Nutritional Quality - Residues of Pesticides and Heavy Metals (Hg, Cd, Pb, As) in the Flesh of Shrimps of the Genus *Macrobrachium* Fished in Fresh and Brackish Water of Côte D'Ivoire

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Received November 01, 2021; Revised December 03, 2021; Accepted December 09, 2021

**Abstract** The present study was conducted on 180 specimens of *Macrobrachium vollenhovenii* sampled from May to October 2019 respectively in the Bandama River in freshwater and in the Grand-Lahou Lagoon in brackish water. The nutritional analysis of the flesh showed that this species is an excellent source of protein and humidity with low lipid contents. The high ash content is related to heavy metals and pesticide residues found in the shrimp meat. The determination of heavy metals (Cd, As, Pb, Hg) by SAA in the *Macrobrachium* flesh showed that in freshwater and lagoon shrimp, have average concentrations of Arsenic (As) higher than the standard for all shrimp sampled while those of lead and mercury are in accordance with the standards of the FAO and WHO. As for the average concentrations of Cadmium, 40% of the shrimp analyzed in freshwater have levels above the standard against 6.67% of shrimp in brackish water. The study of the distribution and concentration of pesticide residues in the flesh of freshwater and lagoon shrimps showed the presence of 4 families (Herbicides, Rodenticides, Triazines and Organophosphates) of these molecules with the predominance of Herbicides. All the families of pesticides studied are represented in the flesh of freshwater shrimps against two families (Herbicides and Triazines) in brackish water shrimps. The analysis of the concentrations showed a high concentration of Rodenticides in freshwater shrimp compared to the concentrations of the other families studied in both environments.

**Keywords:** nutritional quality, heavy metals, pesticides, shrimps, freshwater and brackish water

**Cite This Article:** N’ZI Konan Gervais, and BODJI Iridjé Marcelle, “Nutritional Quality - Residues of Pesticides and Heavy Metals (Hg, Cd, Pb, As) in the Flesh of Shrimps of the Genus Macrobrachium Fished in Fresh and Brackish Water of Côte D'Ivoire.” *Applied Ecology and Environmental Sciences*, vol. 9, no. 12 (2021): 1004-1010. doi: 10.12691/aees-9-12-3.

1. Introduction

Shrimps are natural resources of primary importance [1]. They include species of great economic value and many of them are used as food for humans. Due to the high demand on the world market for decapod crustaceans, the fishing of this resource is constantly developing with a production of about one million tons per year [2]. Indeed, according to the same author, shrimp by their abundance, as well as their high nutritional value and the exceptional gastronomic quality of their flesh are very exploited. There are more than twenty (20) different families of shrimp throughout the world and more than two thousand (2000) species described, most of which are native to the marine environment. Only the Palaemonidae and Atyidae, with about thirty species each, are commonly found in fresh and brackish waters [3]. Among the crustaceans of the Palaemonidae family, *Macrobrachium vollenhovenii* not only represents a commercial interest but also an interest in food because of its flesh which constitutes a source of proteins of animal origin, fatty acids and vitamins [4]. It constitutes a food of interest because of the nature, bioavailability, number and quality of nutrients it contains [5]. Indeed, shrimp is a food that can contribute to cover a significant portion of human needs in Omega-3 fatty acids [5]. However, human activities contribute strongly to environmental degradation, largely through the increasing dispersion of synthetic and natural substances or elements [6]. These pollutants are introduced into aquatic environments where they are incorporated into the fauna and flora. They interfere with chemical and biological processes in the water column and sediments [7]. Among these pollutants are trace metal elements and pesticide residues that typically enter the aquatic environment through atmospheric deposition, erosion of the geological matrix, or as a result of anthropogenic activities, including the discharge of industrial effluents, domestic sewage, mining waste, pesticide use, and
inorganic fertilizers [8]. They can cause adverse effects on aquatic life and are transmitted to humans as a result of consumption of contaminated fish products that cause serious health deterioration [7]. Unfortunately, the Bandama River and the Grand-Lahou Lagoon, which are a major source of shrimp for the populations living along the river and in Abidjan, are not exempt from this observation. They play the role of receptacle of organic and chemical discharges often without any primary treatment among which are heavy metals and pesticide residues. Studies conducted on the analysis of chemical pollutants in the aquatic environment in Côte d'Ivoire have highlighted the concentration of mercury in crustaceans along the Ivorian coast [9]. However, very few recent studies deal with the contamination of heavy metals and pesticide residues in the flesh of freshwater and brackish shrimp, and even less with the species Macrobrachium vollenhovenii.

