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Physicochemical Characterization of Two Species of Wild Edible Mushrooms: *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae*

Alice Christine Ekissi[1*], Kan Benjamin Kouame[1], Koffi Pierre Valéry Niaba[1], Grah Avit Maxwell Beugre[1], Séraphin Kati-Coulibaly[2]

[1]Agro-Valorization Laboratory, Faculty of Agroforestry, University Jean Lorougnon Guede of Daloa, Daloa, Cote d'Ivoire
[2]Laboratory of Nutrition and Pharmacology, of Biosciences, University Felix Houphouet Boigny of Cocody-Abidjan, Cote d'Ivoire
Email: *ekissialicec@gmail.com

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Abstract

In tropical Africa, mushrooms play an important role for people in rural areas as a source of food, medicine and income. In order to promote the mycology sector in Côte d'Ivoire, a study was carried out on the determination of the biochemical parameters of the mushroom *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae* found in the localities of Daloa and Yamoussoukro. The samples were purchased in the markets of Daloa and Yamoussoukro. The dry matter, ash and lipid contents were determined by the AOAC method. Those of proteins, total sugars, reducing sugars were carried out respectively by the methods of Kjeldahl, Bernfeld and Dubois, and six minerals (potassium, phosphorus, calcium, magnesium, iron and sodium) were quantified by atomic absorption spectrophotometry (AAS). The results showed that the ash (3.46 - 7.74%) and protein (6.10 - 12.40%) levels were high, but the lipid contents (4% to 6.60%), total sugars (1.34 - 5.16%) and reducing sugars (0.01 to 0.27%) are low. The major minerals are calcium (898 to 1006 mg/100g), potassium (1182 to 2433 mg/100g) and phosphorus (2091 - 4375 mg/100g). Magnesium (270 - 433 mg/100g) is represented in average proportion. Iron (2.83 to 46.17 mg/100g) and sodium (4.87 to 5.99 mg/100g) are in low amounts. The mushrooms *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae* are low in fat, high in ash, and are good sources of protein and minerals.

Keywords

Lentinus brunneofloccosus pegler, *Auricularia auricularia judae*, Mushrooms

1. Introduction

Interest in mushrooms has jumped dramatically in recent decades. The fruit of a booming multiculturalism or an openness to the world [1], this trend continues to emerge and the birth of wild mushroom picking networks are supplying markets, specialized grocery stores and large restaurants. Mushrooms feature prominently in the emerging industry of non-timber forest products [2]. More than 3000 species of mushrooms are consumed around the world [3]. In West Africa, very little data is available on higher mushrooms [4] [5]. Most of the data on wild edible mushrooms come from temperate climates and Asia. Like medicinal plants, mushrooms are recognized for several biological properties (anticancer, cholesterol lowering, immune stimulants, antioxidants) [6]. In addition, wild edible mushrooms have a very large contribution to the life of rural African populations [7]. They are part of African gastronomy and are among the non-timber forest products (NTFPs) known to African populations [8]. To this end, they constitute an important product to accompany meals, mainly in rural areas and provide excellent nutritional value comparable to that of milk, soybeans and beans [9] [10]. In fact, they are rich in protein and fiber, and contain vitamins and minerals in significant amounts, in addition to being an interesting source of essential amino acids [11]. They are thus the subject of seasonal harvests by women and children, in ecosystems of natural production by local populations [4] [12]. In Côte d'Ivoire, the harvest period, which corresponds to the start of the rainy season, coincides with periods of shortage (rarely famine). It is exactly in these difficult times that the supply of vitamins, minerals and amino acids (proteins), through edible mushrooms, becomes very important for balancing the diet. Indeed, wild edible mushrooms are collected and sold by women and children during this period. They are additional products for human food and also provide a significant source of income for the populations [10] [13] Note that wild edible mushrooms are part of the essential component of tropical biodiversity likely to complete the food arsenal of Côte d'Ivoire. Studies on biological diversity are recent in Côte d'Ivoire with the work of [12] [14]. The work focused on the investigation which made it possible to identify species belonging mainly to the genera *Chlorophyllum*, *Hirneola*, *Termitomyces*, *Lentinus*, *Psathyrella* and *Volvariella* edible commonly used by local populations. For the moment, emphasis has been placed on the inventory, knowledge and biochemical characterizations of certain wild fungi constituting Ivorian biodiversity with the work of [15] [16]. Despite these various studies, much remains to be done. Very little work has been done on the physicochemical characterization of the wild edible fungi *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae*. The results of the physicochemical characterization could make it possible to better understand the nutritional value of two species and allow the efficient valuation of these local wild edible fungi. It is with this vision that the present study was initiated. Its main objective is to assess the biochemical characteristics of two species of wild edible mushrooms commonly encountered in Côte d'Ivoire with a view to their valorization in the Ivorian diet.

