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Contribution to the Characterization of Edible Insects in the Republic of Congo: The Case of the Desert Locust (*Schistocerca gregaria*)

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Abstract

In the Congo Basin, edible insects are consumed as an alternative to animal proteins, although their nutritional value remains largely unknown. The objective of this study was to determine the physicochemical composition of insects, particularly the desert locust (*Schistocerca gregaria*), consumed in the Republic of Congo. The samples used were desert locusts purchased at the Intendance market in Brazzaville, specifically in the 6th district of Talangaï. They were oven-dried at 70˚C (minimum temperature required to prevent the alteration of nutritional properties) and then ground into powder prior to characterization. For the characterization, several parameters were assessed, including physicochemical properties and functional properties. Data processing allowed the calculation of the mean and standard deviation. The average results showed that *Schistocerca gregaria* contained 58.49% ± 0.26% proteins, 8.15% ± 0.22% lipids, 1.70% ± 1.02% carbohydrates, and an energy value of 314.12 ± 0.99 kcal per 100 g. The pH and titratable acidity were 5.33 ± 0.00 and 35.14 ± 3.52 mmol H^+ per 100 g, respectively. Regarding functional properties, the locust powder exhibited an oil absorption capacity of 52.46% ± 1.22%, a water absorption capacity of 40.32% ± 1.35%, and a solubility index of 93.98 ± 6.50. Owing to its high protein content and elevated energy density, *Schistocerca gregaria* can be incorporated into infant flour formulations to enhance their protein value and thereby contribute to the fight against child malnutrition. Its lipid and mineral contents also make this insect a useful source of vitamins and minerals. Its moderate functional properties allow locust pow-

der to be combined with other flours, such as starchy products, to improve technological applications, including bakery products.

Keywords

Meat, Proteins, Infant Flours, Insects, Congo-Brazzville

1. Introduction

The consumption of insects, known as entomophagy, is an ancient practice widely observed in several regions of the world, particularly in Africa, Asia, and Latin America [1]. In sub-Saharan Africa, many communities regularly consume edible insects such as caterpillars, termites, grasshoppers, and beetles, which account for 31% of all insects consumed according to Cerritos [2]. These insects are valued not only for their accessibility as sources of animal protein but also as a potential sustainable alternative in response to the growing pressure on conventional food resources such as meat, fish, and eggs [3].

These species are often harvested from forests and incorporated into traditional dishes. Several studies have shown that edible insects are rich in proteins (up to 70.60%), lipids (15.20%) [4], vitamins, and minerals. Their consumption represents a relevant nutritional solution in contexts marked by malnutrition and food insecurity, particularly in rural areas where access to conventional animal proteins is limited [5].

In Congo-Brazzaville, certain species of edible insects are regularly consumed by both rural and urban populations. However, their physicochemical composition and nutritional value remain poorly documented and underexploited in food and nutrition policies [4].

The desert locust (*Schistocerca gregaria*) is one of the edible insects consumed in Congo-Brazzaville, but its precise nutritional value remains insufficiently known. It is therefore essential to determine whether these insects can serve as viable alternatives or complementary sources of proteins and nutrients, and whether insect-based preparations such as porridges can be used as suitable complementary foods in the fight against malnutrition.

Characterizing these insects makes it possible to accurately determine their true nutritional value and position them as significant sources of nutrients in local diets. Determining their biochemical composition also helps evaluate their susceptibility to oxidation and enzymatic or microbial degradation, and to identify optimal processing and storage methods that can reduce post-harvest losses—one of the major challenges in the valorization of edible insects.

2. Materials and Methods

2.1. Biological Material

The biological material used in this study consisted of desert locusts (*Schistocerca*

gregaria) (Figure 1) purchased at the Intendance Market in Brazzaville, specifically in District 6 (Talangaï). The choice of this market was justified by its proximity to the locust harvesting areas located in the northern region of Congo-Brazzaville, and because it is one of the main distribution points for agricultural products originating from the northern part of the country.

Source: https://www.fao.org/locusts/fr (Read on 16/12/2025 at 9: 40 PM).

Figure 1. Desert locust (*Schistocerca gregaria*) mature adults.