In this context, this study aims to highlight the nutritional quality of M. vollenhovenii shrimp specimens as well as the evaluation of the content of heavy metals and pesticide residues in their flesh in order to preserve the health of the populations.

2. Materials and Methods

2.1. Study Environment

![Figure 1](image1.png)

Figure 1. Geographical location of the sampling sites on fresh and brackish water.

This study was conducted in fresh and brackish water (Figure 1). Freshwater is downstream of the Taabo dam lake in the main course of the Bandama River between 6°00'- 6°20' N latitude and 4°90' - 5°00' W longitude. This area is characterized by a substrate of large rocks, sands and gravels. The locality of Taabo was selected with the station of N'Dénoü for the present study. The village of N'Dénoü is the most important fishing site in the basin. The Azagny canal station is located on the Grand-Lahou Lagoon between 5°25 W and 5°10 N [10]. The lagoon, with a surface area of 190 km², communicates naturally with the Atlantic Ocean through the pass of Grand-Lahou and artificially with the Ebrié Lagoon, through the Azagny canal, and to the west through the Fresco canal. Shrimp were sampled in the brackish water of the Azagny canal.

2.1.1. Sampling and Laboratory Analysis

The shrimps were captured using beaked traps. The samples were wrapped in aluminum foil and then put in food bags and stored in an adiabatic chamber containing ice. At the laboratory, the specimens were identified according to [11] and [12], measured with a 0.01mm precision TESA caliper, model TESA-00510008, and weighed with a 0.0001 g precision Sartorius electronic balance, model BP 221S. The samples were then prepared for nutritional and eco-toxicological analysis according to different methods.

2.1.2. Data Processing

2.1.2.1. Nutritional Analysis

Chemical analyses were performed using the proximate analysis methods proposed by [13]. These are the oven drying method for relative humidity, the dry oven calcination method for minerals, the SOXHLET extraction method followed by distillation, drying and weighing for fats and finally the KJELDAHL nitrogen method for proteins. The conversion of nitrogen content to protein content was done using a multiplication factor of 6.25 according to the equation: % protein = % N x 6.25.

2.1.2.2. Humidity Content

The humidity level is defined as:

\[ TH = \frac{P_1 - P_0}{P_0} \times 100 \]

where

- TH: humidity level (%)
- P0: mass of the empty aluminium crucible (g)
- P1: mass of the crucible + the sample at the exit of the oven (g)
- PE: mass of initial sample (5g)

2.1.2.3. Lipid Content

The percentage of fat is defined according to:

\[ Fat = \frac{P_1 - P_0}{P_0} \times 100 \]

where

- P0: mass of empty flask (g)
- P1: mass of flask + sample after evaporation (g)
- PE: mass of initial sample (10g)

2.1.2.4. Nitrogen Content

The determination of ammonia collected after distillation (300 mL) is done by chloridric acid (HCl) with a normality (N) of 0.1N.

The percentage of Nitrogen by the Kjeldahl method is defined as follow:
2.1.2.5. Protein Content

The percentage of crude protein content is calculated according to the following formula:

\[
\text{Protein} = \left( \frac{\text{Nitrogen} \times \text{Normality} \times \text{HCl}}{6.25} \right) \times \text{Molar Mass of Nitrogen}
\]

Where: \( P \) = percentage of protein; \( N \) = percentage of Nitrogen; 6.25 = conversion coefficient of Nitrogen to protein.

2.1.2.6. Ash Content

\[
\text{TC} \times \frac{\text{P1} - \text{P0}}{\text{PE}} \times 100
\]

Where TC: ash content (%); P0: mass of the empty crucible (g); P1: mass of the crucible + the sample at the exit of the oven (g); PE: test sample (10g).

