*Original Research Article*

Physicochemical and nutritional properties of two insect species (*Cirina butyrospermi* and *Zonoceros variegatus*) consumed in Northern Benin

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ABSTRACT

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| Insects are increasingly being consumed as unconventional food resources in Benin. This study aims to characterize the physicochemical and nutritional properties of shea caterpillars and grasshoppers consumed in northern Benin. A total of 1000 g of fresh shea caterpillars and 1000 g of grasshoppers were sampled, dried and ground for the study from the edible insect traders of Parakou. The physico-chemical and nutritional parameters were measured according to the methods of AOAC from February 2024 to May 2025. The results of the study showed that the pH of *Zonoceros variegatus* was 6.22 to 6.15 for *Cirina butyrospermi* (P=0.003). The luminance, red index, yellow index, hue, and chroma values of *Cirina butyrospermi* were 23.3, -5.12, 12.3, -1.2, and 13.26, respectively. For *Zonoceros variegatus*, these values were respectively 41.5, -1, 16.4, -1.52, and 16.4. Nutritionally, the dry matter, ash content, fiber content, and sodium level of *Zonoceros variegatus* were significantly higher than those of *Cirina butyrospermi* (P<0.001). In contrast, the crude protein content, fat content, sugar, potassium, calcium, magnesium, and iron contents of *Cirina butyrospermi* were higher than those of *Zonoceros variegatus* (P<0.001). *Zonoceros variegatus* and *Cirina butyrospermi* offer significant technological and nutritional assets and can be promoted for food security and nutrition. |

***Keywords****:, Benin, Insects as food, Proximate Composition, Quality, Food security.*

1. INTRODUCTION

Sub-Saharan Africa faces severe food insecurity and malnutrition issues due to population growth, global changes, and a lack of employment, which weaken agricultural production and the purchasing power of local populations (FAO, FIDA, OMS, PAM & UNICEF, 2019; Fraval et al., 2019). According to recent FAO data, 21% of the sub-Saharan population suffers from undernourishment (FAO et al., 2021; Dury, 2017). The growing vulnerability of food systems to climatic constraints leads women to rely on Unconventional Food Resources (UFRs) to supplement the necessary food supply for their families and socio-community groups, ensuring sustainable food availability (Tougan et al., 2020; FAO, 2022; Attanasso, 2004).

About 2,000 animal species are part of the human food resources (Ramos Elorduy, 2009). Among them, 1,900 edible insect species exist globally, with at least 250 species in Africa. Approximately 2.5 billion people, or 35% of the world population, live in countries where entomophagy is well developed (Cloutier, 2015). In countries where malnutrition and food insecurity are persistent challenges, unconventional food resources such as edible insects can provide a rich source of proteins, lipids, minerals, and vitamins that are easily accessible and affordable, especially for vulnerable communities (FAO, 2021; Rumpold & Schlüter, 2015; FAO, 2013; Alamu et al., 2013). Scientific research shows that four main insect orders are most consumed worldwide: beetles (including grasshoppers, locusts, and crickets), orthopterans, hymenopterans, and lepidopterans (including caterpillars) (Nsevolo, 2012). Edible insects are rich in amino acids, fatty acids, lipids, essential minerals, and vitamins for human health (Durst et al., 2010; Malaisse, 2005; Mignon, 2002). To improve household food security and fight rural poverty, particular attention should be paid to promoting the consumption and commercialization of traditional wild local foods (FAO/WHO, 2010). According to Mabossy-Mobouna et al. (2017), and Okangola et al. (2016), these unconventional foods offer humans nutrients, amino acids, fatty acids, vitamins, minerals, and sugars. These edible insects belong to animal species used in human nutrition and also serve as income sources for households (Okangola et al., 2016). Fourteen major products have drawn attention, including nine insect species from four orders: Lepidoptera (Saturniidae being the most important), Coleoptera, Blattoptera, and Orthoptera (Matandirotya et al., 2022; Ombeni et al., 2019). Several other authors highlighted the rich nutritional profile of edible insects showing that insects provide high-quality proteins, essential amino acids, fats, vitamins, and minerals, making them a valuable food source especially in regions with limited access to conventional animal proteins (Guiné et al., 2021; Hwang & Kim, 2021; Payne et al., 2021).