2. Materiel

Biological Materiel

The biological material is made up of two species of local edible mushrooms. These mushrooms were bought in the markets of the towns of Yamoussoukro and Daloa from October 2019 to November 2019. They are: *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae* (Figure 1).

(a) (b)

Figure 1. Photograph of the two species of edible wild mushrooms (a) and (b). (a) *Auricularia auricularia judae*; (b) *Lentinus brunneofloccosus pegler*.

3. Methods

3.1. Study Zone

The towns of Daloa and Yamoussoukro are the study areas. Daloa is located in the Haut-Sassandra region in the center-west of the Ivory Coast in the department of Daloa. The department of Daloa located between 6˚53'58" North latitude and 6˚26'32"W West longitude has an area of 15,205 km^2 for an estimated population of 1,430,960 inhabitants. Côte d'Ivoire is the political capital of the country, located on latitude 6˚49'N and longitude 5˚16'W.

3.2. Biochemical Analyzes of Mushrooms

3.2.1. Sampling Methods for the Two Species of Edible Wild Mushrooms

To ensure the homogeneity of the samples, the species of *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae* dry from the two localities (Yamoussoukro and Daloa). A number of thirty (30) samples of each species of mushroom were collected per city. These mushroom samples were purchased at random in the markets of the said towns and transported in sachets to the laboratory of the Jean Lorougnon Guédé University in Daloa and other analyzes were carried out at the Institut National Polytechnique Félix Houphouët-Boigny (INP-HB) from Yamoussoukro.

3.2.2. Physico-Chemical Analysis of Two Species of Edible Wild Mushrooms

1) Protein content

Crude protein is determined from the determination of total nitrogen, according to the Kjeldhal method [17]. The nitrogen in the dry matter is determined using the Kjeidahl method after sulfuric mineralization, in the presence of a selenium catalyst. The nitrogen content is multiplied by 6.25 (conversion coefficient of nitrogen to protein).

2) Lipid content

The lipid content is determined according to the method described by [18] using the Soxhlet as an extractor. The extraction of the oils is obtained by hexane in a Soxhlet type extractor (Unid Tecator, System HT2 1045, Sweden). After evaporating the solvent and drying the capsule in an oven at 105˚C for 30 minutes, the difference in weight gives the lipid content of the sample.

3) Total sugars and reducing sugars content

The determination of the total sugars was carried out according to the method of [19] using phenol and sulfuric acid and that of reducing sugars was carried out according to [20] using 3,5-dinitro-salicylic acid (DNS).

4) Ash content

The method used for the determination of ash is that described by [17] which consists of incinerating a sample until white ash is obtained. The capsule containing the sample is placed in a muffle furnace (NABERTHERM, Germany), then subjected to 550˚C ± 2˚C for 24 hours. After removing the capsule from the muffle furnace and cooling it in a desiccator (GLASWERK WERTHEIM at 2 bar), it is weighed again.

3.3. Determination of Mineral Contents

The determination of the mineral elements was carried out according to the method [21]. This method includes digestion of the mushroom samples and the actual assay. A quantity of 0.4 g of a sample of dried and ground mushrooms, passed in an oven (60˚C), is introduced into a 125 mL Erlenmeyer flask previously washed with perchloric acid and with distilled water. A volume of 4 mL of concentrated perchloric acid, 25 mL of concentrated HNO_3 and 2 mL of concentrated H_2SO_4 are added thereto. Everything is well stirred. Under a hood for perchloric acid, the whole is gradually heated on a moderately hot plate. The operation is continued until the appearance of thick white smoke. The whole is heated over an open flame (moderate to high temperature) for 30 seconds. After cooling, a quantity of 40 mL of distilled water is added thereto. Everything is brought to the boil for 30 seconds using the same plate (moderate temperature). After cooling, the solution is filtered (Whatman filter paper) into a 100 mL flask and is made up to the mark with distilled water. This solution is stored in the refrigerator for the determination of P (by colorimetry), and Fe, K, Ca, Na and Mg (by atomic absorption spectrometry).