2.1.2.7. Concentration of Heavy Metals

Ten grams (10g) of shrimp sample was taken in a previously weighed empty porcelain crucible (P0) and put in the oven at 550°C for four hours (4H). After four hours (4H), the crucible containing the sample was weighed at the exit of the oven (P1). The resulting ash was collected in a fifty milliliter (50 mL) flask and twenty milliliters (20 mL) of chloridric acid (HCl) was added to solubilize the ash. The sample was transferred to a one hundred milliliter (100 mL) flask and then filtered through whatman paper. The filtrate obtained was made up to the mark with distilled water. Finally, the reading was taken with the Atomic Adoption Spectrometer (AAS).

2.1.2.8. Pesticide Residue Concentration

One hundred milliliters (100 mL) of dichloromethane was added to fifty grams (50g) of samples. Then, mixture was ground in a jar with a blender for two minutes. The resulting grind was filtered through whatman paper into a fifty milliliter (50 mL) flask. The filtrate obtained was evaporated with Rotavapor to get rid of any solvent (dichloromethane). The dichloromethane-free filtrate was recovered with five milliliters (5 mL) of methanol in the flask. The recovered sample was placed in the freezer to solidify the fat. Finally the supernatant liquid was recovered in two milliliter (2 mL) ampoules before performing the high performance liquid chromatography (HPLC) reading.

2.2. Statistical Analysis

For nutritional quality and pesticide residues, Microsoft Excel 2010 and STATISTICA version 7.1 were used to process the data to ensure that the observed differences between the averages of the measured parameters were not the result of random sampling fluctuations. The same software was used for the analysis of heavy metals to compare the obtained means with the maximum allowable standards [14]. In this study, the Mann-Whitney U-test was used to assess the degree of significance of the levels and concentrations metals recorded in the flesh of shrimp sampled in fresh and brackish water. This test is a non-parametric alternative to the t-test, used to compare two independent samples and test the null hypothesis (significant test at p < 0.05) that the different samples to be compared are from the same distribution.

3. Results

3.1. Nutritional Quality

Table 1 presents the nutritional value of 180 shrimp specimens belonging to the species Macrobrachium vollenhovenii sampled in fresh and brackish water respectively.

At N’denou in freshwater, the shrimp sampled have a standard length of the specimens between 7.4 and 13.63cm and a weight between 11.7 and 90.4g. The analysis of the table shows that the percentage of moisture present in the shrimp varies between 62.49 and 67.12%, with an average of 65.04 ± 1.59%. The percentage of ash varies from 1.54 to 3.41%, with an average of 2.55 ± 0.62%. Nitrogen content ranged from 2.88 to 3.61%, with an average of 3.19 ± 0.24%. The protein content varies between 18 and 22.6%, with an average of 19.95 ± 1.52%. As for the lipid percentage, it varies from 1.5 to 3.46% with an average of 2.73 ± 0.69%.

At Grand-Lahou in brackish water, the shrimp sampled have a standard length between 5.5 and 13.6 cm and a weight between 13.20 and 75.76 g. The percentage of moisture present in the shrimp ranged from 63.4 to 72.3%, with an average of 67.87 ± 2.78%. The percentage of ash varies from 1.09 to 3.7%, with an average of 2.49 ± 0.75%. Nitrogen content ranged from 2.84 to 3.84%, with an average of 3.34 ± 0.27. The protein content varies between 17.77 and 24.06%, with an average of 20.94 ± 1.73%. As for the lipid percentage, it varies from 1.11 to 3.6% with an average of 2.30 ± 0.89%.

The Mann-Whitney U-test showed no significant difference (P > 0.05) between freshwater and brackish shrimp for all the parameters studied except for the moisture content.