In Benin, unconventional foods including bushmeat and edible insects have gained increasing attention last decade due to their nutritional benefits, sustainability, and potential to improve food security. Tohozin et al. (2024) found that shea caterpillars (*Cirina butyrospermi*) and edible grasshoppers (*Zonoceros variegatus*) are the main insects consumed in the North of the Country. These invertebrate insects offer multiple nutritional benefits capable of addressing several food insecurity and malnutrition problems in communities (Main et al., 2024; Koffi et al., 2019). However, cultural factors, lack of awareness, and ignorance regarding the nutritional benefits of these insects may explain their low consumption. Unfortunately, no scientific data on their physicochemical and nutritional properties have been documented to date, warranting further investigation. This study was initiated as part of the implementation of the International Research Project Macky Sall 2023–2024 of the African and Malgassy Council for Higher Education (CAMES).

The aim of this study was to characterize the physicochemical and nutritional properties of shea caterpillars and grasshoppers consumed in northern Benin. Specifically, the study aims to:

* Assess the technological properties (pH and color CIE L\*, a\*, b\*) of shea caterpillars and grasshoppers consumed in northern Benin;
* Determine nutritional value of shea caterpillars and grasshoppers consumed in northern Benin.

2. material and methods

**2.1 Study Area**

The study was performed from February 2024 to May 2025 in collaboration with women traders of edible insects of the Department Borgou (in Nikki and Parakou). The lab analyses were done conjointly at the Quality and at the Food Safety Unit/ LARAEQ of the University of Parakou and the laboratory of National Agency of Food Safety of Benin with technical supports of Gembloux Agro-Bio Tech (Belgium) and the Laboratory of Analytical Chemistry of ISAV-Faranah in the Republic of Guinea.

The Borgou Department is located in northeastern Benin, between 8°52' and 10°25' N latitude and 2°36' and 3°41' E longitude, covering an area of 25,856 km². The climate is Sudanese type, characterized by a dry season (November to May) and a rainy season (June to October) with annual rainfall ranging from 900 to 1200 mm (Adam and Boko, 1993).

**2.2 Methodology**

**2.2.1 Identification and Sampling of** **Shea Caterpillars and Grasshoppers**

Identification and sampling of shea caterpillars collected from Vitellaria paradoxa trees (Figure 1) and grasshoppers (Figure 2) were done with the support of women traders of edible insects of Nikki and Parakou in the Northern Benin. A total of 1000 g of alive shea caterpillars and 1000 g of grasshoppers were sampled and cleaned with distilled water, oven dried and ground for the study.

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**Figure 1. Shea Caterpillars Figure 2. Grasshoppers**

**2.2.2 Data Collection**

**2.2.2.1 pH and Color**

Determination The pH was measured in a fresh homogenized insect samples using a portable pH meter (HANNA Instruments®, Italy) calibrated using two standard buffers (pH 4 and pH 7) (Tougan et al., 2025).

Color was determined using the standards of the International Commission on Illumination (CIE Lab\*). L\* represents Luninance, a\* the red index, and b\* the yellow index. Chroma (C\*) and hue angle (h\*) were calculated using the formulas:

**(a\*2 + b\*2)1/2**

Three replicates were done per species for each measurement.

**2.2.2.2 Evaluation of Macronutrient Composition**

Physicochemical analyses were performed according to AOAC (2016) recommendations and described by Tougan et al. (2025). Dry matter content was determined by oven drying the sample at 105°C until a constant weight. Ash content was measured by incinerating 3–5 g of sample in a muffle furnace at 550°C until light grey ash was obtained.

Crude protein content was determined using the Kjeldahl method, with nitrogen content converted to protein by the factor 6.25 (Protein content = 6.25 × N)

Fat content was measured according to standard NF V 04-402 of January 1968 (ISO 1443:1973), involving acid hydrolysis with HCl, filtration, fat extraction, and result expression (Tougan et al., 2025). Each measurement was repeated twice.

Mineral content (potassium, calcium, magnesium, sodium, iron) was determined by Flame Atomic Absorption Spectrophotometry (FAAS), following standard NF EN 15621.