2.2. Methods

2.2.1. Desert Locust Flour Production

To characterize the desert locust, the purchased samples were ground and dried to facilitate certain analyses. The diagram showing the production process for desert locust flour is presented in Figure 2 below:

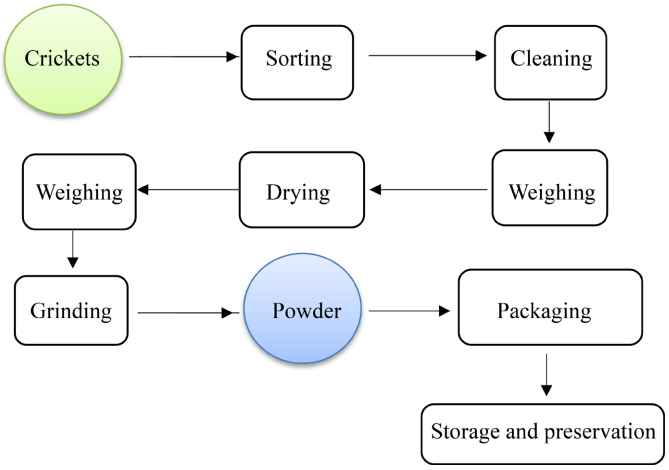

Figure 2. Production of desert locust flour (*Schistocerca gregaria*).

2.2.2. Explanation of the Process Diagram

When the desert locusts arrive at the laboratory, they undergo the following procedures:

Sorting: This step consists of removing stems and leaves, as well as insects

showing early signs of deterioration.

Cleaning: This involves eliminating dust and all types of impurities that could affect the quality of the raw material.

Weighing: This step consists of determining the initial mass of the sample, which is necessary when yield calculations must be performed.

Drying: This step removes free water to stabilize the sample, prevent deterioration, and prepare it for grinding. The samples were dried at 70˚C for 24 hours to facilitate grinding and prevent product deterioration.

Grinding: The dried sample is reduced to flour to facilitate subsequent operations such as extractions and other physicochemical analyses.

Packaging: The resulting flour was placed in glass jars.

Storage and preservation: The flour was then stored in a refrigerator to prevent any microbial deterioration before subsequent use.

2.2.3. Physicochemical Characterization

The physicochemical parameters determined in this study were as follows:

1) Moisture Content [6]

The analysis was performed according to method AOAC 925.10.

The moisture content was determined after drying 10 g of sample in an oven (BIOBASE 0 - 300˚C) at 105˚C for 12 h. After successive weighings and stabilization of the mass, the moisture content was calculated using the following formula:

$$\%\text{Eau} = \frac{fm - dm}{fm} \times 100 \quad (1)$$

where: *fm*: fresh mass of the sample; *dm*: dry mass of the sample.

2) Protein Content [6]

The analysis was performed according to method AOAC 920.87.

The protein content was determined after measuring the total nitrogen using the Kjeldahl method (behrotest S5) following sulfuric acid mineralization in the presence of a selenium catalyst. The nitrogen content value obtained was multiplied by 6.25 [7] to quantify the protein content.

3) Lipid Content [6]

The analysis was performed according to method AOAC 945.16.

Lipid extraction was carried out using n-hexane in a six-position Soxhlet apparatus (ESBFA-1S). After extraction, the recovered oil was placed in an oven at 50˚C to evaporate the remaining solvent. The lipid content was calculated using the following relationship

$$\%\text{Lipids} = \frac{M_1}{M_0} \times 100 \quad (2)$$

where: M_0: mass in grams of the sample; M_1: mass in grams of the quantity of oil after extraction.

4) Ashneur [6]

The analysis was performed according to method AOAC 942.05.

The ash content is determined after incinerating 10 g of shredded material at a

temperature of 550˚C in an electrically heated muffle furnace (Nabertherm 0 - 3000˚C) for 8 hours until a constant mass is obtained. The ash content is given by the following equation:

$$\%\text{Ashes} = \frac{M_1}{M_0} \times 100 \tag{3}$$

where: M_0: mass in grams of the sample; M_1: mass in grams of the ashes after incineration.

5) Total carbohydrate content (Tshite *et al.,* 2015) [8]

The carbohydrate content was determined by difference using the following method:

$$\%\ \text{Carbohydrates} = 100 - (\%\ \text{Water} + \%\ \text{Protein} + \%\ \text{Fat} + \%\ \text{Ash}) \tag{4}$$

6) Determination of energy value

The energy value was calculated using Atwater's specific coefficients for proteins, lipids, and carbohydrates.

$$\begin{aligned}&\text{Energy value}\ (\text{kcal/100g})\\&= \left[(\%\ \text{carbohydrates} \times 4) + (\%\ \text{Protein} \times 4) + (\%\ \text{Fat} \times 9)\right]\end{aligned} \tag{5}$$

7) Determination of total dietary fiber [6]

The analysis was performed according to method AOAC 2011.25.

