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Full Length Research Paper

Comparative assessment of some physico-chemical properties of seed oils of *Parkia biglobosa* and *Monodora myristica* with some commercial oils

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The demand for oils has increased in recent times as a result of industrial and nutritional processes. There is therefore the need to search for oils from different types of seeds. As part of an on-going work to search for alternate sources of oils, seed oils from *Monodora myristica* and *Parkia biglobosa* were extracted, analysed and some of their physicochemical properties were compared with those of vegetable and palm oils. The results show that seed oils of *M. myristcia* and *P. biglobosa* have some physicochemical properties comparable with those of the commercial oils and hence have great nutritional and industrial potentials. It is therefore recommended that more studies be undertaken for this abundant source of natural nutritious oil.

Key words: Physicochemical properties, vegetable oils, *Monodora myristica, Parkia biglobosa.*

INTRODUCTION

Globally, natural vegetable oils and fats are increasingly becoming important in nutrition and commerce because they are sources of dietary energy, antioxidants, biofuels and raw materials for the manufacture of industrial products. They are used in food, cosmetic, pharmaceutical and chemical industries. Vegetable oils account for 80% of the world's natural oils and fat supply (Okullo et al., 2010). Vegetable oils are sourced from diverse varieties of leguminous plants, which are considered the major sources of dietary proteins. They are consumed worldwide, especially in developing and underdeveloped countries where consumption of animal protein may be limited as a result of economic, social, cultural or religious factors (Oluwole and Oluremi, 2012). In 2011/2012 alone, about 184.6 million tonnes of world production of oils and fats was from vegetable and animal sources (FAO, 2014). With only a limited number of oils and fats available on a commercial scale, it is not surprising that these are sometimes inadequate to meet the physical, nutritional and chemical properties required for use in food products (Gunstone, 2011). Industrial and nutritional processes have increased the demands for oil and this in turn has led to the search for oils from different types of seeds. Fats and oils are nutritionally important because they form one of the three major classes of food (Dhellot et al., 2006).Oils are used for food texturing,

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baking and frying. Industrially, oils are used in the manufacture of soap, detergent, cosmetics, pharmaceuticals, petroleum and oil paints (Dhellot et al., 2006).

In plants, oil is found mainly in the endosperms of the seeds together with carbohydrates where they jointly nourish the embryo (FAO, 2007). Oils can also be found in the mesocarp of some plants, for example, in palm fruits (FAO, 2007). Due to the increase in nutritional and industrial processes, the demands for oils have increased which in turn has led to the search for oils.

Monodora myristica commonly called calabash nutmeg is a perennial edible plant of the family *Annonaceae*. It is found most commonly in the evergreen forests of West Africa (Liberia, Nigeria, Cameroon, Angola, Uganda and west Kenya) and common names are African nutmeg, calabash nutmeg, and in Nigeria, it is called *ehuru, ariwo, ehiri* and *airama* (Burabai et al., 2007). This tropical shrub is of the family of flowering plants (Weiss*,* 2002; Omobuwajo et al., 2003). *M. myristica* fruit is a berry of 20 cm diameter; it is smooth, green and spherical, and becomes woody at maturity. It is attached to a long stalk which is up to 60 cm long. Inside the fruit are the numerous oblong, pale brown seeds which are usually 1.5 cm long and are surrounded by a whitish fragrant pulp. *M. myristica* is a species of calabash nutmeg, the edible seeds yield a nutmeg-flavoured oil which is used in West Africa for cooking (Eggeling, 2002). *M. myristica* seed extract contains important pharmacological compounds like alkaloids, flavonoids, and vitamins A and E as well as many important lipids (George and Osioma, 2011). Alcoholic extracts of *M. myristica* is known to reverse the toxigenic effect of aflatoxins (Oluwafemi and Taiwo, 2004). In Eastern Nigeria, the seeds are used as condiment and one of the spices used as postpartum tonic. *M. myristica* has been proven to have anti-sickling properties (Uwakwe and Nwaoguikpe, 2008). The essential oil from the leaves contains *β*-caryophyllene, *α*-humulene and *α*-pinene, while that from the seeds contains *α*-phellandrene, *α*-pinene, myrcene, limonene and pinene (Nguefack et al., 2004). Phytochemical screening carried out on *M. myristica* extract revealed the presence of tannin, saponin, flavonoid, steroid, terpenoids, cardiac glycoside, alkaloid and phenol. Earlier determination of the chemical constituents of the seeds revealed the presence of Fiberro-latic oils, resins, terpene, lactose, arocine, saponins, flavonoids and tannins (Iwu, 1993).

In the arid and semi-arid regions of Africa, *Parkia biglobosa* (African locust bean) is very important for food security particularly during food shortage and drought periods (Kourouma et al., 2011). *P. biglobosa* (named after the famous Scottish botanist and surgeon Mungo Park by Robert Brown in 1926) has long been widely recognized as an important indigenous multipurpose fruit tree whose uses include food, medicine, manure, tannin, shade, wind-breaks, bee food, stabilization of degraded environment, livestock feeds, fuel, fibre, fish poison and several other domestic uses (Sadiku, 2010). African locust bean, as it is commonly known, is a tree legume that belongs to the family *Mimosoideae* (Adejumo et al., 2013). It grows in the savannah region of West Africa up to the southern edge of the Sahel zone 13°N (Campbell-Platt, 1980). These trees are not normally cultivated but can be seen in population of two or more in the savannah region of Ghana (Hopkins, 1983). The locust beans are the mature seeds that come from the parkia pods. The pods are harvested and processed into the fermented product known as '*Iru'*, *'Dawadawa*' and '*Ogiri*" in the Yoruba, Hausa and Igbo languages, respectively (Sadiku, 2010). It is characterized by its fruits, which are elongated pods, 5-11 inches long and found in clusters. It flowers from December to March and brings out fruits from February to July. The immature fruits are green and brown when it is mature. The mature seeds are made up of husk which is embedded in dark brown pod. The seeds of *Parkia* plants are eaten as food in Ghana, especially Northern Ghana. The seeds are fermented to give condiments and used as ingredients to prepare soup and stew in most cases as alternative to meat in low income families (Irvin, 1961). It has been reported that the husks and pods are good food for livestock (Elemo et al., 2011). Earlier investigations have mentioned the food and nutritive values of *P. biglobosa* and other species seeds (Alabi et al., 2004). Alabi et al. (2005) reported that locust bean is rich in lipid, protein, carbohydrate, soluble sugars and ascorbic acid. The cotyledon is very nutritious, has less fibre and ash contents. The oil content is suitable for consumption since it contains very low acid and iodine contents. The oil has very high saponification value and hence would be useful in the soap industry.