The phosphorus assay was carried out after the development of the yellow coloration obtained by virtue of a reaction between a quantity of 5 mL of the solution previously acquired and 20 mL of vanado-molybdic reagent. A UV/VIS spectrophotometer (JASCO V-530, B187360512) was used to determine the

phosphorus concentrations from a standard range.

The determination of metal cations by Atomic Absorption Spectrometry (AAS) was carried out using a spectrometer (SPECTR AA20 Varian, Australia). SAA is based on a phenomenon based on the absorption or emission of radiation at well-defined wavelengths characteristic of an element [22]. Usually the assay was done at a wavelength corresponding to a maximum absorption or emission. Absorbance measurements of standard solutions prepared from certified standard solutions allow the concentration to be related to the absorbance according to the Beer-Lambert relationship.

3.4. Statistical Analysis

The data collected was entered and processed using Microsoft Excel 2016 and Statistica 7.1 software (Statsoft Inc., Tulsa-USA Headquarters). The biochemical and mineral parameters were subjected to statistical analyzes. Thus, an analysis of variance was carried out in order to appreciate the significant differences between the various parameters determined for each sample of mushroom. Multiple comparison tests (Tukey HSD) were conducted when the difference was found to be significant ($p < 0.05$) for the purpose of separating the different samples. Finally, principal component analysis was carried out in order to visualize the differences and associate the different groups identified with their main characteristics.

4. Results

4.1. Biochemical Composition of the Two Species of Wild Mushrooms

The physicochemical composition of the samples of mushrooms from the two localities was determined. The results obtained are shown in **Table 1**. On analysis, there is a significant difference ($p < 0.05$) between the protein contents of the two species of mushrooms Indeed, in the two localities the mushrooms *Lentinus brunneofloccosus pegler* (11.90 ± 0.50 to 12.40 ± 0.50%) have higher contents than those of *Auricularia auricularia judae* (6.10 ± 0.50% at 6.70 ± 0.50%).

Ash contents of the mushroom samples are between 3.46 ± 0.03% of the species of *Auricularia auricularia judae* from Daloa and 7.74 ± 0.76% for the species of *Lentinus brunneofloccosus pegler* from Yamoussoukro.

Concerning the average reducing sugar content, they are between 0.01 ± 0.00% of the two species of mushrooms (*Auricularia auricularia judae* and *Lentinus brunneofloccosus pegler*) of Daloa and 0.27 ± 0.03% for the species of *Lentinus brunneofloccosus pegler* from Yamoussoukro. Likewise, the total sugars and lipid contents of the mushroom samples varied from 1.34 ± 0.17% (*Lentinus brunneofloccosus pegler* from Yamoussoukro) to 5.16 ± 0.50% for the species of *Auricularia auricularia judae*, respectively from Daloa and 4.00 ± 0.10% for the species of *Lentinus brunneofloccosus pegler* from Yamoussoukro and 6.60 ± 0.20% for the species of *Auricularia auricularia judae* from Yamoussoukro.

4.2. Mineral Composition of the Two Species of Mushrooms from the Two Localities

Analysis of two species of fungi from two localities showed the presence of different mineral elements whose concentrations are expressed in mg/100g. The major elements are potassium, calcium and phosphorus. Magnesium is in average proportion, iron and sodium exist in small amounts. It can be seen from the analysis of Table 2 that there is a significant difference ($p < 0.05$) between the potassium contents of the two species of fungi. Indeed, in two localities (Yamoussoukro and Daloa), the mushroom *Lentinus brunneofloccosus pegler* (2000.00 ± 5.00 to 2433.00 ± 5.00 mg/100g) have higher contents than those of *Auricularia auricularia judae* (1126.00 ± 5.00 to 1182.00 ± 5.00 mg/100g). This difference is also observed at the level of each species. This is because high levels of phosphorus are recorded by the fungi *Lentinus brunneofloccosus pegler* and those of *Auricularia auricularia judae* have the low levels.

Table 1. Physicochemical characteristics of the two species of mushrooms from the two localities.