Table 1. Moisture, ash, nitrogen, lipid and protein contents in shrimp meat sampled from May to October 2019 at N’denou (Bandama River) and in the Azagny canal (Grand-Lahou Lagoon)

| Areas            | Values | Humidity (%) | Ash (%) | Nitrogen (%) | Total Lipid (%) | Protein (%) |
|------------------|--------|--------------|---------|--------------|----------------|-------------|
| Freshwater       | Min    | 62.49        | 1.54    | 2.88         | 1.5            | 18          |
|                  | Max    | 67.12        | 3.41    | 3.61         | 4.1            | 22.6        |
|                  | Ave    | 65.04±1.59   | 2.55±0.62 | 3.19±0.24 | 2.73±0.69 | 19.95±1.52 |
| Brackish water   | Min    | 63.4         | 1.09    | 2.84         | 1.11           | 17.77       |
|                  | Max    | 72.3         | 3.7     | 3.84         | 3.6            | 24.06       |
|                  | Ave    | 67.87±2.78   | 2.49±0.75 | 3.34±0.27 | 2.30±0.89 | 20.94±1.73 |
| Mann-Whitney U-test | 0.0065 | 0.74         | 0.13    | 0.21         | 0.13           |

Min = Minimum; Max = Maximum; Ave = Average.
3.2. Heavy Metal Contents

Table 2 shows the heavy metal content in the flesh of *Macrobrachium vollenhovenii* sampled in fresh and brackish water. The amount of Cadmium (Cd) found in the flesh of the shrimp sampled at N’dénou in fresh water ranged from 0.017 to 0.045 mg/kg, with an average of 0.026 ± 0.008 mg/kg. The study shows that 40% of the shrimp have Cadmium (Cd) levels above the standard (0.025 mg/kg) allowed by [14]. Arsenic (As) concentration ranged from 0.98 to 2.01 mg/kg, with an average of 1.461 ±0.332 mg/kg. All freshwater shrimp (100%), have Arsenic (As) levels above the standard (0.2 mg/kg) required by FAO and WHO. Lead (Pb) concentrations ranged from 0.009 to 0.031 mg/kg, with an average of 0.019 ± 0.007 mg/kg. Mercury (Hg) concentrations determined ranged from 0.229 ± 0.111 mg/kg, with a mean of 0.229 ± 0.111 mg/kg. Lead (Pb) and mercury (Hg) were below the standard (0.3 mg/kg for lead and 0.5 mg/kg for mercury) required by FAO and WHO.

For shrimp sampled in brackish water, the amount of Cadmium (Cd) ranged from 0.002 to 0.041 mg/kg, with an average of 0.013 ± 0.009 mg/kg. The study shows that 6.67% of the shrimp have Cadmium (Cd) levels above the standard (0.025 mg/kg). The concentration of Arsenic (As) varied from 0.53 to 0.90 mg/kg, with an average of 0.764 ± 0.104 mg/kg. All the shrimp (100%) analyzed at Grand-Lahou had Arsenic (As) levels above the maximum standard (0.2 mg/kg). The concentration of Pb ranged from 0.008 to 0.021 mg/kg, with an average of 0.012 ± 0.004 mg/kg. Mercury (Hg) concentrations range from 0.075 to 0.45 mg/kg, with an average of 0.299 ± 0.111 mg/kg. Lead (Pb) and mercury (Hg) were below the standard (0.3 mg/kg for lead and 0.5 mg/kg for mercury) required by FAO and WHO.

Table 2. Trace element concentrations (mg/kg) in the flesh of *Macrobrachium vollenhovenii* shrimp sampled between May and October 2019 at N’dénou (Freshwater) and in the Azagny canal (Brackish water)

| Areas          | Values | Cadmium (Cd) | Arsenic (As) | Plomb (Pb) | Mercure (Hg) |
|----------------|--------|--------------|--------------|------------|--------------|
|                | Min    | Max          | Ave          | Min        | Max          | Ave        | Max         | Ave         | Max         |
| Freshwater     | 0.017  | 0.045        | 0.026 ± 0.008| 0.98       | 2.01         | 0.019 ± 0.007| 0.0009      | 0.031       | 0.229 ± 0.111|
|                | 0       | 100          | 0            | 0          | 0            | 0          | 0           | 0           |
| Brackish water | 0.002  | 0.041        | 0.013 ± 0.009| 0.53       | 0.9          | 0.764 ± 0.104| 0.008       | 0.21        | 0.041 ± 0.022|
|                | 0       | 100          | 0            | 0          | 0            | 0          | 0           | 0           |

Min = Minimum; Max = Maximum; Ave = Average; X = Percentage of shrimp above the maximum allowable standard [14].

