Original Article

Entomophagy evaluation and nutritional potential of two edible insects sold in the markets of the city of Man (Côte d'Ivoire)

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Abstract

Background: Insect consumption remains an important part of the culture of many people around the world, particularly in Africa and Asia. Nearly 1900 edible species have been recorded worldwide. In terms of nutrition, insects are very rich in protein. They contain protein 3–4 times more than pork or chicken for the same weight of material. This content varies greatly depending on the species of insects and their diet, but some insects are more nutritious than beef, crustaceans, and fish. Entomophagy would represent an alternative for people in developing countries and a solution against hunger for under-nuanced populations. In Côte d'Ivoire, nine species have been identified.

Aims and Objectives: This study was conducted to evaluate entomophagy in the city of Man and to establish nutritional potential of two edible insect species sold on the markets.

Materials and Methods: To do this, a survey was conducted of which 150 people were interviewed randomly and properties of two edible insects *Imbrasia oyemensis* and *Macrotermes subhyalinus* were determined.

Results: In total 63.7% consumed insects. Entomophagy was related to sex ($\chi^2 = 5.17$, ddl = 1, 1 − p = 97.71). However, the consumption is motivated by nutritional value (48%) and taste (25.4%); however, disgust (38.1%) and culture (23.8%) limit entomophagy. Furthermore, this study showed that caterpillars (35.9%) and termites (25.0%) were highly prized by the population. Physicochemical characteristics of *Imbrasia oyemensis* and *Macrotermes subhyalinus* collected were analyzed. Indeed, insects consumed consist of various nutrients such as lipids, proteins, vitamins, and carbohydrates. About analyses, protein contents ranged from 32.065% ± 2.385% to 51.545% ± 2.385% had a significantly higher content for *I. oyemensis*. In addition, these species had a high-fat content of up to 46.065% ± 0.31% dry matter (DM). The energy values of 100 g of DM of *I. oyemensis* and *M. subhyalinus* were 532.448 ± 1.82 and 616.529 ± 6.87 kcal, respectively.

Conclusion: These insects therefore represent a great nutritional value and a real source of energy for humans.

Keywords: Consumer, entomophagy, insects, nutritional value

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INTRODUCTION

Food insecurity is a scourge that still undermines the 21st century, mostly in developing countries.[1] According to Durst *et al.*,[2] one billion people in the world suffer from malnutrition and 98% of

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these people live in Asia and Africa.[3] The demographic forecasts for the coming years do not seem to make this situation better because of not only population growth (estimated to 9 billion in 2050)[4] but also climatic change.[5]

As a response to this scourge, the FAO advocates entomophagy (consuming insects) as a substantial means to improve food security and livelihoods of people living with low income.[6] Indeed, edible insects actually contain several nutritional benefits. They offer many calories, proteins, lipids, vitamins, and minerals, depending on their species, their metamorphic stage, and their diet.[7,8] Currently, 1700–2000 edible insect species divided into 16 orders of which four represent more than 80% of the edible species have been listed.[2] In Côte d'Ivoire, more than 5% of the population has difficulty accessing conventional animal proteins, such as meat and fish,[9] because it is too expensive. The consumption of insects would be palliative to this problem. Entomophagy is already present in several countries with a rate of 85% for the Central African Republic and 70% in the Democratic Republic of Congo.[10,11] However, it remains very rare because of the primitive character and disgust associated. Its valorization and its industrialization thus remain a way of future.

Although, in Cote d'Ivoire, studies are already carried out on the nutritional characteristics of some edible insect species,[12-14] none on entomophagy was not conducted in the city of Man. This city is mainly populated by Dan (Yacouba), Wê (Wobé, Guéré), and Toura representing the peoples consuming the most insects.[15] Thus, the present study, which is part of the fight against food insecurity, aims to evaluate entomophagy at the city of Man and to characterize the nutritional potential of insects sold on the markets in the city of Man.