Compositions	Daloa		Yamoussoukro	
	Auricularia auricularia judae	*Lentinus brunneofloccosus pegler*	*Auricularia auricularia judae*	*Lentinus brunneofloccosus pegler*
Proteins (%DM)	6.70 ± 0.50^{b}	12.40 ± 0.50^{a}	6.10 ± 0.50^{b}	11.90 ± 0.50^{a}
Ashes (%DM)	3.46 ± 0.03^{c}	5.54 ± 0.81^{b}	3.48 ± 0.00^{c}	7.74 ± 0.76^{a}
Reducing sugar (DM%)	0.01 ± 0.00^{c}	0.01 ± 0.00^{c}	0.07 ± 0.03^{b}	0.27 ± 0.03^{a}
Total sugar. (DM%)	5.16 ± 0.50^{a}	5.13 ± 0.17^{a}	2.70 ± 1.08^{b}	1.34 ± 0.17^{c}
Lipids (%DM)	5.70 ± 0.00^{b}	5.33 ± 0.17^{b}	6.60 ± 0.20^{a}	4.00 ± 0.10^{c}

The values are the mean ± the standard deviation (n = 3). The contents with the different alphabetical letters on the same line are significantly different ($P < 0.05$), according to the Tukey HSD test.

Table 2. Mineral characteristics of the two species of mushrooms from the two localities.

Composition (mg/100g)	Daloa		Yamoussoukro	
	Auricularia auricularia judae	*Lentinus brunneofloccosus pegler*	*Auricularia auricularia judae*	*Lentinus brunneofloccosus pegler*
Iron (Fe)	4.12 ± 3.04^{a}	6.17 ± 3.04^{a}	5.19 ± 3.04^{a}	2.83 ± 3.04^{a}
Magnesium (Mg)	270.00 ± 5.00^{d}	325.00 ± 5.00^{c}	300.00 ± 5.00^{b}	463.00 ± 5.00^{a}
Sodium (Na)	5.23 ± 2.81^{a}	5.99 ± 3.04^{a}	5.55 ± 3.04^{a}	4.87 ± 3.04^{a}
Potassium (K)	1182.00 ± 5.00^{c}	2000.00 ± 5.00^{b}	1126.00 ± 5.00^{d}	2433.00 ± 5.00^{a}
Phosphorus (p)	2091.00 ± 5.00^{d}	4026.00 ± 5.00^{b}	2152.00 ± 5.00^{c}	4375.00 ± 5.00^{a}
Calcium (Ca)	1006.00 ± 5.00^{a}	959.00 ± 5.00^{b}	898.00 ± 5.00^{c}	904.00 ± 5.00^{c}

The values are the mean ± the standard deviation (n = 3). The contents with the different alphabetical letters on the same line are significantly different ($P < 0.05$), according to the Tukey HSD test.

4.3. Differentiation between Edible Mushroom Samples

In addition, a principal component analysis was performed. The representation of the various wild edible mushrooms in a two-dimensional space is shown in Figure 2. This makes it possible to visualize the differences between the species of fungi studied in a factorial plane (F1-F2). In this plan, which summarizes the differentiations at nearly 89.31%, the two species of mushrooms are distinct. In addition, the *Lentinus brunneofloccosus pegler* of the two localities show differences.

Figure 3 shows the circle of correlation between the physicochemical parameters of the different species of mushrooms. It emerges from the analysis that the first component (F1) is characterized by parameters such as lipids, total sugars, reducing sugars, ash, iron, sodium, magnesium and potassium, the coefficients of which are greater at 56.40% (in absolute value) while component 2 (F2) is defined by variables such as proteins, nitrogen, phosphorus and the energy value whose coefficients are greater than 32.91% (in absolute value). Comparative analysis of the two figures revealed that *Auricularia auricularia judae* is characterized by its lipid content which is the highest of all. In addition, *Lentinus brunneofloccosus pegler* from the city of Yamoussoukro is characterized by its high levels of reducing sugars and potassium. As for the *Lentinus brunneofloccosus pegler* from the city of Daloa. *Lentinus brunneofloccosus pegler* from the town of Daloa are also characterized by their high levels of sodium, iron and total sugars.

5. Discussion

The valuation of the species of *Auricula auricula judae* and *Lentinus brunneofloccosus pegler*, taken into account in this scientific work, mainly concerned the biochemical characteristics of said species of mushroom. It should be noted that the biochemical compositions of the species of *Auricularia auricularia judae* and *Lentinus brunneofloccosus pegler* have been determined in order to understand their nutritional importance and their contribution in the treatment of diseases. This study indicated that both species have ash contents between 3.46 - 3.48% for the species *Auricularia auricularia judae* and 5.54 - 7.74% for the species *Lentinus brunneofloccosus pegler*. These ash contents are close to those of [23] who found levels of 3.60% in *Auricularia auricularia judae* and those (4.26 - 7.72%) of [24] on *Auricularia auricularia judae* and *Lentinus brunneofloccosus pegler*, respectively.