3.3. Pesticide Residues in Shrimp Meat

3.3.1. Distribution of Active Molecules in Shrimp Meat

In total, twelve (12) active molecules were detected in the flesh of shrimp collected in fresh water and brackish water (Table 3). These active molecules belong to 4 families with a preponderance of Herbicides (72% of the total number of molecules detected). They are followed by the Rodenticides family (14%), Triazines and Organophosphates (7% respectively) (Figure 2). The number of pesticide families found shows the preponderance of Herbicides in brackish water with seven (7) active molecules against two (2) active molecules determined in freshwater shrimp. The Rodenticides and Organophosphorus families were absent in brackish water, whereas they were present in freshwater shrimp with respective values of 2 and 1 active molecule (Figure 3).

Six molecules were found in the flesh of freshwater shrimp with a prevalence of 50% and 8 molecules in the flesh of brackish water shrimp, i.e. a prevalence rate of 66.67%. At the level of Herbicides, eight (8) active molecules of this family were detected, including 2 in the flesh of freshwater shrimp and 7 in the flesh of brackish water shrimp. The Herbicide family is followed by the Rodenticide family, of which 2 active molecules were determined. All the two (2) active molecules of the Rodenticide family were detected in freshwater shrimp. The family of Triazines and Organophosphates presented only one active molecule. The Triazine molecule was determined in freshwater and lagoon shrimp while the Organophosphorus family molecule was recorded in freshwater shrimp.

Table 3. Pesticide concentrations (µg/kg) in the flesh of *Macrobrachium vollenhovenii* shrimp collected at N’dénou (Freshwater) and in the Azagny canal (Brackish water) between May and October 2019

| Families          | Active molecules | Freshwater | Brackish water |
|-------------------|------------------|------------|----------------|
| Carbamate         | -                | -          | -              |
| Fenuron           | 0.00180          | 0.000600   | -              |
| Simazine          | -                | 0.001100   | -              |
| Cyanazine         | -                | 0.000900   | -              |
| Metamitron        | -                | 0.001495   | -              |
| Metoxuron         | 0.00160          | 0.000850   | -              |
| Isoproturon       | -                | 0.000020   | -              |
| Cyanazine         | -                | 0.005100   | -              |
| Rodenticides      | Crimidine        | 0.0730     | -              |
|                   | Bromadiolone     | 0.0110     | -              |
| Triazines         | Desethylatrazine | 0.0016     | 0.0033         |
| Organophosphates  | Chlorpyrifos     | 0.0022     | -              |
| Total active molecules | 12    | 6          | 8              |
| Prevalence rate   | 50%              | 66.67%     | -              |
3.3.2. Concentration of Pesticides in Shrimp Meat

In the flesh of freshwater shrimp, the concentrations of Herbicides varied from 0.0016 to 0.0018 µg/kg with an average of 0.0017 ± 0.0014 µg/kg, the maximum value was observed for the Fenuron molecule. The concentration of Rodenticides ranged from 0.011 to 0.073 µg/kg with a mean of 0.042 ± 0.044 µg/kg. The maximum value was observed at the level of the Crimidine molecule. The Triazines family presented a concentration of 0.0016 µg/kg at the level of Desethylatrazine. The molecule Chloropyrifos belonging to the family of Organophosphates is present with a concentration of 0.0022 µg/kg (Table 3).

In brackish water shrimp, the concentrations of herbicides varied from 0.0002 to 0.0051 µg/kg with an average of 0.0014 ± 0.0017 µg/kg with the maximum value observed for the Cyanazine molecule. Rodenticides and Organophosphates were absent in brackish water shrimp. Triazines had a concentration of 0.0033 µg/kg and determined at the level of Desethylatrazine molecule (Table 3).