1 g of delipidated shredded material was placed in an empty flask, 100 mL of 0.235 N sulfuric acid was added, and the mixture was heated to reflux for 30 minutes and then filtered. The residue was placed in a flask and treated with 100 mL of 0.313 N NaOH. The mixture was brought to the boil again for 30 minutes before being filtered. The wet residue was washed with distilled water and alcohol at 95˚C, then transferred to a pre-weighed dish, which was placed in an oven at 130˚C for 2 hours.

After cooling the dry residue in the desiccator, it was weighed and then calcined for 30 minutes at 600˚C in a muffle furnace. After cooling and weighing.

The fiber content was determined using the following formula:

$$\text{Fiber content}(\%) = \frac{(P_2 - P_1) - (P_3 - P_1)}{\text{Mass de l'sample}} \times 100 \tag{6}$$

where: P_1: Mass of the crucible; P_2: Mass of the crucible with the sample test piece; P_3: Mass of the sample in the crucible after incineration and drying.

8) Determination of pH

Five (5) grams of powder were dissolved in 50 mL of distilled water. The mixture obtained was macerated for 30 min and centrifuged. 10 mL of the supernatant obtained was sampled and the pH was measured using a pH meter (VWR pH1100L). The pH value was read directly on the pH meter display.

9) Titratable acidity [9]

The analysis was performed according to method ISO 750: 1981.

In a beaker, 25 g of sample were added with 10 mL of distilled water that had been heated beforehand. The mixture was homogenized and heated under reflux

for 30 min. After cooling, the mixture was transferred to a 250 mL volumetric flask and made up to the mark with distilled water. The mixture was homogenized and filtered.

25 mL of the filtrate was taken and titrated with 0.1 N NaOH until it turned pink.

Titratable acidity was calculated using the following formula:

$$\text{Titratable acidity}\left(\text{mmol } H^+/100\text{ g}\right) = \frac{V_1 \times N \times 1000}{m} \quad (7)$$

where: V_1: volume of NaOH used (mL); N: Normality of NaOH (0.1 N); m: mass of the test sample

10) Determination of free fatty acids [10]

The analysis was performed according to method NF ISO 7305: 2019.

In a beaker, 10 g of the sample and 50 mL of 95% ethanol were added and gently heated. The mixture was homogenized for 1 to 2 minutes to extract the free fatty acids. Two to three drops of phenolphthalein were added.

The mixture was titrated with 0.1 mol/L NaOH until a persistent pink color appeared (30 seconds).

The fatty acid content was calculated using the following formula:

$$\text{fatty acid}\left(\text{mg } H_2SO_4/100\text{ g}\right) = \frac{V \times N \times 49}{m} \times 100 \quad (8)$$

where: V: volume of NaOH used (mL); N: normality of NaOH (0.1 N); m: mass of test sample; 49: gram equivalent of $H_2SO_4/2$

2.2.4. Determination of Functional Properties

Among the functional properties determined, we have:

1) Water absorption capacity

Water absorption capacity (WAC) and solubility index (SI) were evaluated according to Phillips *et al.,* [11] and methods by Anderson *et al.,* [12].

1 g of the flour (M_0) was mixed with 10 mL of distilled water and shaken for 30 minutes using a shaker. The mixture was kept in a water bath (37˚C) for 30 minutes and centrifuged at 5000 rpm for 15 minutes. The resulting sediment (M_2) was weighed and then dried at 105˚C to constant weight (M_1).

The CAE was then calculated as follows:

$$\text{WAC} = \frac{M_2 - M_1}{M_1} \times 100 \quad (9)$$

where: WAC: water absorption capacity in %; M_1: mass of dried sediment (in g) in g and M_2: mass of resulting sediment (in g).

2) Water solubility index

The solubility index was determined and calculated using the following formula:

$$\text{IS} = \frac{M_0 - M_1}{M_1} \times 100 \quad (10)$$

With: IS: solubility index, M_0: mass of flour (in g) and M_1: mass of dried sediment (in g).

3) Oil absorption capacity

The oil absorption capacity (OAC) of the flours was analyzed using the method described by Sosulski [13].