**2.3 Statistical Analysis**

Statistical analysis was conducted using Statistical Analysis System software (SAS, 2006). Means were computed using the PROC MEANS procedure and frequencies using PROC FREQ. Correlations between variables were determined by species using PROC CORR.

3. results and discussion

**Color (CIE L a b\*) and pH of *Cirina butyrospermi* and *Zonoceros variegatus***

The technological parameters of *Cirina butyrospermi* and *Zonoceros variegatus* are given in Table 1. There is a significant difference in pH (P = 0.003), luminance (P = 0.000), red index, yellow index (P = 0.001), hue (P = 0.001), and chromaticity (P = 0.001) between the two insect species. Zonoceros variegatus had a significantly higher pH than *Cirina butyrospermi* (6.22 vs. 6.15; P =0.003). For *Cirina butyrospermi,* the luminance, red index, yellow index, hue, and chromaticity were 23.3, -5.12, 12.3, -1.2, and 13.26 respectively. For *Zonoceros variegatus*, these parameters were 41.5, -1, 16.4, -1.52, and 16.4 respectively.

The pH values for Zonoceros variegatus (6.22) and *Cirina butyrospermi* (6.15) align with Bomar et al. (1991), who reported values between 6.4 and 6.68 for *Zonoceros variegatus*. However, our values are lower than those by Zhang et al. (2022), who found values between 9 and 11 for *Locusta migratoria*.

**Table 1. Color (CIE L a b\*) and pH of *Cirina butyrospermi* and *Zonoceros variegatus***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variables | *Cirina butyrospermi* | | *Zonoceros variegatus* | | Effect of species (P value) | Methods |
| Mean | Standard Error | Mean | Standard Error |
| PH | 6.15 | 0.01 | 6.22 | 0.01 | 0.003 | Glass Electrode pH Meter (Tougan et al., 2025) |
| Luminance L\* | 23.3 | 0.3 | 41.5 | 0.07 | 0.000 | CIE Lab colorimeter CR400 (Tougan et al., 2025) |
| Red index a\* | -5.12 | 0.04 | -1 | 0.06 | 0.000 |
| Yellow index b\* | 12.3 | 0.1 | 16.4 | 0.45 | 0.001 |
| Hue H\* | -1.2 | 0.01 | -1.52 | 0.14 | 0.001 |
| Chroma C\* | 13.26 | 0.11 | 16.39 | 0.19 | 0.001 |

**Proximate Composition of *Cirina butyrospermi* and *Zonoceros variegatus***

Table 2 presents the proximate chemical composition of the two insect species.

The contents in dry matter, ash, fiber, crude protein, fat, sugar, potassium, calcium, magnesium, iron and sodium of *Zonoceros variegatus* were respectively 87.63%, 10.03%, 21.89%, 30.66%, 18.78%, 6.18%, 1914 mg/kg, 328.9 mg/kg, 126.75 mg/kg, 2.77 mg/kg and 1660.5 mg/kg. For *Cirina butyrospermi*, these respective values were 71.50% for dry matter, for 4.54% ash, 18.57% for fiber, 40.96% for crude protein, 19.07% for fat, 23.79% for sugar, 2857 mg/kg for potassium, 925 mg/kg for calcium, 468 mg/kg for magnesium, 22.4 mg/kg for iron and 425 mg/kg for sodium.

Overall, *Zonoceros variegatus* had significantly higher values (P < 0.001) in dry matter, total ash, fiber, and sodium compared to *Cirina butyrospermi*. Conversely, *Cirina butyrospermi* showed significantly higher values for moisture, crude protein, fat, sugar, potassium, calcium, magnesium, and iron (P < 0.001).