Despite the numerous uses of the seeds of *M. myristica* and *P. biglobosa* seeds, little attention has been paid to their seeds as sources of oil. The study was therefore aimed at the determination of the physicochemical properties of the seed oils of *P. biglobosa* and *M. myristca* and comparing these properties with those of commonly used vegetable oils to ascertain the suitability or otherwise of the seed oils for nutritional and industrial applications.

MATERIALS AND METHODS

Sampling

The seeds of *M. myristica* and *P. biglobosa* were purchased from the local market at Ejura in the Ashanti region of Ghana. The seeds were grounded using an electric grinder into powder and kept in an air-tight Teflon-lined container and capped prior to extraction. Vegetable oil (Frytol oil) and palm oil were purchased from the retail market at Ejura sealed and kept in a cool dry place prior to analysis.

Oil extraction and determination

The oils were extracted using hexane by adopting the method

Table 1. Physico-chemical properties of the oils.

Parameters	*Monodora myristica* oil	palm oil	*Parkia biglobosa* oil	Vegetable oil (Frytol oil)
Density (g ml^{-1})	0.860±.001	0.891±0.002	0.884±0.001	0.881±0.002
Specific gravity	0.956±0.002	0.955±0.002	0.947±0.001	0.944±0.001
Refractive index (D, 20°C)	1.467±0.003	1.450±0.002	1.465±0.002	1.458±0.001
Moisture Content (%)	10.59±1.245	0.35±0.002	3.165±0.234	0.230±0.001
Acid value (mgKOHg^{-1})	21.14±0.003	13.35±0.011	15.23±0.251	1.02±0.002
Free Fatty Acid (%, oleic acid)	10.27±0.654	6.67±0.002	7.62±0.012	0.51±0.001
Peroxide value (meq g^{-1})	0.415 ±0.002	0.601±0.001	1.414±0.012	0.608±0.002
Iodine value (g $100g^{-1}$)	64.9±1.015	58.42±1.508	61.73±0.569	59.06±1.002
Saponification number (mg KOH g^{-1})	150.07±1.013	138.57±2.021	176.15±1.005	188.22±2.012
Ester value (mg g^{-1})	128.93±4.25	125.21±3.51	160.92±2.50	187.20±6.10

Values of means ± standard deviation of triplicates.

described by AOAC (1990). Oil was extracted from the samples using Soxhlet apparatus with n-hexane as the extracting solvent. After extraction, the solvent was removed in *vacuo*. The oil obtained was stored under refrigeration (4°C), until used for further analysis. Extracted oil was quantified gravimetrically.

Physicochemical analysis

The extracted oil was immediately analysed for moisture content, oil density, specific gravity, refractive index, pH, iodine value, saponification value, free fatty acid, peroxide value, ester and acid values following the method described by the Association of Official Analytical Chemists (AOAC, 2000).

Statistical analysis

All values were expressed as the mean ± S.D of triplicates. Data were analyzed using one-way analysis of variance (ANOVA) followed by the post-hoc Duncan multiple test for analysis of biochemical data using SPSS program (version 17, SPSS Inc., USA). *P* Values < 0.05 were considered statistically significant.

RESULTS AND DISCUSSION

The studied physicochemical properties oil extracted from two Ghanaian seeds (*M. myristica* and *P. biglobosa*) and two references oils (palm and vegetable) are shown in Table 1. The *P. biglobosa* and *M. myristica* seeds had appreciable amounts of oil (16.50 and 26.8%w/w, respectively). This shows that if commercially exploited, they could serve as one of the major additional sources of oil.

Moisture content is an important characteristic for oils and fats as it determines the rate of rancidity and oxidation process of the oils. It is desirable to keep the moisture content low as it will increase the shelf life by preventing oxidation and rancidity processes (Mansor et al., 2012). The high moisture content will assist in hydrolysis process (Osawa et al., 2007). *M. myristica* seed oil has the highest moisture content whilst the vegetable oil has the least. This means that the *Monodora* seed oil will easily go rancid and thus will have the shortest shelf life whilst the vegetable oil will have the longest shelf life. Also, the higher the moisture content of the oil, the greater the value used for food texturing, baking, and frying and industrially in the manufacture of soaps, detergents, cosmetics and oil paints (Mansor et al., 2012). *Monodora* oil will therefore, require more for its industrial and commercial purposes.

Iodine value is a measure of degree of unsaturation of a lipid (Muhammad et al., 2012). *M. myristica* oil had the highest iodine value whilst palm oil had the lowest. This means that the *M. myristica* oil contained the highest degree of unsaturation and hence had the highest ability to remain in liquid form at room temperature. Palm oil has the lowest iodine value meaning that it is the most saturated. From Table 1, the values classify the tested oils as non-drying oils. The relatively high iodine numbers may be indicative of the presence of much unsaturated bond and high susceptibility to oxidative rancidity (Olaniyi et al., 2014).