1 g of flour (M_0) was mixed with 10 ml of oil. The mixture obtained was shaken for 30 minutes on a shaker and centrifuged at 4500 rpm for 10 minutes. The resulting sediment (M_1) was weighed.

The OAC was calculated using the following formula:

$$\text{OAC}=\frac{M_1-M_0}{M_0}\times 100 \tag{11}$$

where: OAC: oil absorption capacity (in %); M_0: mass of flour (in g) and M_1: mass of resulting sediment (in g).

4) Hydrophilic-lipophilic balance

The hydrophilic-lipophilic ratio was calculated by dividing the water absorption capacity by the oil absorption capacity. This ratio allows the comparative affinity of flours for water and oil to be assessed ([14] [15]).

5) Density

The density of a solid is the ratio between the mass of a given volume of that solid and the mass of the same volume of water taken under the same conditions.

$$D=\frac{\text{mass d'a given volume of the solid}}{\text{mass d'the same volume of water}} \tag{12}$$

2.3. Statistical Analysis of Results

For the analysis of the results of the biochemical composition and functional properties, the following statistical values were considered: mean and standard deviation.

3. Results and Interpretation

The parameters relating to knowledge of the biochemical composition and techno-functional properties of desert locust samples (*Schistocerca gregaria*) are presented in Table 1 and Table 2.

3.1. Biochemical Composition of Desert Locust (*Schistocerca gregaria*)

Table 1 below shows the results of the average biochemical composition of grasshoppers.

Examination of Table 1 shows that: the locust samples have a moisture content of 26.5% ± 0.89%, a high protein content of 58.49% ± 0.26%, an ash content of 6.88% ± 0.36%, a lipid content of 8.15% ± 0.22% (equivalent to 73.35 kcal/g), a low carbohydrate content (1.70% ± 1.02%) and a high energy value of 314.12 ± 0.99 kcal/100 g. The dietary fiber content of desert locusts is 10.27% ± 0.14%. The

pH of the samples is 5.33 ± 0.00 with a titratable acidity of 35.14 ± 3.51 mmolH^+/100 g. The fatty acid value is 1.05 ± 0.016 mgH_2SO_4/100 g.

Table 1. Average biochemical composition of desert locust (*Schistocerca gregaria*).

Parameters	Desert locust (*Schistocerca gregaria*)
Humidity (%)	26.5 ± 0.89
Proteins (%)	58.49 ± 0.26
Ashes (%)	6.88 ± 0.36
Lipids (%)	8.15 ± 0.22
Carbohydrates (%)	1.70 ± 1.02
Total dietary fiber (%)	10.27 ± 0.12
Energy value (kcal/100g)	314.12 ± 0.99
pH	5.33 ± 0.00
Titratable acidity (mmolH^+/100g)	35.14 ± 3.52
Fatty acidity (mg H_2SO_4/100g)	1.05 ± 0.02

3.2. Functional Properties of Desert Locust (*Schistocerca gregaria*)

The functional properties of the desert locust samples are presented in Table 2 below:

Table 2. Functional properties of desert locust (*Schistocerca gregaria*).

Parameters	Values
OAC (%)	52.46 ± 1.22
WAC (%)	40.32 ± 1.35
IS	93.98 ± 6.50
H/L	0.76 ± 0.02
D (density)	0.25 ± 0.21

WAC: water absorption capacity; SI: solubility index; TA: titratable acidity; OAC: oil absorption capacity; H/L: hydrophilic-lipophilic ratio; D: density.

Analysis of Table 2 shows that the oil absorption capacity (OAC) of the cricket samples is 52.46% ± 1.22%. The water absorption capacity (WAC) is 40.32% ± 1.35% with a solubility index of 93.98 ± 6.50. The samples have a hydrophilic-lipophilic (H/L) ratio of 0.76 ± 0.02 and a density relative to water (D) of 0.25 ± 0.21.

4. Discussion

4.1. Biochemical Composition

4.1.1. Content of Humidity

The moisture content found is higher than the 9.9% and 7.19% respectively found

in dried caterpillars of *Imbrasia truncata* by Mabossy-Mobouna *et al.,* [7] and Foua Bi *et al.,* [16] on the powder of *Imbrasia oyemensis* caterpillars, but also higher than 10.04% with *nsangui* fish (*Pellonula loenensis*) by Gampoula *et al.,* [17]. These values show that these insects are susceptible to rapid deterioration if they are not properly preserved immediately after harvesting. Microbial deterioration of foodstuffs begins when their moisture content exceeds 12% [18].