The crude protein values in our study of 30.66% for *Zonoceros variegatus* and 40.96% for *Cirina butyrospermi* are lower than those reported by Clarkson et al. (2018), Yapo et al. (2017), Elagba (2015), Wahed et al. (2019), Murugu et al. (2024), Okangola et al. (2016), Anvo et al. (2016), and Mabossy-Mobouna et al. (2017), who reported values between 50.42% and 70.63%. Fat contents in our study (18.78% for *Zonoceros variegatus* and 19.07% for *Cirina butyrospermi*) are close to Elagba (2015), Wahed et al. (2019), and Okangola et al. (2016), but lower than Clarkson et al. (2018), Murugu et al. (2024), and Yapo et al. (2017), and higher than Anvo et al. (2016) and Kim et al. (2015). The ash content of Cirina butyrospermi (4.54%) matches Yapo et al. (2017) and is higher than Okangola et al. (2016) and Mabossy-Mobouna et al. (2017). *Zonoceros variegatus* had higher ash (10.03%) than Elagba (2015) and Wahed et al. (2019). Dry matter of *Zonoceros variegatus* (87.63%) is lower than Elagba (2015) but higher than Wahed et al. (2019). The dry matter content (71.50%) and sugar content (23.79%) of *Cirina butyrospermi* are higher than the value reported by Okangola et al. (2016), Mabossy-Mobouna et al. (2017), and Yapo et al. (2017). The samples of *Zonoceros variegatus* investigated herein in Benin shows higher values of protein, fat and ash contenrts than the concentrations found by Elagba (2015) and Wahed et al. (2019) for this insect species.

As observed herein, the findings of Koffi et al. (2019) indicates also that *Cirina butyrospermi* larvae can be used in human diets to prevent protein-deficiency malnutrition. Its flour has favorable functional properties for various food product formulations. According to these authors, the flour and oil extracted from dried and ground *Cirina butyrospermi* larvae contain 60.09% crude protein, 22.23% crude fat, 3.71% ash, and 6.69% total carbohydrates (Koffi et al., 2019). Even when defatted, the flour retains functional properties such as water and oil absorption capacity, dispersibility, wettability, and foam stability (Koffi et al., 2019). Our findings confirm also the results of the Studies of Koffi et al. (2019) and Anvo et al. (2016) who observed that shea caterpillars have high protein and moderate lipid contents and are a potential source of protein, fat, and minerals for human nutrition. Their nutritional parameters values include 62.74% of protein, 14.34% of lipids, 5% of ash and chitin, 1160 mg/100g for potassium, 12.97 mg/100g for iron, 47.64% for total amino acids, 35.82% for linoleic acid, and 35.40% for stearic acid (Anvo et al., 2016).

Ramos-Elorduy et al. (1997) also highlighted the rich nutritional profile of edible insects from Oaxaca, Mexico, showing that insects provide high-quality proteins, essential amino acids, fats, vitamins, and minerals, making them a valuable food source especially in regions with limited access to conventional animal proteins. In Burkina Faso, Payne et al. (2020) demonstrated how the edible caterpillar *Cirina butyrospermi* (locally called ‘chitoumou’) significantly contributes to the food security of smallholder farmers. The seasonal availability of these insects offers a reliable source of nutrition and income, underlining their socio-economic importance. From a sustainability perspective, Guiné et al. (2021) discussed the role of edible insects in mitigating environmental challenges associated with conventional livestock farming. Insects require less land, water, and feed while producing fewer greenhouse gases, positioning them as a promising alternative to reduce the ecological footprint of food production. Moreover, Hwang and Kim (2021) addressed behavioral aspects related to insect consumption in modern contexts, identifying strategies to increase sustainable consumption behaviors among restaurant consumers. Their work emphasizes the need to overcome cultural barriers and promote edible insects as acceptable, tasty, and nutritious food options in urban settings.

Overall, the current study and the findings of the literature confirm that edible insects hold substantial promise for enhancing nutrition, supporting livelihoods, and promoting environmental sustainability, especially in regions facing food insecurity and ecological constraints like Benin.

