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Seasonal variation in nutritional value of variegated grasshopper *Zonocerus variegatus* in Abeokuta Ogun state Nigeria

Adeniyi AV[1+]
Ademolu KO[2]
Iyeh CI[3]
Osipitan AA[4]
Idowu AB[5]

[1,2,5]*Department of Pure and Applied Zoology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.*
[1]*Email: victorakinkunle@gmail.com*
[2]*Email: kennyademolu@yahoo.com*
[5]*Email: idowuab@unaab.edu.ng*
[3]*Department of Animal and Environmental Biology, Federal University Oye Ekiti, Oye Ekiti Nigeria.*
[3]*Email: concillia.iyeh@fuoye.edu.ng*
[4]*Department of Crop Protection, Federal University of Agriculture, Abeokuta, Ogun state, Nigeria.*
[4]*Email: osipitanaa@funaab.edu.ng*


(+ Corresponding author)

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ABSTRACT

Zonocerus variegatus is a polyphagous species capable of consuming most of the plant species in its surroundings, climatic conditions and pesticide application have been reported to affect their natural life. In our locality, little or no information is available on the seasonal variation in the nutritional value of *Zonocerus variegates.* This study therefore evaluated the seasonal variation in the nutritional value of Z. *variegatus* in Abeokuta, Ogun state, Nigeria. Adult male and female *Z. variegatus* were collected during dry and wet seasons using a sweep net from an uncultivated farm at the Federal University of Agriculture, Abeokuta. Proximate composition, mineral composition, antinutrients, and vitamins) were determined using standard methods. All data collected were presented as Means±S.D. and compared using the T-test at ($p < 0.05$). Results showed that dry-season populations of *Z. variegatus* had significantly ($p < 0.05$) higher moisture content, crude protein, and carbohydrates than wet-season counterparts. Similarly, phosphorus concentration showed significant differences ($p < 0.05$) in the sample population for both seasons with the wet season population having higher values than the dry season. Vitamin A had a higher value (121.38 mg/100g) in the wet season than during the dry season (13,877 µg/100 g), while Vitamins D, B2, B6, and B12 values were higher during the dry season than in the wet-season. Antinutrient concentration was higher ($p < 0.05$) in the wet-season population than in the dry-season population. This study has shown that the dry-season *Z. variegatus* population is richer in nutrients than the wet-season population.

Contribution/Originality: This study provides the first comprehensive analysis of seasonal variations in the nutritional composition of *Zonocerus variegatus* in Abeokuta, Nigeria, highlighting significant differences in nutritional and antinutrient contents between dry and wet season populations thereby offering insights into optimizing its potential as a sustainable nutritional resource.

1. INTRODUCTION

Zonocerus variegatus, a brightly coloured grasshopper belonging to the Order Orthoptera, Family Pyrgomorphidae, is a significant agricultural pest due to its group behavior and diverse diet [1, 2]. However, this insect also holds potential as a nutritious food source. Okoye, et al. [3] highlighted its nutritional value for animals, while Idowu and Modder [4] noted its consumption by humans in certain Nigerian regions. Idowu, et al. [5]

confirmed its high protein and mineral content, aligning with broader trends in insect consumption as a food source [6]. By promoting human consumption of *Z. variegatus*, we can reduce reliance on harmful insecticides and improve environmental sustainability [7]. The mineral composition of edible insects, including Z. variegatus, is influenced by their diet and can provide essential nutrients like potassium, sodium, and calcium [8-10]. Minerals are known to play important metabolic and physiologic roles in the living system; Iron, zinc, copper, and manganese strengthen the immune system as antioxidants and cofactors of enzymes [11] Similarly, Magnesium, Zinc, and Selenium prevent cardiomyopathy, muscle degeneration, growth retardation, impaired spermatogenesis, immunologic dysfunction, and bleeding disorder [12]. Iron deficiency is a major problem in women's diets in the developing world, particularly among pregnant women, and especially in Africa [13]. *Z. variegatus* contain a high amount of Calcium (42.16%), Phosphorus (131.2%), and Magnesium (8.21%) [14].

It is In Nigeria, the species exhibits varying seasonal population dynamics. While some studies report a single population (wet season) in the northern regions [15, 16] others suggest two distinct populations (wet and dry seasons) in the southern parts [17, 18].

Nanta [19] proposed two generations of *Z. variegatus* per year in the Ivory Coast, while Oyidi [16] described two distinct Mendelian populations (dry and wet seasons) in Ibadan, Nigeria. However, Oyidi [16] also reported a single generation in Zaria, northern Nigeria. Notably, neither Nanta [19] nor Oyidi [16] provided substantial empirical data to support these conclusions.