The saponification value is a measure of the proportion of low molecular weight triacylglycerols (Oladiji et al., 2010). It also indicates the foaming ability of the oil. Foaming is a desired characteristic of good surfactants with applications in preparation of emulsions, soaps and detergents formulation (Muhammad et al., 2006). Saponification values determined for the four oils were greater than 100, indicating that the oils can be used for making soap (Oladiji et al., 2010). However, vegetable oil is least suitable and palm oil the most suitable ingredient for soap manufacture. Saponification value is an index of average molecular mass of fatty acids in oil sample (Oladiji et al., 2010). The high value of saponification

value in the seed oils suggests that the mean molecular weight of fatty acids is high or that the number of ester bonds is high. Also, saponification value basically refers to the mean molecular mass of the fats and oils and has an inverse relationship with the chain length of the fatty acid in fats and oils. This means, the longer the average fatty acid chain length, the smaller the saponification value (Mansor et al., 2012). It can be concluded that vegetable oil contains the fatty acid with the longest chain length followed by *P. biglobosa* oil and *M. myristica* oil with palm oil being the shortest. From Table 1, the values ranged from 138.57- 188.13 mg KOH g^{-1}. The relatively high saponification value recorded for the seed oils is indicative of their potential use in the industry (Amoo et al., 2004).

The peroxide value is an index of rancidity and its susceptibility to oxidation, thus low peroxide value indicates resistance of the oil to peroxidation during storage (Muhammad et al., 2006). The peroxide values of both *P. biglobosa* and *M. myristica* are comparable to the peroxide values obtained for the palm oil and the vegetable oil. All the oils recorded low peroxide values, as compared to the maximum acceptable value of 10 meq KOH/g (meq/Kg or g) set by the Codex Alimentarius Commission for groundnut seed oils. The oils are thus stable and would not easily go rancid (CODEX, 2001).

Peroxide values is used as an indicator of deterioration of oils. Fresh oils have values less than 10 mEq/kg. A rancid taste often begins to be noticeable when the peroxide value is between 20 and 40 mEq/kg (Egan et al., 1981).

The acid value (AV) is a common parameter in the specification of fats and oils. It is a measure of the free fatty acids (FFA) present in the fat or oil (Popoola and Yangomodou, 2006). The acid value is often a good measure of the breakdown of the triacylglycerols into free fatty acids, which has an adverse effect on the quality of many lipids. An increment in the amount of FFA in a sample of oil or fat indicates hydrolysis of triglycerides (Akubugwo et al., 2008). In general, it gives an indication of edibility of the lipid and suitability for used in the paint industry (Olaniyi et al., 2014). Oils with acid values of more than one, indicates an edible oil whilst pharmaceutical oil must not contain acidity at all (Oladiji et al., 2010). The acid values and the free fatty acids values recorded for all the oils were more than one signifying the edibility of the oils (Olaniyi et al., 2014). The oils of *P. biglobosa* and *M. myristica* can therefore be utilized as a source of edible oil. The values recorded for the free fatty acids correspond with that of the acid values, palm oil recorded the highest, followed by *P. biglobosa*, *M. myristica* and vegetable oil.

The mean refractive index recorded for all the oils were within the range 1.466 to 1.470 which is in close agreement with values reported for conventional oils from soybean (Akubugwo et al., 2008). The high refractive index of the oils seems to confirm the high number of carbon atoms in their fatty acids (Akubugwo et al., 2008). Refractive index also increases as the double bond increases meaning high degree of unsaturation (Akubugwo et al., 2008). Based on the recorded values, *M. myristica* oil has the highest refractive index (1.467±0.003) meaning that it has the highest number of carbon atoms and double bonds, followed by *P. biglobosa* seed oil (1.465±0.002), the vegetable oil (1.458±0.001) with palm oil (1.450±0.002) having the lowest number of carbon atoms and double bonds.

The specific gravity of oils ranged between 0.86 to 0.98. These values are within the range of 0.89 and 0.92 at 20°C for specific gravities reported for the fats and waxes (Ajayi and Oderinde, 2002).

CONCLUSION AND RECOMMENDATION

The physico-chemical properties of the *P. biglobosa* and *M. myristica* seed oils determined are comparable to those of palm oil and vegetable oil (frytol oil) and that the seed oils are not inferior to other edible oils used for cooking. It is therefore recommended that more studies such as toxicological study investigations, mycotoxins or alkaloids or glycosides analysis be carried out to explore its viability for both nutritional and industrial use.

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Full Length Research Paper

Assessment of entomophagy in Abidjan (Cote D'ivoire, West Africa)

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In order to assess the contribution of edible insects to the efforts for combatting food insecurity and poverty in Côte d'Ivoire, a survey aimed at identifying edible insects in Côte d'Ivoire was conducted from August 2014 to August 2015 in three communes in the city of Abidjan (Abobo, Adjamé and Yopougon). Four hundred and seventy-two people were interviewed at random. The results revealed that 59.72% of the respondents consume insects against 40.27% who do not consume them. This study has helped to identify nine edible insect species belonging to eight families and five orders. The species *Imbrasia oyemensis* (Lepidoptera, Satunidae) and *Macrotermes subhylinus* (Isoptera, Macrotermitidae) are widely consumed due to their availability in markets. The species *Rhyncophorus phoenicis* (Coleoptera, Curculionidae) or palm tree caterpillar is one of the most prized by 40% of the surveyed population. The statistical analyses applied to the 365 people surveyed revealed that insect consumption is a function of the cultural area (X^2=76.7; ddl= 4, $p < 0.05$) and the age ((X^2=54.88, ddl=3; $p < 0.05$) of the consumers. In economic terms, insect trade remains a significant source of income in households having an average income estimated at 58,666.66±11216 FCFA per seller and per month. However, their availability in markets is seasonal. A mastery of the biology of these insects could ensure their permanent availability in markets.