**Table 2. Proximate Composition of *Cirina butyrospermi* and *Zonoceros variegatus***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | *Cirina butyrospermi* | | | *Zonoceros variegatus* | | Effect of species (P value) | Methods |
| Mean | Standard Error | Mean | | Standard Error |
| Dry matter (g/100g) | 71.50 | 0.07 | 87.63 | | 0.37 | 0.000 | AOAC (2000) |
| Moisture (g/100g) | 28.49 | 0.07 | 12.36 | | 0.37 | 0.000 | AOAC (2000) |
| Ash (g/100g) | 4.54 | 0.06 | 10.03 | | 0.24 | 0.000 | AOAC (2000) |
| Crude protein (g/100g) | 40.96 | 0.45 | 30.66 | | 0.35 | 0.000 | Kjeldahl Method; AOAC (2000) |
| Fat (g/100g) | 19.07 | 0.14 | 18.78 | | 0.25 | 0.343 | AOAC (2000) |
| Fibre (g/100g) | 18.57 | 0.19 | 21.89 | | 0.19 | 0.000 | AOAC (2000) |
| Sugar g/100g) | 23.79 | 0.21 | 6.18 | | 0.38 | 0.000 | AOAC (2000) |
| K (mg/kg) | 2857 | 2636 | 1914.0 | | 2.77 | 0.725 | Flame Atomic Absorption Spectrophotometry (standard NF EN 15621) |
| Ca (mg/kg) | 925 | 488 | 328.90 | | 0.27 | 0.237 |
| Mg (mg/kg) | 468 | 246 | 126.75 | | 0.96 | 0.182 |
| Na (mg/kg) | 425 | 224 | 1660.5 | | 1.38 | 0.000 |
| Fe (mg/kg) | 22.4 | 12.0 | 2.77 | | 0.13 | 0.118 |

**Correlations between Technological Parameters and Physicochemical Composition of *Zonoceros variegatus and*** ***Cirina butyrospermi***

The correlations between technological and nutritional parameters of *Zonoceros variegatus* are presented in Table 3. Dry matter content was positively and moderately correlated with ash, crude fiber, and crude protein content (0.66 < r < 0.80; p < 0.05), negatively and moderately correlated with sugar content (r = -0.76; p < 0.01), and negatively and strongly correlated with moisture (r = -1.00; p < 0.01). Moisture content was positively and moderately correlated with sugar content (r = 0.76; p < 0.01) and negatively correlated with ash and protein content (r = -0.80 and -0.77 respectively; p < 0.01), and weakly negatively correlated with crude fiber (r = -0.66; p < 0.05). Ash was positively and moderately correlated with protein content (r = 0.73; p < 0.01) and weakly with sugar (r = 0.71; p < 0.05). Protein was negatively and moderately correlated with sugar (r = -0.83; p < 0.01). Potassium content was positively and weakly correlated with calcium, magnesium, sodium, and iron (r = 1.00; p < 0.05).

The relationships between technological and nutritional traits for *Cirina butyrospermi* are given in Table 4. It appears that dry matter content was negatively and weakly correlated with moisture (r = -1.00; p < 0.05). Crude protein was positively and moderately correlated with crude fiber (r = 0.81; p < 0.01). Fat content was negatively and weakly correlated with fiber, potassium, calcium, magnesium, sodium, and iron (-0.64 < r < -0.63; p < 0.05). Fiber was negatively correlated with sugar (r = -0.63; p < 0.05). Sugar was positively and weakly correlated with calcium, magnesium, sodium, and iron (r = 0.61; p < 0.05). Potassium was strongly positively correlated with calcium, magnesium, sodium, and iron (r = 0.99 to 1.00).

Significant positive and negative correlations were found between technological and physicochemical parameters, indicating predictive potential for insect quality based on technological indicators. Similar results were also observed in beef (Salifou et al., 2013) and poultry (Tougan et al., 2013a, b; 2024).

**Table 3. Relations between technological and nutritional parameters of *Cirina butyrospermi***

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **pH** | **Dry Matter** | **Ash** | **Protein** | **Fat** | **Fibre** | **Sugar** | **K** | **Ca** | **Mg** | **Na** | **Fe** |
| **pH** | 1 |  |  |  |  |  |  |  |  |  |  |  |
| **DM** | 0,25NS | 1 |  |  |  |  |  |  |  |  |  |  |
| **Ash** | 0,02NS | 0,21NS | 1 |  |  |  |  |  |  |  |  |  |
| **Protein** | -0,03NS | 0,15NS | -0,54NS | 1 |  |  |  |  |  |  |  |  |
| **Fat** | 0,13NS | 0,22NS | 0,03NS | -0,59NS | 1 |  |  |  |  |  |  |  |
| **Fibre** | -0,25NS | -0,03NS | -0,35NS | 0,81\*\* | -0,63\* | 1 |  |  |  |  |  |  |
| **Sugar** | 0,42NS | -0,35NS | 0,60NS | -0,50 NS | -0,05NS | -0,63\* | 1 |  |  |  |  |  |
| **K** | 0,17NS | -0,35NS | 0,06NS | 0,30NS | -0,64\* | 0,07NS | 0,59NS | 1 |  |  |  |  |
| **Ca** | 0,21NS | -0,34NS | 0,06NS | 0,29NS | -0,63\* | 0,05NS | 0,61\* | 0,99\*\*\* | 1 |  |  |  |
| **Mg** | 0,21NS | -0,34NS | 0,07NS | 0,29NS | -0,63\* | 0,05NS | 0,61\* | 0,99\*\*\* | 0,99\*\*\* | 1 |  |  |
| **Na** | 0,21NS | -0,34NS | 0,07NS | 0,29NS | -0,63\* | 0,05NS | 0,61\* | 0,99\*\*\* | 0,99\*\*\* | 0,99\*\*\* | 1 |  |
| **Fe** | 0,22NS | -0,34NS | 0,06NS | 0,29NS | -0,63\* | 0,04NS | 0,61\* | 0,99\*\*\* | 0,99\*\*\* | 0,99\*\*\* | 0,99\*\*\* | 1 |