4. Discussion

4.1. Nutritional Quality

The analysis of moisture in individuals belonging to fresh and brackish water shows values between 62.49 and 72.3%. This high content could be explained by the fact that our analyses were performed on fresh shrimp meat. These values are close to those found in the shrimp *Penaeus kerathurus* (73.23%) [14]. The ash content of shrimp caught at Grand-Lahou and Ndènou are higher than the ash content found in the same context in white shrimp and black tiger shrimp from Thailand. Our samples recorded levels ranging from 1.54 to 3.7% compared to 0.95% in black tiger shrimp and 1.47% in white shrimp [15]. This observed difference could be explained by the presence of heavy metals found in our samples, which are absent in the ashes of the two shrimp species *Penaeus monodon* and *Penaeus vannamei* studied by [15]. The total lipid contents in our samples ranged from 0.0236 to 0.0254g/10g or between 2.36 to 2.54%. These values are comparable with those of the tropical shrimp *Penaeus monodon* and white-legged shrimp *Penaeus vannamei* (0.03 to 0.05 g/10g) [16]. However, [5] reports that the amount of fat is estimated to be 0.1 to 0.2 g/10g or to 20% in crustaceans in general. Generally speaking, shrimp have a low fat content due to the absence of adipose tissue [5]. Many other factors, such as age, sex, year, location and season of fishing, weight, muscle part considered, can make these properties vary within the same species [17]. Shrimp is an excellent source of protein with high biological value as it contains all essential amino acids [5].

The quantitative evaluation of the proteins of the flesh of these studied organisms showed that the values oscillate between 17.77 and 24, 06% with an average that varies from 19.95 ± 1.52 to 20.94 ± 1.73 which agrees with the results of the food table by referring to the method of kjeldahl that estimate the protein contents between 16.4 and 21.3%. This study reveals that there is no significant difference (P > 0.05) between freshwater and brackish water shrimp for all parameters studied except for moisture content. The environment has no effect on the nutritional quality of the shrimp. Freshwater and brackish *Macrobrachium vollenhovenii* species have the same nutrient intake for humans. This significant difference in moisture content observed could be related to the shelf life from one environment to the other.

4.2. Heavy Metals

The analysis of trace metal concentrations in shrimp flesh is a very important aspect for understanding their fate and must take into account the possible influence of variables such as body size, age, season and even the health status of the organisms [18]. Indeed, in this study it is the shrimp meat that was analyzed. This choice is related to the fact that it is the main part of the shrimp consumed by humans and is involved in cases of health risks. In the flesh of the freshwater and brackish shrimp analyzed, Cadmium and Arsenic present concentrations above the maximum international standards allowed for human consumption recommended by [14] (0.025mg/kg for Cd and 0.2mg/kg for As). All shrimp have concentrations above the standards for Arsenic against respective percentages of 40% and 6.67% in freshwater and brackish shrimp for cadmium. They could be unfit for human consumption because of the presence in their flesh of at least one trace element in quantities higher (0.017 to 0.045mg/kg for Cd and 0.98 to 1.461mg/kg for As) than the standard required by [14]. With reference to the concentrations of Lead and Mercury, all the shrimps...
analyzed are consumable and present concentrations inferior to the maximum standards allowed in the consumption products (0.3 mg/kg for Pb and 0.5 mg/kg for Hg) recommended by [14].

The presence of these metals could be related to pollution by agricultural inputs consisting of fertilizers and pesticides used in the plantations that border the sampling stations from runoff. Pesticides and fertilizers used in the plantations bordering the Bandama River and the lagoon are potential sources of trace elements. These study areas are covered by abundant vegetation consisting of primary forests and plantations. This vegetation cover could also contribute to the increase in trace element concentrations in both aquatic environments. According to [19], the rainfall of trees and the decomposition of litter lead to a return of trace elements to the soil. Leaching from these contaminated soils carries the elements to the continental and lagoon planes. In the aquatic environment, contamination of shrimp could occur through direct contact and feeding. According to the work of [20], this feeding consists of worms, slime, dead fish, snails, fry, plankton, sand, sludge, and detritus. The high accumulation of Arsenic content (0.98 to 2.01 mg/kg in fresh water and 0.53 to 0.98 mg/kg in brackish water) above the required standard (0.2 mg/kg) could be explained by the fact that some compounds of this metal are used as herbicides in plantations. This suggests that the Arsenic (As) pollution comes from the agricultural inputs (fertilizers and pesticides) used in the plantations located near the Bandama River and Grand-Lahou Lagoon. According to [21], in water, cadmium comes from natural erosion, soil leaching (phosphate fertilizers) as well as from industrial dumps, industrial effluent treatment and mines. In the Grand-Lahou Lagoon, the leaching of domestic waste is a major source of trace metal elements. These elements are found in all compartments of household waste [22]. The populations cross the lagoons using motorized boats that use fuel, the residues of which are discharged into the waters, thus contributing to their pollution by heavy metals. The study by [23] indicates that the fuels contain Mercury (Hg), Lead (Pb), and Cadmium (Cd), which could justify the presence of these metals in the shrimp analyzed in this locality. Statistical analysis (Mann-Whitney U-test) reveals that there is a significant difference (p < 0.05) between shrimp in freshwater environment and shrimp in brackish water environment for all heavy metals studied. These variations in metal concentrations in shrimp flesh could be explained by changes in water properties such as pH, temperature, salinity, conductivity, and dissolved oxygen levels [24]. Indeed, brackish water and freshwater are two different aquatic environments and therefore do not necessarily have the same physico-chemical properties. This difference could have an impact on the intrinsic physicochemical properties of the heavy metals studied. Concerning temperature, for example, [25] states that metals such as Mercury (Hg), Arsenic (As) and Lead (Pb) that are liposoluble tend to escape under the effect of heat.

