month, season, and study site. This dietary plasticity emphasises the lizard's ability to adapt to its feeding activities in response to changes in the environment, which could enhance its survival across various habitats.

In this study, we observed that Rainbow lizards (*Agama agama*) showed no statistically significant ($p>0.05$) relationship between their sex and food consumption patterns. Although differences in plant and insect consumption between male and female lizards were observed, these variations were not significant enough to indicate sexual dimorphism in the diet of the specimen. Our findings were consistent with the results of Santamaría et al. (2020), who recorded that food content preference and types in certain lizard species are not strongly influenced by sex. However, some authors have recorded sexual based dietary preferences of lizards. The authors revealed that some lizard species exhibit sexual dietary differentiation as a result of variations in body size, metabolic behaviour, or reproductive function (French & Moore, 2008). However, in species like *Agama agama,* it has been documented that diet preference could lead to feeding overlap in the sexes of the lizards since they shared typical ecological roles and feeding behaviours (Rabiu, 2019; Tan et al., 2020). Our findings showed that both sexes consumed available food materials in their respective habitats, with no preference for food based on sex. As a result of their feeding behaviour, they are mostly regarded as opportunistic feeding strategies. These revealed that *Agama agama* in the four sites has the ability to adjust to habitat-specific resources.

Also, across all the study areas, plant materials were predominant in Sites 2 and 4, while insect food content was predominant in Sites 1 and 4, and the sites did not reveal significant variations ($p>0.05$). This may be a result of many factors, such as environmental homogeneity and prey availability, which led to consistent feeding patterns among the lizards across sites. The *Rainbow lizard* has specific habitat preferences that were met across all the studied sites, leading to similar feeding behaviours. And since the habitats provide similar resources, the lizard's dietary choices might not differ significantly. The study was conducted during the rainy season when plant and insect food availability was relatively consistent across the sites, which is why the differences were not significant (Perez-Martinez et al., 2020).

We subjected the body weight and food content weight of males and females to statistical analysis. A significant correlation was observed between the female body weight and female food content weight. This showed that the female body weight increased as the female total food content weight increased, and this may be due to the fact that larger females appear to consume more food as a result of their increased energy requirements. Factors such as growth enabled the animal to accommodate larger prey, support reproduction, and perform ecological roles within their habitat (Olsson et al., 2002; Pandav et al., 2010).

Despite differences in plant and insect type consumption between male and female *A. agama*, sex does not impact their food preferences. Food content was determined dominated in some sites, insect food content prevailed in others, and this highlights the consistent feeding behaviours that go beyond habitat differences

and sexes. The uniformity in feeding patterns could be attributed to the shared habitat preferences of the lizards across the various sites, resulting in similar dietary choices.

Conclusion

The study highlights a connection between female lizards' larger body size and a stronger preference for plant-based foods. This aligns with the broader idea that body size influences what lizards eat. By determining these links between body size, diet preferences, and habitat similarities, these findings provide valuable insights into the factors shaping the dietary behaviour of these lizards and enhance our understanding of their ecological roles within their respective environments.

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