NS: P>0.05; \*: p< 0.05; \*\*: p< 0.01; \*\*\*: p< 0.001.

**Table 4. Relations between technological and nutritional parameters of *Zonoceros variegatus***

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **pH** | **Dry Matter** | **Ash** | **Protein** | **Fat** | **Fibre** | **Sugar** | **K** | **Ca** | **Mg** | **Na** | **Fe** |
| **pH** | 1 |  |  |  |  |  |  |  |  |  |  |  |
| **DM** | -0,04NS | 1 |  |  |  |  |  |  |  |  |  |  |
| **Ash** | -0,24NS | 0,80\* | 1 |  |  |  |  |  |  |  |  |  |
| **Protein** | -0,24NS | 0,77\* | 0,73\*\* | 1 |  |  |  |  |  |  |  |  |
| **Fat** | 0,56NS | 0,30NS | 0,14NS | 0,01NS | 1 |  |  |  |  |  |  |  |
| **Fibre** | 0,14NS | 0,66\* | 0,21NS | 0,43NS | 0,09 NS | 1 |  |  |  |  |  |  |
| **Sugar** | -0,09NS | -0,76\*\* | 0,71\* | -0,83\*\* | -0,50NS | -0,44NS | 1 |  |  |  |  |  |
| **K** | 0,16NS | -0,24NS | -0,04NS | -0,02NS | -0,36NS | -0,01NS | 0,06NS | 1 |  |  |  |  |
| **Ca** | 0,16NS | -0,24NS | -0,04NS | -0,02NS | -0,36NS | -0,01NS | 0,06NS | 0,99\*\*\* | 1 |  |  |  |
| **Mg** | 0,16NS | -0,24NS | -0,04NS | -0,02NS | -0,36NS | -0,01NS | 0,06NS | 0,99\*\*\* | 0,99\*\*\* | 1 |  |  |
| **Na** | 0,16NS | -0,24NS | -0,04NS | -0,02NS | -0,36NS | -0,01NS | 0,06NS | 0,99\*\*\* | 0,99\*\*\* | 0,99\*\*\* | 1 |  |
| **Fe** | 0,16NS | -0,24NS | -0,04NS | -0,02NS | -0,36NS | -0,01NS | 0,06NS | 0,99\*\*\* | 0,99\*\*\* | 0,99\*\*\* | 0,99\*\*\* | 1 |

NS: P>0.05; \*: p< 0.05; \*\*: p< 0.01; \*\*\*: p< 0.001.

4. Conclusion

The present study shows that *Cirina butyrospermi* and *Zonoceros variegatus* can play an important role in human nutrition and help reduce food insecurity and malnutrition issues in Benin, particularly in vulnerable areas of the Northern Benin. Our study shows that *Zonoceros variegatus* has significantly higher pH, dry matter, total ash, crude fiber, and sodium content than *Cirina butyrospermi*. Conversely, *Cirina butyrospermi* has higher concentrations of crude protein, fat, energy, potassium, calcium, magnesium, and iron. Significant and positive relationships were also observed between the pH values, color parameters and nutritional traits of both insect species, indicating a strong link between technological traits and nutritional quality.

Ethical approval

There is no ethical issue in the current study.

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