Key words: Edible insects, Abidjan, motivations, age, region, consumers.

INTRODUCTION

The global demand for food, especially animal protein, is continuously increasing due to population growth and urbanization (Lavalette, 2013). According to the studies of Durst et al. (2010) one billion people worldwide suffer from malnutrition and 98% of these people live in Asia and Africa (Lavalette, 2013).

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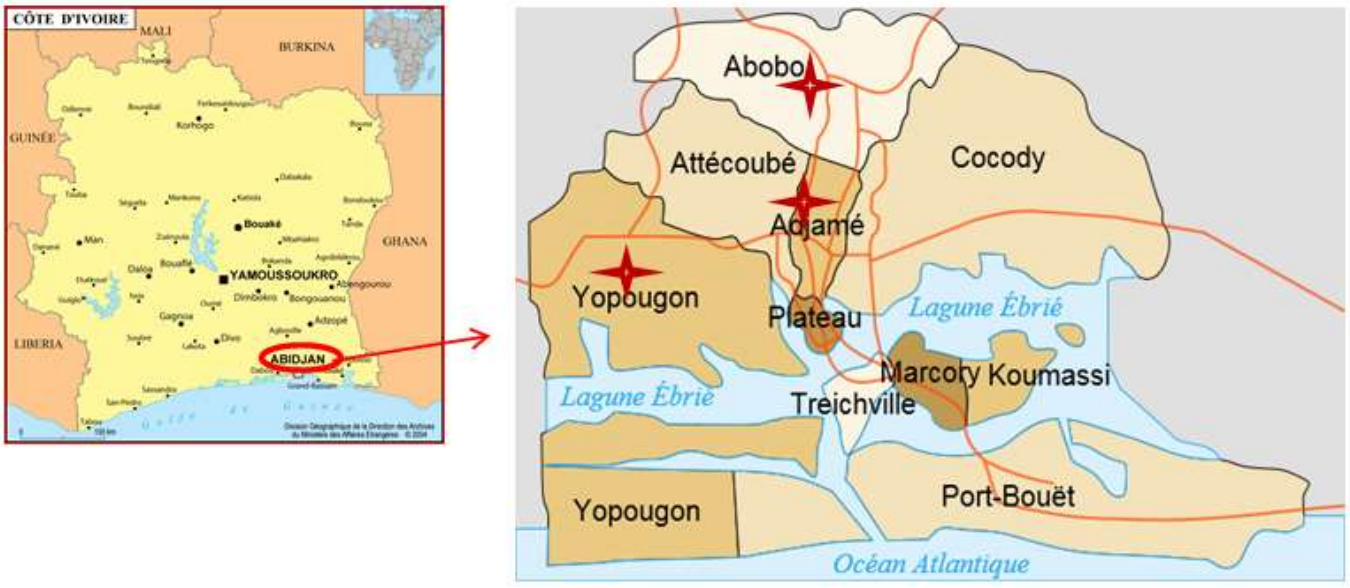

Figure 1. Location of the study area.
Source: Wikipedia.

In response to these challenges, Food and Agriculture Organization (FAO) has opted for entomophagy or insect consumption as an alternative to the food and nutritional challenges of low-income populations (FAO, 2013). These animals are an important source of protein and energy for various populations (Chutima et al., 2015). Insects are already consumed in several countries. In the Central African Republic, 85% of the population consume caterpillars (N'gasse et al., 2003). Moussa (2002) reported a consumption rate of 70% in the Democratic Republic of Congo. In Botswana, Van Huis et al. (2013) estimate the rate of insect consumption by the population at 91%. Although insect consumption is still common, the total number of species consumed tends to decline due to urbanization and wildlife extinction. In Côte d'Ivoire, more than 5% of the population is affected by difficulties in accessing traditional animal proteins such as meat and fish (INS, 2008) because of the often high prices. Consumption of insects would be a way out of this situation. The collection and sale of insects not only generates substantial income for the vulnerable population but also provides a significant additional protein supply to women and children (Akpossan et al., 2009). The seasonality of these insects remains a challenge faced by the populations involved in this field. Indeed, the world of tomorrow is likely to be confronted with problems of food supply and durability of these insects. The shift from a gathering system to an organized mode of production through mass animal husbandry is therefore a path of the future. Studies on the nutritional value of certain edible insect species were made in Abidjan (Akpossan et al., 2009; Niaba et al., 2011; Gbogouri, 2013). A survey was conducted by Niaba et al (2012) on the consumption of winged termites in Côte d'Ivoire. However, few studies on the inventory and diversity of edible insects in Côte d'Ivoire have been carried out. The present study, which is part of the fight against food insecurity, has the long-term objective of promoting entomophagy in Côte d'Ivoire. Specifically, it is about inventorying the insect species consumed in Abidjan and assessing the factors related to their consumption.

Study environment

The study was carried out in the district of Abidjan, which covers an area of 57 735 ha inhabited by 4 707 000 inhabitants, that is, 20% of the country's total population (RGPH, 2014). The city of Abidjan has ten (10) communes, three of which have been selected for this study. These are the communes of Adjamé, Abobo, and Yopougon whose total population represents 3/4 of the total population of the city (RGPH, 2014). The common feature of these communes is the existence of the largest wholesale markets for food supplies in all the cities of the country and the subregions. In addition, these markets constitute sources of supply for other markets in the city (Figure 1).