An extensive review by Phillips [20] on the life cycles of African grasshoppers suggests that while a single generation may be typical in some West African regions, the life history of *Z. variegatus* can be influenced by local environmental factors, particularly rainfall patterns. In regions with distinct wet and dry seasons, multiple generations may occur annually. Finke and Oonincx [21] reported that factors such as sex, stage of life, and environmental factors (temperature, day length, humidity, light intensity, etc.) can influence the chemical composition of insects.

The abundance, nutritional, and chemical composition of insects varies in seasons, Hahn and Orrock [22]. Previous reports show that dry season populations are more abundant, and more widely distributed, and they consume greater quantity and variety of food, they cause extensive damage to farm crops than the wet season population, Chapman, et al. [2]. Though various work has been done on the nutrient content and morphometrics during the dry season, little or no attention has been paid to the comparison of *Z. variegatus* in both dry and wet seasons. Availability of vegetation and weather conditions tend to affect the nutrient composition, and chemical composition of insects irrespective of the seasons, therefore this work aimed to determine the seasonal variation in the nutritional value of *Zonocerus variegates* in Abeokuta Ogun State, Nigeria.

2. MATERIALS AND METHODS

2.1. Collection of Zonocerus variegatus

Adult individuals of Z. variegatus male and female were collected randomly from uncultivated farmland at the Federal University of Agriculture, Abeokuta Ogun State, during the dry season (November 2017 - January 2018) and rainy season between (June-September 2018). They were collected very early in the morning between 6:30 am – 7:30 am using a sweep net as described by Van Huis [9]. After being collected from the field they were kept in wire cages (30×30×45cm), they were taken to the Insectary of the Department of Pure and Applied Zoology, the Federal University of Agriculture Abeokuta, and Identification of insects was done based on the descriptions of Youdeowei [23].

3. DISSECTION OF *Z. VARIEGATUS*

Each insect was surface-sterilized prior to dissection. This involved swabbing the insect with iodine followed by 70% ethanol [24, 25]. Dissection then proceeded using established methods described by Youdeowei [23] and

Ademolu and Idowu [26]. A ventral longitudinal incision was made to access the alimentary canal. The gut was carefully separated from surrounding tissues (fat bodies and Malpighian tubules) and then sectioned using sterilized forceps into three distinct regions: the foregut, midgut, and hindgut. The contents of each gut section were carefully emptied into pre-labeled Petri dishes.

Following dissection, each gut section was homogenized in 1 mL of sterile distilled water using a sterilized mortar and pestle. The homogenate was then transferred to labeled bottles containing 9 mL of additional sterile water. A 1 mL aliquot of this diluted homogenate was further diluted 1:10 in sterile water to create a six-fold serial dilution series.

4. PROXIMATE ANALYSIS

The Moisture content was determined by the moisture extraction method. The mass/ weight in grams of each stage was taken using a sensitive electronic balance (SCILOGEX MS-H-PRO) before drying in the oven (wet weight). The specimen was then oven-dried to a constant weight at 60 ^{0} C for 24 hours. The dry weight of each insect sample was taken and the moisture content was calculated. Fat content, ash content, crude fibre and crude protein were determined using the method by Association of Official Analytical Chemicals (AOAC) [24]. Percentage carbohydrate was obtained using formula: % carbohydrate= 100 - (% moisture+ % Ash + % crude fibre + % fat + % crude protein)

5. VITAMIN ANALYSIS

Assays of vitamins A, B_2, B_6, B_{12} C, and D of the whole insect were carried out following the method of the Association of Official Analytical Chemicals (AOAC) [24].

6. MINERAL ANALYSIS

The dried insect sample was analyzed to determine the concentration of magnesium (Mg2+), zinc (Zn2+), calcium (Ca2+), iron (Fe2+), sodium (Na+), potassium (K+) and phosphorus (P). Mg2+, Zn2+, Ca2+, and Fe2+ were determined using a BuckVGP210Atomic Absorption Spectrophotometer (AAS). Na+ and K+ were assessed using a Corning 410 Flame Photometer and phosphorus was determined colorimetrically using a Gallenkamp (U.K.) Spectronic 20 photospectrometer.

6.1. Sodium (Na^+) and Potassium (K^+) Determination

Flame photometry method Association of Official Analytical Chemicals (AOAC) [24] was used. 9.9 ml of distilled water 0.1 ml of the sample homogenates and a few ml of standard were poured into a universal bottle and was capped with paraffin and mixed by inversion. Calculation sodium m Eg/d=galvanometer reading x 2 for monovalent cations. MEq/l=nmol for potassium (K^+) Potassium= galvanometer reading x 0.1mEq/l.