MATERIALS AND METHODS

Study area

The survey was conducted in the city of Man located at 7°24'45" north latitude and 7°33'13 " west longitude. The city of Man is home to 188,704 inhabitants, according to the RGPH.[16] The city of Man and its region are fairly humid because of its particular altitude and forest cover, which gives it a lot of agricultural activity. From the ethnic point of view, the city of Man is a relatively homogeneous locality.[17] The department is mainly populated by Dan (Yacouba), Wê (Wobé, Guéré), and Toura. In addition to these indigenous populations, other populations from Northern and Central Côte d'Ivoire (Mahou, Dioula, Malinké, Sénoufo, and Baoulé) and neighboring countries, including Guinea, because of its proximity, Mali, Liberia, Burkina Faso, and Nigeria, constitute the strongest human presence in this department.

Biological materials

The biological material consists of dried samples of *Imbrasia oyemensis* [Figure 1a] and *Macrotermes subhyalinus* [Figure 1b] harvested from the markets in the city of Man.

Methods

Survey

The information was collected from 150 people across the city by random survey using a closed and open questionnaire based on the model of Balinga *et al.*[18] The number of respondents is related to the availability of people. Respondents were divided into four age groups (15–17, 18–35, 36–50, and 51 and over years) and of both sexes National Institute of Statistics (INS) (2016). Official languages and national languages. http://www.ins.ci/gene/langues/20officiel/%20et/%20langues/%20nationales.html. Information was collected on the level of consumption according to gender and level of education, factors limiting consumption, and insects generally consumed.

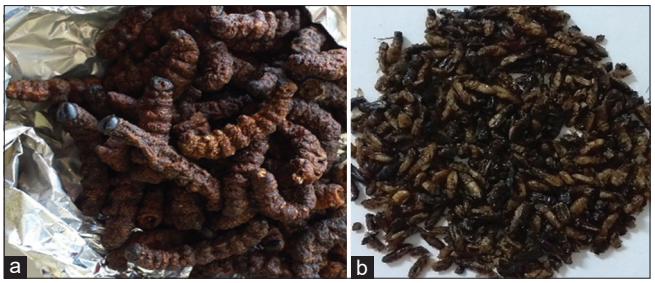

Figure 1: Types of edible insects analyzed: *Imbrasia oyemensis* (a); *Macrotermes subhyalinus* (b)

Physicochemical analyses

Insects collected in the markets have been sorted and cleared of all kinds of waste. They are put in an oven at 65°C for 72 h and then ground with a porcelain mortar to obtain the insect meal.

pH and humidity were determined according to the AOAC[19] method and the ash according to NF V03-760 method.[20] Titratable acidity was determined by titration with sodium hydroxide solution (0.1 N) in the presence of phenolphthalein.[21] Dry matter (DM) was obtained by drying in an oven according to the method described by the AOAC.[22] Brix degree was identified by a refractometer according to Monrose method.[23]

Extraction and Estimation of Fat content

The lipid content was estimated by the Soxhlet method.[24]

Estimation of Vitamin C

The Vitamin C content of insect extracts was determined according to the method described by Elgamouz.[25]

Estimation of proteins

Kjeldahl's method[26] was used for determining crude protein from the nitrogen content.

Estimation of Peroxide value

It was determined according to the method described by Javanmard *et al.*[27]

Estimation of total carbohydrates

The determination was made according to the formula: %Carbohydrates = 100 − (%Moisture + %Protein + %Fat + %Ash).[28]

Energy value

The energy value (EV) corresponding to the available energy is calculated using the specific coefficients of Atwater and Benedict[29] for proteins, lipids, and carbohydrates.

% EV = {4 × (%Protein + %Carbohydrate)} + 9 × (+%Lipid)

EV (in kcal/100 g) fatty acid profile.

Statistical analysis

Survey data was collected and processed using the software Sphinx lexica, version 4.5, Le Sphinx Développement, Parc Altaïs, 74650 Chavanod. χ^2 tests followed by correspondence analysis were carried out to determine the relationships between insect consumption, sex, level of education, appearance of insects, etc. As for the analysis of physicochemical data, the STATISTICA, version 7.1, Stat Soft.Inc., Tulsa, Oklahoma software was used. These data were subject to dimensional variance analysis to assess the existence of statistically significant difference between samples. In addition, bivariate Pearson correlations were used to establish a relationship between the different parameters. Finally, a principal component analysis was performed to visualize the samples in a two-dimensional space.