Ash contents indicate the presence of minerals in food products [25]. This is because ashes are residues of mineral compounds that persist after incineration of a sample containing organic substances of animal and plant origin [26]. Mushrooms are good nutritional sources because according to [27] the leaves or vegetables which are to be used as food for humans, should contain about 3.0% ash.

Taken individually, the protein contents of *Auricularia auricularia judae* (6.10 - 6.70%) approximate those of [24] [28] who obtained successively grades

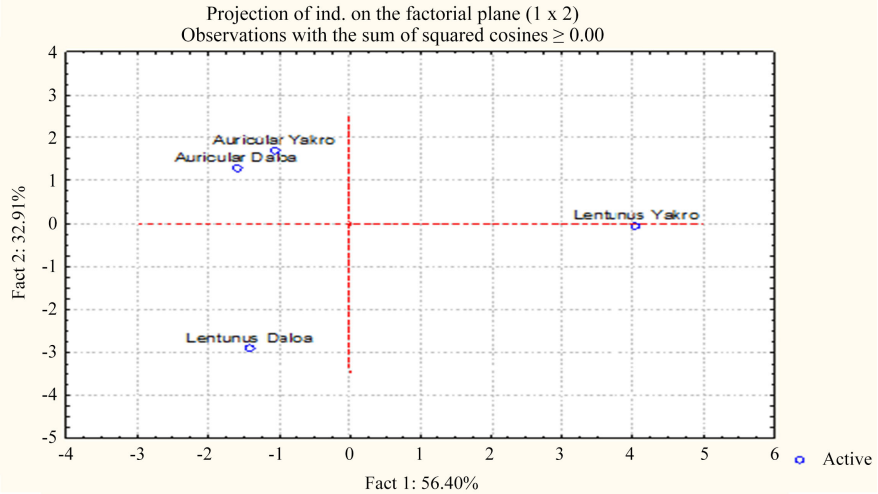

Figure 2. Principal component analysis on the samples of mushroom (factorial plane F1-F2).

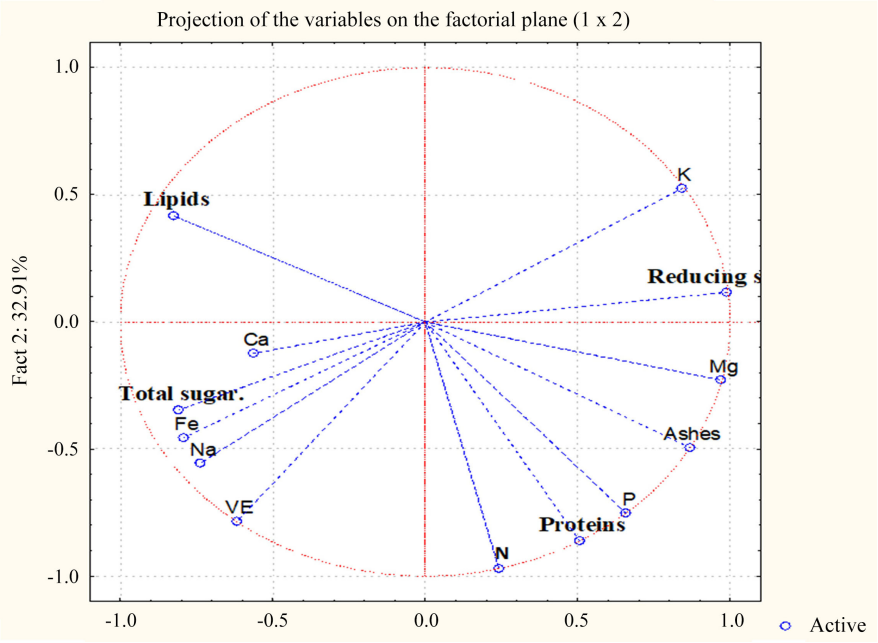

Figure 3. Circle of correlation of biochemical parameters.

of 8.90% and 7.58% for *Auricularia auricularia judae*. Average protein values of 11.90 - 12.40% of the species *Lentinus brunneofloccosus pegler* are similar to those observed by [24] in these same species.