7. STATISTICAL ANALYSIS

Data generated from the above analyses were presented as a t-test, and Mean± Standard deviation, ($p < 0.05$) was considered to be statistically significant using Statistical Package for Social Sciences (SPSS) version 20.0 [25].

8. RESULTS

8.1. Proximate Analysis of Adult Male and Female Z. variegatus During wet and Dry Season

Table 1 present the proximate analysis of dry and wet season populations of adult *Z. variegates*. The result below shows the variation in comparison of values for moisture content, fat content, ash content, crude protein, crude fibre, and Carbohydrates in *Z. variegatus* during the dry and wet seasons. Moisture content showed

significantly higher values during the wet season than dry season as shown below, while values for Crude protein and Carbohydrate were significantly higher during the dry season than in the wet season.

Table 1. Proximate Analysis (mg/100g) of Adult *Z. variegatus* during Dry and Wet Season populations.

Proximate analysis (mg/100g)	Dry	Wet	p(Value)
Moisture content	65.22±0.88	73.33±2.56	0.01*
Fat content	1.21±0.68	0.99±0.62	0.65
Ash content	1.52±0.56	1.20±0.56	0.44
Crude fibre	1.30±0.60	1.05±0.56	0.57
Crude protein	19.51±1.36	15.05±0.32	0.00*
Carbohydrates	11.98±0.82	8.96±1.08	0.00*

Note: *Means values having asterisk across the row are significantly different at $p < 0.05$

8.2. Mineral Content of Adult Male and Female Z. variegatus During the Wet and Dry Season

Table 2 present the mineral content of adult *Z.variegatus* during the dry and wet seasons. The variations in the values of phosphorus, magnesium, calcium, iron, sodium, zinc, potassium, and copper are presented below. Phosphorus, Potassium, and iron showed significantly higher concentrations during the wet season than dry season while copper, sodium, and calcium values were significantly higher during the dry season than the wet season.

Table 2. Mineral content (mg/100g) of adult male and female adult *Z. variegatus* during dry season and wet season populations.

Mineral content (mg/100g)	Dry	Wet	p(Value)
Phosphorus	209.42±2.64	219.30±8.86	0.00*
Magnesium	0.60±0.3	0.62±0.29	0.93
Calcium	2.01±0.30	1.90±0.30	0.60
Iron	2.10±0.30	2.15±0.30	0.80
Sodium	3.19±0.30	2.95±0.41	0.37
Zinc	0.41±0.29	0.41±0.30	0.97
Potassium	7.88±0.35	8.31±0.30	0.11
Copper	0.44±0.28	0.35±0.30	0.66

Note: *Means values having asterisk across the row are significantly different at $p < 0.05$.

8.3. The Vitamin Content of Male and Female Adult Z. variegatus

Table 3 present the Vitamins A, C, D, B2, B6, and B12 were detected in the male and female adult Z. variegatus. Vitamin A had the highest concentration compared to other vitamins in the two seasons and was significantly higher during the wet season than in the dry season. Vitamins C, D, B2, B6, and B12 values are higher during the dry season than in the wet season.

Table 3. Vitamins content (mg/100g) of adult *Z. variegatus* during dry and wet season populations.

Vitamins content (mg/100g)	Dry	Wet	p(Value)
Vitamin A	116.14±11.2	121.38±9.75	0.00*
Vitamin C	8.79±0.56	8.54±0.66	0.04*
Vitamin D	0.55±0.28	0.45±0.58	0.39
Vitamin B2	0.95±2.88	0.35±0.71	0.16
Vitamin B6	0.61±0.28	0.31±0.57	0.45
Vitamin B12	0.55±0.25	0.35±0.05	0.27

Note: *Means values having asterisk across the row are significantly different at $p < 0.05$.

8.4. Antinutrient Composition of Adult Male and Female Z. variegatus

Table 4 present the anti-nutrient composition of adult *Z. variegatus*. There is a variations in the values of tannin, saponin, alkaloid, flavonoid, oxalate, and phytate concentrations are presented below for the dry season and wet season. The antinutrients composition of Z. *variegatus* was significantly higher during the wet season than during the dry season.

Table 4. Anti-nutrients composition of adult male and female *Z. variegatus* during dry and wet season populations.

Anti-nutrients (%)	Dry	Wet	p(Value)
Tannin	4.53±0.47	5.04±0.72	0.28
Saponin	9.14±0.38	9.24±0.66	0.83
Alkaloid	6.23±0.32	6.78±0.70	0.20
Flavonoid	10.77±4.77	13.44±0.80	0.31
Oxalate	11.73±0.37	13.78±0.65	0.00*
Phytate	2.28±0.33	2.73±0.63	0.25

Note: *Means values having asterisk across the row are significantly different at $p < 0.05$.