4.1.2. Protein Content

The protein content obtained is lower than the 70.63% found in dried *Imbrasia truncata* caterpillars by Mabossy-Mobouna *et al.,* [7] but higher than the 42.66% obtained with larvae of *Oryctes rhinoceros* (*Scarabeidae*) according to Lenga *et al.,* [19], at 40% and 26.7% respectively for soybeans, known as the meat of the poor, and grilled beef, according to Huneau *et al.,* [20]. This content is also found in certain fishery products, such as: 45.46% for *nsangui* fish (*Pellonula loenensis*) according to Gampoula *et al.,* [17], 16.5% for smoked herring according to Ponka *et al.,* [21], and 18.10% for tilapia (*Oreochromis niloticus*) according to Médale [22]. These insects are very rich in protein and can be used as alternative sources of meat protein. They can be used in the formulation of infant formula to increase the protein content of porridge in order to combat infant malnutrition [5]. This is because some infant formulas given to children in African countries are often low in protein (7.61% ± 1.09%) according to Elenga *et al.*, [23] compared to the 13% recommended by the FAO/WHO [24]. Their consumption represents a relevant nutritional solution in a context marked by malnutrition and food insecurity, particularly in rural areas where access to traditional animal proteins is limited [5].

4.1.3. Ash Content

Desert locust have an ash content of less than 11.05% for *nsangui* (*Pellonula loenensis*) [17] to 19% for the species *Sardinella cameronensis* and 18.1% for *Corvina nigrita* [25]. However, this value is higher than 2.75% for *Imbrasia truncata* [7]. Thanks to this high ash content, these insects can be important sources of micronutrients needed to enrich infant formula formulations.

4.1.4. Lipid Content

The lipid content is lower than that of *Imbrasia truncata* 15.22% [7], that of *Pellonula loenensis* 28.45% [17] and that of the larvae of *Oryctes rhinoceros* (28.85%) and *Rhynchophorus phoenicis* (28.85%) [19]. This value is higher than that of herring (*Clupea harengus*) 10.6% (fatty herring), 3.7% (lean herring) and 2.1% for tilapia (*Oreochromis niloticus*) according to Médale [22]. Thanks to this lipid content, insects can be an important source of essential fatty acids and fat-soluble vitamins (A, D, E, and K) in certain preparations [7].

4.1.5. Carbohydrate Content

The carbohydrate content is less than 4.64% found respectively on *Imbrasia truncata* [7] et *Pellonula loenensis* [17]. However, it is slightly closer to 1.5% for *Im-*

brasia truncata [7]. These insects have a low carbohydrate content. Carbohydrates are essential for providing energy to the body, particularly the brain and muscles. The consumption of insects needs to be accompanied by a carbohydrate-rich food (e.g., starchy foods) because, according to the WHO, the recommended daily intake of carbohydrates is 45% to 65% of total energy intake [26].

4.1.6. Energy Value

The energy value is less than 456.45 kcal/100g for fish meal (*Pellonula leonensis*) [17] and 430.29 kcal/100g (1804.57 kj/100g) for *Imbrasia truncata* [7]. Thanks to its high energy value, cricket flour could be an ingredient of choice to better address concerns related to nutritional imbalances in certain infant flours, which will help combat child malnutrition. According to the WHO, the energy value of standard infant formula is around 400 kcal/100g [21].

4.1.7. Total Fiber Content

Fiber also plays a role in preventing cardiovascular disease, colon cancer, and diabetes, as it can capture some of the lipids and carbohydrates, which helps to regulate blood sugar levels and prevent excess cholesterol [27].

4.1.8. pH and Titratable Acidity

The pH obtained is lower than 6.9 found with the fish (*Pellonula leonensis*) [17]. Products with an acidic pH are likely to keep well because acidic pH levels inhibit microbial growth, extending the shelf life of food [28].

The titratable acidity of the samples was 35.14 ± 3.51 mmolH^+/100g. Titratable acidity allows the level of organic acids present in the product to be measured. It increases as the pH decreases, which may be due to fermentation that can occur after an animal's death. It also determines a food's ability to inhibit microbial growth [29].

4.1.9. Fatty Acidity

The fatty acid value confirms that the oils from these insects are not adulterated according to Codex STAN 152 [30], which sets a maximum limit of 70 mgH_2SO_4/100g. High fatty acidity indicates triglyceride hydrolysis, often caused by enzymes or moisture. This can alter the flavor and stability of the product [31].