RESULTS

Tendency of entomophagy

Characteristics of the people interviewed

A total of 150 respondents were made up of 60% of male and 40% of female. Subjects were grouped into four age groups with the highest rate of respondents aged between 18 and 25 years (61.3%). Regarding education level, 87.3% of subjects were literate against 12.7% of illiterates.

Consumption rate and insects generally consumed

Statistical analysis applied showed that 63.7% of the respondents consume insects while 32.7% are nonconsumers. Insects generally consumed are caterpillars such as *I. oyemensis* (34.9%) and garlic termites, *M. subhyalinus* (25%) [Figure 2]. From a cultural point of view, the results of the survey showed that Yacouba (38.4%) consume more insects [Figure 3], than Senoufo (16.2%), Guéré (12.7%), Malinké (11.6%), Baoulé (9.5%), Bété (6.7%), and Gouro (4.9%).

Consumption by sex, age, level of education, environment

The Pearson's 2-test performed showed that the insect consumption was related to sex ($\chi^2 = 5.17$; ddl = 1; 1 − p = 97.71%). Men represent 66.3% of consumers and women the minority with 33.7%. This consumption was very significantly influenced by the entourage ($\chi^2 = 18.59$, ddl = 2; 1 − p = 99.99%); among these consumers, 85% have an entourage-consumer. On the other hand, the age ($\chi^2 = 0.17$, ddl = 1; 1 − p = 32.2%) and the level of education ($\chi^2 = 5.26$; ddl = 4; 1 − p = 73.88%) do not influence insect consumption. However, 67.3% of people who consume insects were 18–25 years old and the proportion of literate people (88.1%) consuming insects is higher than that of illiterates (11.9%).

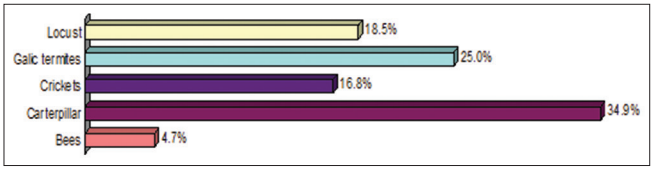

Figure 2: Types of edible insects consumed from our surveys

Motivating or limiting factors of consumption

There were many sources of motivation for insect consumption. The majority of consumers, i.e., 48%, were motivated by the nutritional value (vitamins, minerals, proteins, etc.), 24.5% by the taste, and finally 14.3% by the character of originality. Cost (6.1%), environment (2.6%), curiosity (4.1%), and lack of food (0.5%) were the minor factors motivating the consumption of insects. Regarding limiting factors for nonconsumers, 38.1% found them as disgusting, 23.8% as noncultural, and 11.9% due to their own principle. This consumption was also limited by fear (9.5%) and by being unfit for health (9.5%). However, nonconsumers would be more comfortable consuming them if the insects were masked in food as flour.

Physicochemical characteristics of some edible insects of the city of Man

The physicochemical composition of insects was determined [Table 1]. Insect samples had an acidic pH with values ranging from 5.407 ± 0.057 (*I. oyemensis*) to 6.36 ± 0.01 (*M. subhyalinus*). This variation was also observed at the level of the moisture content with a significantly higher content in *I. oyemensis* (7.076 ± 0.807). In addition, *M. subhyalinus* had higher levels of DM (94.03% ± 2.712% DM) and ash (2.568 ± 0.579). Regarding the nutritional values, i.e., Vitamin C, fat, carbohydrate, and energetic value, *M. subhyalinus* recorded the highest levels with, respectively, 134.76 ± 5.581 mg/100 g DM; 46.065% ± 8.319%; 18.421 ± 2384 g/100 g DM; 616.529 ± 6.879 kcal/100 g DM. However, there was no statistically significant

Table 1: Physicochemical characteristics of samples of *Macrotermes subhyalinus* and *Imbrasia oyemensis*