9. DISCUSSION

This present study showed higher mean values of Proximate composition (fat content, ash content, crude fibre, crude protein, and carbohydrates) in the dry season than in the wet season. Carbohydrate values being between 8.96mg/100g- and 11.98 mg/100g respectively is in agreement with Idowu, et al. [27] which reported similar results in processed Z. variegatus. Crude protein being of higher value in the dry season than in the wet season 19.51mg/100g-15.05mg/100g is an indication that these insects are of high nutritional value during this season. Insect protein could contribute daily protein requirement of humans as recommended by the National Research Council (NRC) [28]. The dry season population having higher values than the wet season population indicates they could be more of a good source of protein, than wet season populations, as reported previously that insects are a good source of protein[29]. Fat is very crucial in human diets as they are carriers of fat-soluble vitamins, aids in their absorption and equally serves as energy sources in the body, this study has shown that dry season populations are a better source of fat content than wet season populations, the values of ash content observed in this study were relatively low for wet season populations compared to dry season populations, previous reports state that Ash is used as an index of mineral content in foods [29].

The moisture content had higher values in the wet season than in the dry season, this indicates that these insects could have gotten water from their environment during the wet season, which is a period of more water in their environment. This result is in agreement with Melo-Ruiz, et al. [30] who reported that Sphenarium histirid (grasshopper) in the wet season had higher moisture content than during the dry season 43.19%-35.29% and also that almost one-third part of the insect is water.

According to Chidiebere, et al. [29]. Since moisture content is an index of water activity and measures the storability of food substances, the lower values of moisture content during the dry season in this study means a better shelf-life characteristic of these insect powders during the dry season and suggests that the dried dry season populations of our study insects could be stored for a long duration without any form of spoilage. This also means that wet season populations may not be advisable for long storage.

The present study revealed a higher Vitamin A content (121.38 mg/100g) in *Z. variegatus* during the wet season compared to the dry season (13,877 µg/100g). This observation aligns with findings by Ssepuuya, et al. [31] who reported elevated Vitamin A levels in *Ruspolia nitidula* during the wet season. This seasonal fluctuation likely reflects the increased availability and diversity of food plants consumed by *Z. variegatus* during the wet season, as it is a phytophagous insect that feeds on a variety of crops and grasses.

Vitamin A is crucial for human health, playing a vital role in maintaining epithelial cell integrity, supporting visual and immune system function, and facilitating reproduction, growth, and development [32]. The higher Vitamin A content in the wet season population suggests it may be a more valuable dietary source of this essential nutrient.

In contrast, our study found higher levels of Vitamin D, B2, B6, and B12 in *Z. variegatus* during the dry season. This observation supports the traditional use of insects as a source of nutrition in Central Africa, particularly to combat malnutrition in children, likely due to their high content of vitamins, minerals, and other essential nutrients, as reported by Vantomme, et al. [33].

B vitamins, including B6, play a crucial role in human metabolism, serving as essential coenzymes in various metabolic processes, such as fat synthesis and breakdown [34, 35]. Vitamin B6 is particularly important for the metabolism of macromolecules in the human body. Therefore, the consumption of *Z. variegatus* populations collected during the dry season may provide a more significant contribution to the recommended daily intake of these essential vitamins, supporting various metabolic activities in humans [36].

The variation in the mineral compositions of the wet and dry season populations indicates seasonal influence and differences in the populations, this agrees with previous reports [29, 32]. This study showed that phosphorus had the highest content of all the mineral elements assessed and the wet season (219.30 mg/100g) content was higher than the dry season (209.42 mg/100g) which agrees with the research of Huberty and Denno [37] which reported that phytophagous insects have higher phosphorus content which may be attributed to fertilizer application as a result of intensive farming during the wet season. This study revealed that Z. variegatus represents a poor source of calcium in both seasons, this could be because these insects do not have a mineralized skeleton Finke and Oonincx [21].

In addition, the results showed that the Z. variegatus at the adult stage had low anti-nutrients, these values were lower than the values recorded by the WHO [34] standard which makes *Zonocerus* a safe diet for consumption. Although the wet season population has higher values than the dry season population, this could be a result of more food plants available and consumed during the wet season, the more food plants consumed, the more the heavy metals and anti-nutrients will be deposited in their body, which is in agreement with work done by Ademolu, et al. [35] and this report suggests dry season populations even safer for consumption than wet seasons.

10. CONCLUSION

This study has shown that Dry season *Z. variegatus* populations are safer for consumption, richer in nutrients, and are suggested to be consumed more than wet populations.

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