4.2. Functional Properties

4.2.1. Oil Absorption Capacity

Locusts have a moderate capacity to absorb oil, unlike fish (*Pellonula leonensis*) and yellowfin tuna (*Thunnus albacares*), which have CAHs of 260.00% [17] and 82% ± 6% [32]. This value limits the use of locust flour in formulations requiring more lipids [33] such as biscuit making. The oil adsorption capacity (OAC) of food flours is important in the food industry because it allows oil to be absorbed through a complex process of capillarity. OAC is a major characteristic in the food industry because it helps retain flavor and enhance mouthfeel ([15] [34]). It indicates the behavior of proteins in binding to lipids in food formulations. Oil ab-

sorption capacity is necessary in many food applications, particularly in baking, where it contributes to flavor retention and improved palatability [35].

4.2.2. Water Absorption Capacity and Solubility Index

The value is low compared to 293.45% ± 32.94% and 94% ± 2% found respectively with nsangui powder (*Pellonula leonensis*) [17] and fish powder (*Thunnus albacares*) [32]. Due to its low WAC, locust flour is not suitable for baking and must be combined with certain cereal flours to facilitate its use in baking. A high water absorption capacity of flour is important in baking because it allows for more hydrated, more extensible dough with better bread yield. This parameter influences the texture, volume, shelf life, and sensory quality of the finished product ([27] [35] [36]).

Insect meal has moderate dispersibility in water. However, this value is higher than the 30.95 ± 10.31 found with fish powder (*Pellonula leonensis*) [17]. With this value, cricket flour can disperse easily in water, which improves digestibility, preparation, and use in instant formulations such as porridge and infant formula [37]. The better a flour dissolves, the better the release of flavors. The Solubility Index (SI) determines the ability of a food or ingredient to dissolve in water. It is particularly useful in characterizing flours, protein powders, plant extracts, and processed products [38].

4.2.3. Hydrophilic-Lipophilic Ratio

The hydrophilic-lipophilic ratio found is lower than that of fish powder (*Pellonula leonensis*) according to Gampoula *et al.,* [17], which is 1.13 ± 0.75. The H/L is slightly hydrophilic. This is important because cricket flour can be easily incorporated into other flours such as cereal or other tubers for the formulation of enriched breads and porridges.

4.2.4. Density

Density influences the processing, formulation, preservation, and sensory acceptability of foods [39]. With a density of less than 1, the insects studied are less dense than water. This low value results in a lighter, more porous flour that absorbs water more quickly, producing more fluid porridges. Light flour produces more airy breads, while dense flour produces crunchy, less moist cookies.

5. Conclusions

This study characterized the physicochemical composition and functional properties of the desert locust (*Schistocerca gregaria*) consumed in the Republic of Congo. The results show that this insect has a high protein content (58.49% ± 0.26%) and high energy density (314.12 ± 0.99 kcal/100g), demonstrating its nutritional value in a context where access to traditional sources of protein remains limited for part of the population. Its high fiber (10.27% ± 0.12%), ash (6.88% ± 0.36%), and lipid content also make it a necessary food for meeting certain nutritional needs.

Functionally, desert locust powder has moderate water absorption capacity (WAC) and oil absorption capacity (OAC) as well as a good solubility index (SI), characteristics that facilitate its integration into other local food products. These properties open the door to numerous technological applications, particularly in the formulation of enriched infant porridges with high energy density and in certain bakery products.

In a country facing malnutrition and food insecurity, the results obtained reinforce the idea that insects, and in particular *Schistocerca gregaria*, represent a local, sustainable, and under-exploited source of protein. Their promotion, supported by reliable scientific data such as that obtained from this study, could contribute to diversifying the diet, improving the nutritional status of populations, and promoting agricultural solutions adapted to the realities of the Congo.

However, further studies on microbiological quality, storage stability, and sensory acceptability would be necessary to promote wider integration of these flours into food products intended for vulnerable populations. These studies could be further developed by determining the amino acid, fatty acid, and mineral profile of *Schistocerca gregaria*. This characterization would provide a comprehensive overview of its nutritional value and identify its limiting amino acids, essential fatty acids, and actual contribution to micronutrient intake.

The study has certain methodological limitations. The desert locusts analyzed came from a single market and a single harvest season, which does not reflect the full nutritional variability that the species may exhibit depending on region, environmental conditions, or harvest period. These results should therefore be interpreted with caution and considered a preliminary approximation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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