Table 1. Data on the different insect species sold and consumed in the three sampled communes.

Order	Family	Species	Common name	Vernacular name (Language)	Stage of consumed
Coleoptera	Curculionidae	*Rhyncophorus phoenicis*	Palm tree *(Elaeis guineensis)* larvae	Anonkplin (Baoulé)	Larvae and adult
Coleoptera	Dynastidae	*Oryctes rhinoceros*	Raffia larvae	Anonkplin (Baoulé)	Larvae and adult
Lepidoptera	Satunidae	*Imbrasia oyemensis*	Sapeli *(Entandrophragma cylindricum)* caterpillar	Zéklé (Gouro)	Larvae
Lepidoptera	Satunidae	*Cirina Butyrospermi*	Shea tree *(Vitellaria paradoxa)* caterpillar	Chétoum (Senoufo)	Larvae
Hymenoptera	Apidae	*Apis melifera*	Bee	Miel	Honey
Lepidoptera	Cossidae	*Cossus cossus*	Carpenter ant	Gnénoukouakoua (Agni)	Larvae
Orthoptera	Acrididae	*Locusta migratoria*	Grasshopper	Aétché (Baoulé)	Adult
Orthoptera	Grillydae	*Acheta domesticus*	Cricket	Klanan (Agni)	Adult
Isoptera	Macrotermitide	*Macrotermes subhyalinus*	Termite	Bli (Maouka)* Mle (Baoule)* Mlimli (Bete)*	Adult

MATERIALS AND METHODS

The biological material consisted of edible insect species identified during the survey. The technical material consisted of a survey form, a digital camera, a notebook and plastic boxes for collecting the insects encountered. The catalog of Delvare and Aberlenc (1989) has helped make the laboratory identification.

Inventory of edible insects

A survey was carried out from August 2014 to August 2015. The sample was composed of 472 respondents consisting of consumers and insect traders. Two questionnaires with open and closed questions adapted according to the model of Balinga et al. (2004) were submitted to the respondents. The first was addressed to insect consumers and the second to wholesalers and retailers. They were distributed to households and markets with a view of assessing the edible insect marketing chain in Côte d'Ivoire. The questionnaires were sent to both men and women aged between 15 and 90 years divided into four age groups (15 to 17 years, 18 to 35 years, 36 to 50 years, 51 years and over) according to the National Institute of Statistics (INS, 2016). In total, samples of 30 fresh insect specimens and 30 dried specimens were collected as part of the survey. As for the larvae, they were reared in the laboratory until the emergence of the adult. The adults were identified in the Laboratory of Zoology and Animal Biology of the University Félix Houphouët-Boigny using a BMK 31 162 binocular magnifier and the catalog of Delvare and Aberlenc (1989).

Consumer survey

The information was gathered from 365 households in the three communes, including 125 in Adjamé, 161 in Abobo and 79 in Yopougon according to random sampling. The number of respondents per commune was related to their availability. The people interviewed in a household should answer questions during an interview. The language used for the survey was French. For the respondents who did not understand this language, translators were requested. Information was given on the vernacular names of the edible insects as well as the reasons for their consumption. The different ethnic groups encountered were grouped in the five cultural areas called Akan, Mandé nord, Mandé sud, Krou and Voltaic in Côte d'Ivoire (INS, 2016).

Trader survey on insect marketing

The marketing survey took place in 3 markets of the three communes visited, namely the Gouro market of Adjamé, the main market of Abobo Gare and the one of Yopougon Gesco. It concerned 107 sellers chosen at random from the 3 markets, including 41 in Adjamé 35 in Abobo and 31 in Yopougon. The number of respondents in each market was related to the availability and number of traders found on site during the surveys. The interviews with the traders concerned the age, gender, education attainment, names of insects in local languages, their availability on the market at each period of year, the areas of provenance and the economic importance of insects sold.

Statistical analyses

The different parameters were studied using STATISTICA version 16 software. The level of significance was set at 5%. A Pearson chi² test followed by correspondence analysis tests was used to determine the different relationships between insect consumption, education attainment, cultural area and age of consumers.

RESULTS

Inventory of insects consumed in Abidjan

A total of nine edible insect species split into seven families and five orders were identified. Table 1 lists the edible insect species consumed by the surveyed population. Among these species, the most consumed

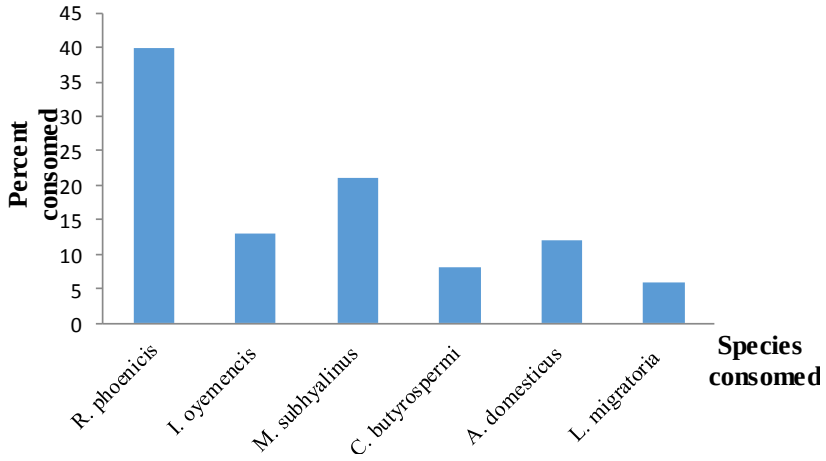

Figure 2. Proportion of respondents who reported having consumed each of these species.