4.3. Pesticide Residues

The study on the distribution of active molecules as well as their concentrations in the flesh of the species Macrobrachium vollenhovenii shows that most of the active molecules belong to the herbicide family. This dominance of herbicides would be due to the frequent use of phytosanitary products to control weeds in rubber plantations and food crops located around water bodies. Indeed, herbicides have become the new agricultural tool in Côte d'Ivoire for both smallholders and agribusinesses [26,27]. This method, which is very common in field crops, reduces weeding time and optimizes farm yields. In addition, many studies have indicated the predominance of Herbicides over other pesticide families on farms [28]. The results of the present study showed the presence of eight (8) active molecules in the flesh of brackish water shrimp and six (6) in freshwater shrimp out of the twelve (12) active molecules determined, representing a respective prevalence rate of 66.67% and 50%. This observation allows us to deduce that the shrimp in freshwater and brackish environments are subject to pesticide pollution at the same rate.

The analysis of the average values of pesticide concentrations in the flesh of freshwater shrimp shows a high concentration of the Rodenticide family with a value of 0.042 µg/kg compared to the concentrations of other families determined in the flesh of shrimp from freshwater and brackish environments. This high concentration could be justified by the fact that our sampling took place during the rainy season. Indeed, during this season, there is a proliferation of rodents in the plantations and food crops. This proliferation leads to extensive use of these products by farmers to control these rodents. Once spilled, these pesticides are drained into the aquatic environment via runoff water, resulting in very high concentrations. This observation is consistent with that of [29], who states that the entry of pesticides into the aquatic environment is essentially linked to agricultural runoff or leaching from storage areas, causing a pollution peak at the first rainfall following application.

5. Conclusion

The present study, which is part of the evaluation of the nutritional quality and the risk of contamination by heavy metals and pesticide residues of the Macrobrachium vollenhovenii shrimp meat caught in the Bandama River (freshwater) and in the Grand-Lahou Lagoon (brackish water) and sold in the markets of Abidjan and other cities, had several specific objectives. It showed that the shrimp Macrobrachium vollenhovenii had a high protein value and presented high moisture and ash contents. In addition, the concentrations of heavy metals are higher than the standards allowed by the WHO and FAO for certain molecules. Regarding pesticides, most of the active substances detected belonged to the herbicide family.

Acknowledgements

The authors thank all the teams of the Natural Environments and Biodiversity Conservation Laboratory of the Félix Houphouët Boigny University for their help in collecting field data and for their valuable advice in writing this document. We also thank the referees who,
through their criticisms and suggestions, contributed to improve the manuscript. This study was done with the collaboration of the Hydrobiology laboratory of the Félix Houphouët Boigny University and the National Agricultural Development Support Laboratory (LANADA) of Côte d'Ivoire.

Consent for Publication

All co-authors give their approval.

Availability of Supporting

All research data on the topic are available.

Competing Interests

The author declares that there are no competing interests.

Funding

No funding was allocated to this research.

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