However, the protein contents of the two species studied are lower than those obtained by the work of [15] [28] [29] [30] respectively in *Psathyrella atroumbonata* (30.40%), *Psathyrella tuberculata* (30%) and *Amanita rubescens* (17.49%), *Termitomyces heimii* (23.75%) and *Termitomyces letestui* (16.22%). However, the two species studied would constitute good sources of protein and can be advised for consumption.

The total sugar contents are 2.70 to 5.16% for *Auricularia auricularia judae*

and 1.34 to 5.13% for *Lentinus brunneofloccosus pegler*. These levels are higher than those obtained in the same species of *Lentinus brunneofloccosus pegler* (1398.07 mg/100g) and *Auricularia auricularia judae* (811.21 mg/100g) reported by [24]. However, some authors have reported higher sugar levels of *Termitomyces heimii* (47.66%) and *Termitomyces letestui* (35.56%) than those obtained in this study [15] [16]. The low content of total sugars is an indication of the nutritional quality of these species, as excess sugars are often associated with certain metabolic diseases such as diabetes [29].

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Auricularia auricularia judae and *Lentinus brunneofloccosus pegler* could be safely consumed by people with diabetes. The amounts of lipids contained in the samples of fungi studied are low and less than 7%. These low levels of lipids could mean that *Auricularia auricularia judae* and *Lentinus brunneofloccosus pegler* are not good sources of lipids. These species could be recommended for individuals with obesity reported by [30].

It seems that the lipids of the fungi contain fatty acids which are necessary from a nutritional point of view. Indeed, according to the work of [31] [32], the fat of several mushrooms is rich in unsaturated fatty acids for more than 70%. Unsaturated fatty acids are very important for the body. Determination of the ash revealed that the main minerals of *Auricularia auricularia judae* and *Lentinus brunneofloccosus pegler* species are phosphorus, potassium, calcium and magnesium. Sodium and iron are less. Our results are superior to those obtained by [33] on the species of *Pleurotus geesteranus* (calcium 9.8 mg/100g), and by [34] (potassium 393.45 mg/100g) and phosphore 149.23 mg/100g) on the species *Russula Lepida*. Since the potassium level of the two mushrooms species is higher than that of sodium, this would mean that the species of *Auricularia auricularia judae* and of *Lentinus brunneofloccosuspegler* could intervene in the prevention of arterial hypertension [35] [36] [37]. This is because the beneficial effect of sodium restriction on the control of arterial hypertension is accelerated by a concomitant increase in potassium intake [38].

The presence of these different minerals in the mushroom studied makes them very beneficial foods for human health due to their role in several physiological activities [39]. The variation in mineral contents in these two mushrooms species examined could be due to ecological factors, the species, the absorption capacity of the mycelia of the mushrooms, the age of the fungus and the envi-

ronment [40].

The analysis of variance further indicated that each of the physicochemical parameters of the two species of wild edible mushroom *(Auricularia auricularia judae and Lentinus brunneofloccosus pegler*) varied significantly from one species to another.

These parameters therefore make it possible to differentiate between the two species. These are protein, ash, fat, total sugars, reducing sugars, energy value, iron, sodium, magnesium, potassium, phosphorus, nitrogen, sodium and of the energy value of mushrooms.

In addition, the principal component analysis performed on the different samples made it possible to group them together on the basis of their similarity. This grouping takes into account more than 89.31% of the differentiations between species of mushroom, attesting to the existence of differences. The differences in content recorded in the physicochemical parameters of the mushroom species could be partly due to the substrates on which the mushroom grows. In short, the high richness in lipids, reducing sugars, lipids, potassium, sodium, iron, magnesium and phosphorus of the species *Auricularia auricularia judae* and *Lentinus brunneofloccosus pegler* testifies to their abundant contribution in the treatment of diseases often evoked by the local populations.

6. Conclusions

The work discussed here is in the context of the nutritional and therapeutic valuation of two species of mushrooms *(Lentinus brunneofloccosus pegler and Auricularia auricularia judae*) through the biochemical characterization of these.

These two species of mushrooms (*Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae*) studied are generally characterized by high levels of proteins, ash, minerals (potassium, phosphorus, calcium and magnesium), total polyphenols and good values calorific. However, these species of mushrooms are low in lipids, total sugars, reducing sugars, iron, and sodium. These mushrooms could be introduced into food formulations. These results could also lead the population to take an interest in the mushroom *Lentinus brunneofloccosus pegler* and *Auricularia auricularia judae*, thus constituting a new agricultural product, serving as a source of income for the population, thus fighting against poverty.

Conflicts of Interest

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

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