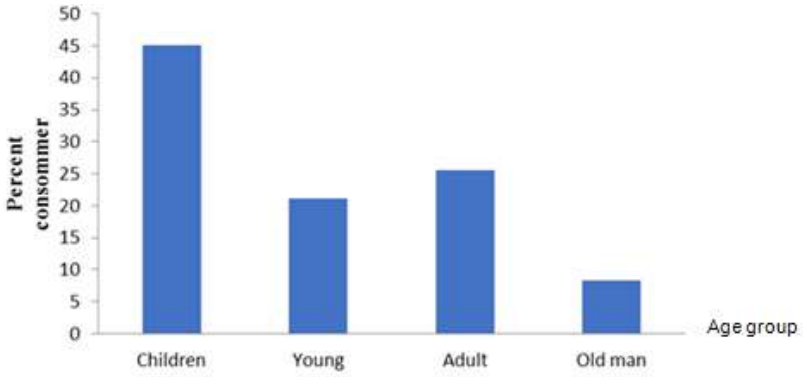

Figure 3. Insect consumption rate depending on the age groups.

and sold are *Rhyncophorus phoenicis* (39.90%), *Macrotermes subhyalinus* (21.13%), *Imbrasia oyemensis* (13.15%), *Acheta domesticus* (11.74%), *Cirina butyrospermi* (7.98%) and *Locusta migratoria* (6.10%) (Figure 2). It appears that the vernacular names of species, vary from one ethnic group to another.

Trends in insect consumption

Demographic characteristics of the surveyed population

The 365 respondents were split into four age groups of15 to 17 years, representing children (30.68%), from 18 and from 36 to 50 years of age representing adults (28.76%).People aged 51 or over (old people) accounted for 12.60% of the respondents. For the entire sample, the male subjects accounted for 52.87% and the female subjects for 47.12%. In terms of educational attainment, 23% were school drop outs, 25.20% had primary education, 30.13% had secondary education and 21.64% had higher education. As for the ethnic group, 18.35% were from the Akan group, 21.64% from the Mandé nord group, 21.09% from the Mandé sud group, 20.54% from the Krou group and 18.36% from the voltaic group.

Consumption of insects by age, sex, educational attainment and cultural area

The statistical analyses applied to the 365 respondents revealed that 59.72% of the respondents consume caterpillars against 40.27% who do not consume them. This consumption of insects is linked to several factors including age, educational attainment and cultural area. Among the consumers, children were the majority (44.95%) and elderly people were the minority (8.25%) (X^2=54.88, ddl=3, $p < 0.05$) (Figure 3). Concerning educational attainment, people out of school (33.48%)

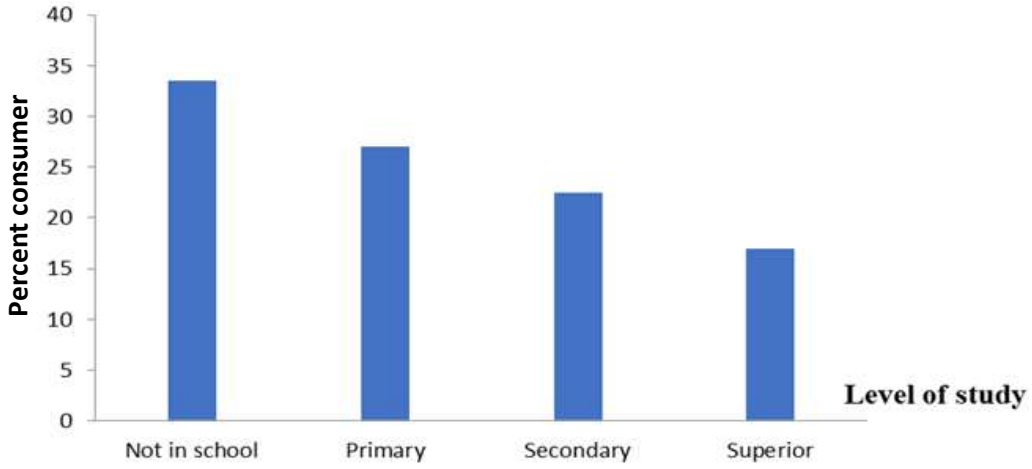

Figure 4. Insect consumption rate depending on educational attainment.

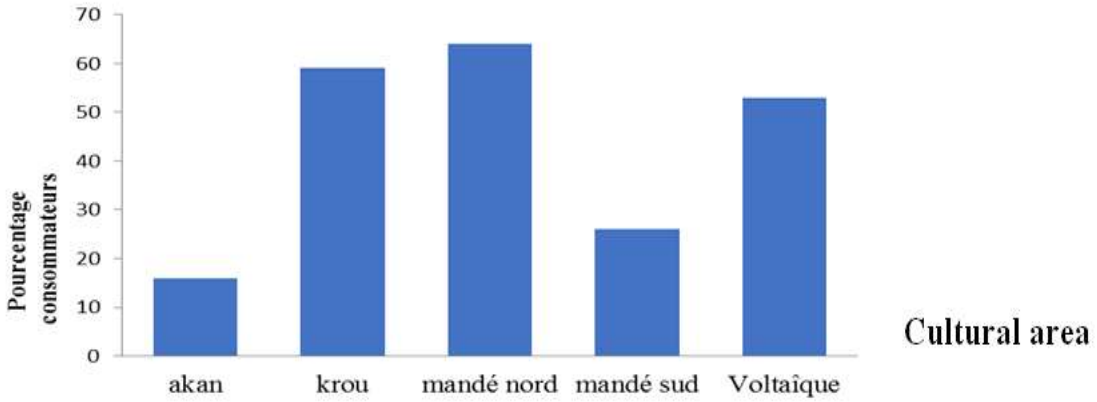

Figure 5. Insect consumption rate depending on cultural area.

consume the most insects and those having higher education consume less (16.97%) (Figure 4). Concerning cultural area, the Krou (76%) were the ones who consume the most insects (Figure 5). They were followed by the Mandé nord (30.05%), the Mandé sud (24.88%), the Voltaic (11.27%) and the Akan (7.05%) (X^2=76.7; ddl=4; $p < 0.05$) (Table 1). The Pearson chi² test applied to the population sample revealed that insect consumption was not a function of gender ($X^2 = 4.32$; ddl = 1; $p = 0.37526$). The results of the survey showed that the proportion of men who consume insects (57.33%) is higher than that of women (42.66%).