Parameters	*Macrotermes subhyalinus*	*Imbrasia oyemensis*
pH	6.36±0.01[a]	5.407±0.057[b]
Percentage moisture	0.881±0.197[a]	7.479±0.805[b]
Titratable acidity (mEq/L)	19.85±0.191[a]	42.45±3.649[b]
Brix degree (°Brix)	4.375±0.189[a]	4.075±0.171[a]
Percentage DM	94.035±2.712[a]	74.848±11.96[b]
Percentage lipid	46.065±8.319[a]	33.40±7.074[a]
Vitamin C (mg/100 g DM)	134.76±5.581[a]	133.16±6.194[a]
Percentage ash	2.568±0.579[a]	1.159±0.591[b]
Protein (g/100 g DM)	32.065±2.385[a]	51.545±0.030[b]
Carbohydrate (g/100 g DM)	18.421±2.384[a]	6.417±0.030[b]
Peroxide index (mEq oxygen/kg DM)	9±1.00[a]	9.67±1.53[a]
Energy value (kcal/100 g of DM)	616.529±6.879[a]	532.448±1.826[b]

Values with different alphabetic letters on the same line are statistically different ($P<0.05$). DM: Dry matter

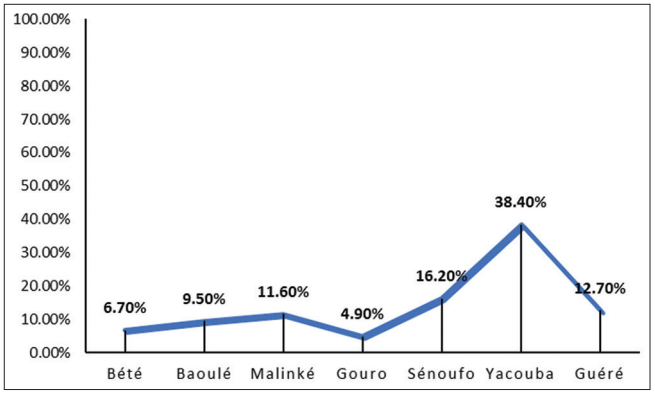

Figure 3: Insect-eating peoples in the city of Man

difference in Vitamin C, lipid contents, and PVs in both species. *I. oyemensis* had the highest protein content (51.545 ± 0.03 g/100 g DM).

DISCUSSION

This study showed that 63.7% of the respondents consumed insects. These results were slightly higher than those of Ehounou *et al.*,[15] who reported that 59.72% of the population of Abidjan consumed insects. However, Balinga *et al.*[18] and Mabossy *et al.*[30] recorded a rate of 65.8% for Brazzaville (Congo) and 85% for Yaoundé (Cameroon), respectively. The high consumption of the species, *I. oyemensis* (32%) *and M. subhyalinus*, could be due to their availability on the markets and their ease of storage.[15] Moreover, Taméssé *et al.*[31] showed that *Lepidoptera* (34.36%) and *Isoptera* (42.94%) were the most commercialized on the markets of Yaoundé (Cameroon). In fact, winged termites, locusts, and caterpillars were the most commonly consumed species in French-speaking West Africa.[32] According to Jongema,[33] *I. oyemensis* was consumed only in Congo and Côte d'Ivoire, unlike *M. subhyalinus*, which was consumed in several African countries, such as Angola, Zambia, Togo, and Burundi.

However, *Rhynchophorus phoenicis* larvae were absent from the visited market of the city of Man. This confirmed the study by Ehounou *et al.*[15] according to which the larvae of *R. phoenicis* were less present in the markets of the city of Abidjan not only because of their rapid decomposition but also because the collectors themselves consume. The high consumption of insects by Yacouba might be cultural in this respect. Moussa[11] stated that insect consumption in the Republic of Congo was a dietary habit. Moreover, nutritional value, taste, and character of originality had been identified as the main sources of motivation. At the same time, disgust engendered, culture, and reasons of use limited their consumption. According to some authors,[34-36] there were three main reasons for refusal by human, danger, aversion, disgust intermediary-associated emotions such as fear, displeasure, and disgust. Indeed, the insect in our dish remains as harmful as it was being alive.[36]