Consumption of insects depending on sources of motivation

The reasons for the consumption of insects were multiple Thus, 49.39% of consumers said that the insects taste good; 12.20% mentioned that they contain proteins, vitamins and minerals such as calcium and iron; 20.62% consumed them by eating habit and finally 17.43% out of curiosity (Figure 6). As for non-consumers of insects, 64.42% did not do so in disgust; 16.56% for fear and 19.02% due to customary considerations.

Insect marketing

Status of traders

The census conducted revealed that 27% of traders in the markets sold insects. Women accounted for 74.4% of these traders. However, the 7 wholesalers encountered in the different markets were men. Ethnically speaking, populations from the West (Gouro, Yacouba Guéré) and

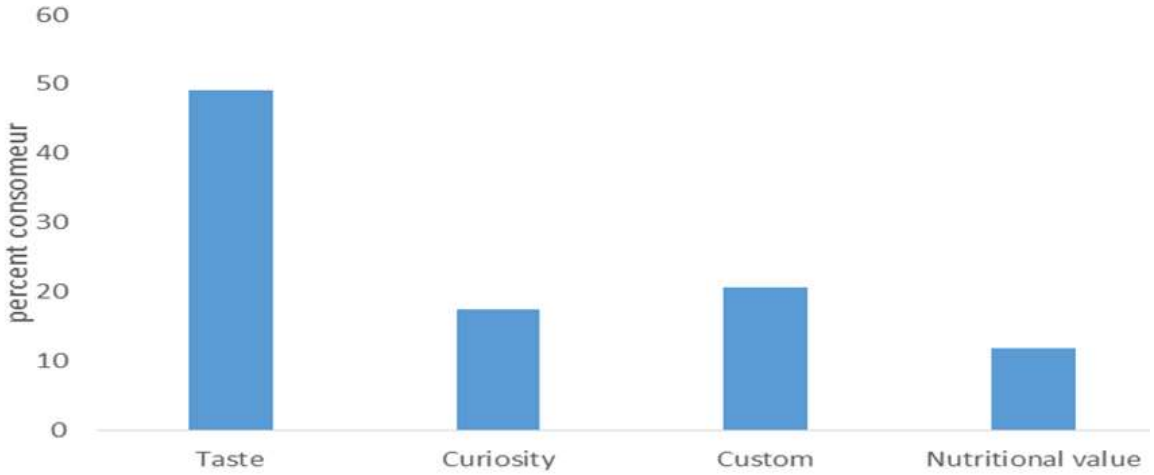

Figure 6. Sources of motivation for insec consumption mntioned by the respondents.

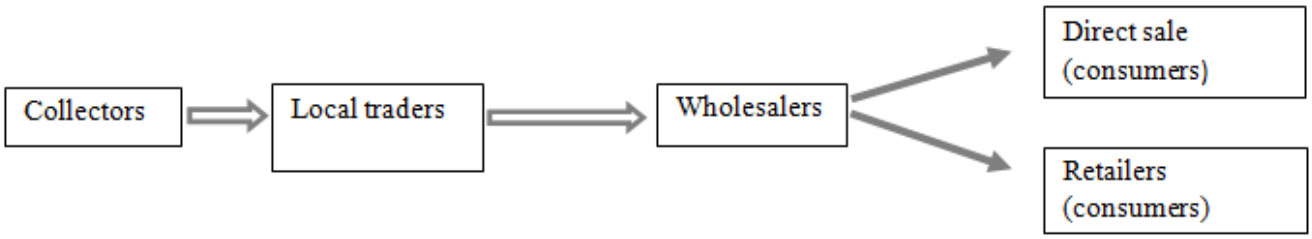

Figure 7. Edible insect distribution channel.

the north (Senoufo, Tagbanan, Malinké etc.) of Côte d'Ivoire were the most involved in insect sale. These two ethnic groups are also major consumers of insects. The average age of traders was between 30.90±10.84 years.

Methods of insect supply

The most common supply method practiced by traders was direct purchase of insects in a wholesale market in Abidjan (54.5%). The second method consisted in moving to insect collection sites (45.5%). The distribution chain from harvest to marketing could be summarized in four steps (Figure 7). In 92% of cases, collectors were usually women (51%) and children (34%). Their first clients were small local traders who, in turn sold the products to wholesalers. The latter supplied the markets of large cities. The supply of the cities with edible insects is therefore carried out by wholesalers. According to the results of the survey, Abidjan receives insects from different cities in Côte d'Ivoire and some neighboring countries such as Ghana, Burkina Faso and Mali during periods of shortages (Figure 8).