The comparative study of the physicochemical characteristics of both species showed a variation of the levels from one species to another. This variation was due to external factors such as climate, food, habitat, substrate, method of preparation, or methods of analysis.[37] Observed moisture of *I. oyemensis* was close to those reported by Foua-Bi *et al.* (7.19 ± 0.02 g/100 g FM) and Mabossy *et al.* (7.3 g/100 g FM).[14,30] In contrast, the study of Niaba *et al.*[13] recorded a higher moisture value for *M subhyalinus*. However, a low moisture content facilitated the physical and nutritional preservation of insects by preventing their deterioration.[14,30] The nutritional values of the species analyzed confirmed the study of FAO,[38] which noted that edible insects were an important nutritional source for fighting malnutrition. Indeed, these species had an important source of proteins ranging from 32.065 ± 2.38 to 51.58 ± 0.03 g/100 g DM. These values were close to those reported by Foua-Bi *et al.*[14] on *I. oyemensis* (55.49 ± 0.175 g/100 g DM); Niaba *et al.*[13] on *M. subhyalinus* (38.2 ± 1.0 g/100 g DM); and Akpossan *et al.*[12] on *I. oyemensis* (55.77 ± 0.02 g/100 g DM). Further, this variation was consistent in the interval of Xiaoming *et al.*,[39] which recorded protein levels ranging from 13% to 77% DM in 100 edible insect species belonging to various insect orders.

The essential role of a dietary protein was to meet the body's needs for essential nitrogen and amino acids.[40] However, its proteins were affected by the method of preparation. Indeed, mopane caterpillars that already have protein levels in the raw state (between 48% and 61%)[41] retain more protein when dried than roasted; 57% versus 48%.[42] Similarly, raw termites have a protein content of 20%, whereas, when they were fried, smoked, or dried, they display an alternative content of between 32% and 38% of proteins.[43-45]

From these results, it appeared that fat content of *M. subhyalinus* is higher than *I. oyemensis*. These results are similar to those of Foua-Bi *et al.*,[14] which obtained a fat value of *I. oyemensis* lower than *M. subhyalinus*. In addition, Malaise[7] (2003) estimated that fat content of winged termites was between 42% and 53% compared to the DM. Thus, it could contribute to the fight against protein-energy malnutrition in developing countries.[46] At the same time, the chemical properties of fat reveal a PV greater than the limit (4) recommended by the Codex Alimentarius[47] for a dietary fat. This would justify oxidation of the latter[12] possibly due to poor storage before oil extraction.[13]

In addition, low carbohydrate content of this study was similar to the study of Chen *et al.*[48] These authors described insects as being low in carbohydrate with levels ranging from 1 to 10%. In addition, lower levels were reported by Niaba *et al.*[13] on *M. subhyalinus* (3 ± 0.4 g/100 g DM) and Foua-Bi *et al.*[14] on *I. oyemensis* (11 ± 0.1 g/100 g DM). Nevertheless, species studied had high EVs ranging from 215.464 ± 2.160 to 616.529 ± 6.879 kcal/100 g DM. Akpossan *et al.* (2009) obtained a lower grade for *I. oyemensis* (470 kcal/100 g DM), while some authors[49,50] have determined higher EVs up to 776 kcal/100 g DM with edible insects. Indeed, some insects are more energetic than beef (150 kcal) and fish (100 kcal).[3] This energy can be used for the daily needs of the human body, and the FAO[51] is right to encourage their incorporation into infant flours and recommend them to the food, pharmaceutical, and cosmetic industries.

CONCLUSION

The aim of this study was to characterize entomophagy and edible insects' nutritional potentials sold in the markets of the city of Man (Côte d'Ivoire). This study showed that 63% of the people interviewed consumed insects. The Yacouba ethnic group was identified as the largest consumer. *I. oyemensis* and *M. subhyalinus* were more consumed species. This consumption was motivated by certain factors such as nutritional value, taste, and character of originality. Moreover, disgust engendered, culture, and reasons of use limit their consumption. In addition, species analyzed (*I. oyemensis* and *M. subhyalinus*) were rich in nutrients (proteins, lipids, EVs, etc.). Apart from their unattractive appearance, insects could become an alternative source of animal nutrition such as meat and fish.

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Conflicts of interest
There are no conflicts of interest.

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