Profitability of insect trade

From the beginning to the end of the marketing channel, that is to say from the collector to the retailer in Abidjan, prices were multiplied by coefficients ranging from 5 to 10 depending on the places of provenance of insects. According to the traders surveyed, the selling prices in the market vary from one species to another and depending on the harvest period. The best-selling species were *R. phoenicis* which is a species more prized by collectors themselves and *I. oyemensis* whose prices at the wholesalers were respectively 5000 and 4000 FCFA per kg of larvae. They were followed by termites that cost 1100 FCFA per kilogram (Table 2). Unfortunately, the species *R. phoenicis* was less present in the markets because of the rapid decomposition of its larvae according to the traders. The majority of retailers surveyed reported that insect trade is profitable and mentioned profit margins estimated at 69.33±11.30 %. The average monthly income was estimated at 58.666.66 ±11216 FCFA in that period of the year. The measuring instruments for sale varied according to the species and its condition (fresh or dried) (Figure 9). Some traders

Figure 8. Edible insect supply area to the city of Abidjan.

Table 2. Estimate of profit margin related to insect sale.

Espèce d'insecte	Poids (Kg)	Prix de gros (FCFA)	Prix détail (FCFA)	Bénéfice (FCFA)
Rhyncophorus phoenicis	1	5000	8000	3000
Imbrasia oyemensis	1	4000	8000	4000
Macrotermes subhyalinus	1	1100	1900	800
Cirina butyrospermi	1	1500	2000	500

(61.2%) said that income from the sale of insects makes it possible to cover household expenses (food, clothing and child health care), and part of this money was used to support their savings account. However, 38.8% argue that this trade is less profitable due to fluctuations in the price of insects with wholesalers but also the seasonality of the activity. For this group of traders, outside the period of abundance, other products such as cassava, vegetables, fruits, and fishes are marketed to cover daily expenses.

DISCUSSION

This study shows that nine insect species, namely *R phoenicis, O. rhinoceros, I. oyemensis, C. butyrospermi, A. melifera, C. cossus, L. migratoria, A. domesticus, M. subhyalinus* split into seven families and five orders are consumed in Abidjan.. In Ghana, Anankwa et al. (2016) identified the same number of insect species. Payne et al. (2016) identified ten species of edible insects in the Democratic Republic of Congo.

In Southwestern Nigeria, the number of insectsconsumed is estimated to be seventeen according to the works of Banjo et al. (2006). Indeed, the different species identified in Côte d'Ivoire are also consumed in some countries such as Ghana where species such as *R. phoenicis, C. butyrospermi, L. migratoria, A. domesticus* and *M. Subhyalinus* are part of the daily diet of the population (Anankwa et al., 2016).

M. subhyalinus is a species of termite whose consumption extends over several African countries including Angola, Zambia, Togo, and Burundi (Jongema, 2015). Like termites, *R. phoenicis* is a species consumed in several western and central African countries (Jongema, 2015). In other countries such as Burkina

Figure 9. Insect species sold on the markets visited.
A:Box of 1 kg *Cirina butyrospermi* dried caterpillar at 2000 FCFA; B: Box of 750 g *Imbrasia oyemensis* dried larvae at 3500 FCFA; C: Box of 200 g *Rhyncophorus phoenicis* fresh larvae at 1000 FCFA; D: Box of 90g *Macrotermes subhyalinus* at 500 FCFA.

Faso, the *C. butyrospermi* caterpillar is an important source of food for the local population (Anvo et al., 2016). The consumption of *I. oyemensis* caterpillar is less diversified, according to the list of Jongema (2015) this species has been reported as edible in Congo and Côte d'Ivoire.

The fact that *I. oyemensis* and *M. subhyalinus* were the most sold in the markets could be linked to their availability and good preservation. These results corroborate those of Tamesse et al. (2015) who showed that larvae of Lepidoptera (34.36%) and Isoptera (42.94%) are the most widely marketed insects in Yaoundé (Cameroon) markets. Larvae of *R. phoenicis* were less represented in the markets visited. This might be due to the fact that the collectors themselves are heavy consumers thereof and also to the rapid decomposition of these larvae because of their high fat content.

Lenga et al. (2012) reported a lipid content of 65.70% of the total weight in *R. phoenicis*. In terms of insect consumption, the results showed that 59.72% of the respondents consume insects against 40.27% who donot consume them. These results are close to those of Balinga et al. (2004) who reported that 65.8% of Cameroonians consume caterpillars against 31.3% who are indifferent. However, 85% of populations in the Central African Republic are fond of caterpillars (Mabossy et al., 2013).

Children are generally out of school in rural areas, making them the main source of collectors and consumers of insects. The low insect consumption among those with higher education could be explained by the change in eating habits resulting from the culture shock due to urbanization, and greater availability of alternative sources of protein in urban areas, which tends to depreciate consumer interest in large cities for insects that are more attracted by elaborate and imported foods (Mabossy et al., 2013; Le Gall, 2015).

The high consumption of insects by the Krou and Mandé is explained by their eating habit. This observation is confirmed by Moussa (2002) who reported that insect consumption in the Republic of Congo is an eating habit. According to our investigations, the trade is carried out only by women and young girls aged between 18 and 50 years. Balinga et al. (2004) point out that in Central African markets, insect sellers are mainly women and

children. Insect trade is a seasonal activity but generates average incomes estimated at 59000 CFAF per seller and per month. These figures may vary from one country to another depending on the period and availability of insects in the markets. Dounias (2003) noted an amount of 50 000 FCFA per seller and per month in southern Cameroon.

Conclusion

This study on edible insects in the city of Abidjan has helped identify nine edible insect species belonging to five orders and seven families. Of the surveyed people, 59.72% consume thereof. This consumption is related to age and cultural area. Children and the people school drop outs, are the biggest consumers, as are the Krou and Mandé. These two ethnic groups are the most involved in edible insect trade. Profit margins related to this activity are estimated at 59000 FCFA/month/merchant during the periods of insect availability. It also contributes to economic equilibrium and poverty reduction in households.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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