Medicinal insects used in Côte d'Ivoire: a field survey in Central and Northeastern provinces

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Research

Abstract

Background: In Côte d'Ivoire, insects hold a crucial role not only in culinary practices but also as vital components in traditional medicinal treatments, a facet often neglected in current research. This study aims to document the insects used in therapeutic practices and evaluate the present utilization of entomotherapy in three distinct district capitals of Côte d'Ivoire: Bondoukou, Bouaké, and Daloa.

Methods: An ethno-entomological survey was conducted in 2022 among 612 informants from four ethnic groups across Central and North-Eastern Côte d'Ivoire. Data collection was performed using a participatory approach with a structured questionnaire addressing sociodemographic characteristics and knowledge about insects used in traditional medicine.

Results: Only 14 % (n = 87) of participants were aware of the medicinal use of insects, with 48 % (n = 42) having personally used them. In total, 10 medicinal insects (103 URs) from six orders and eight families, were used in infusion (43.1 %), crushed (21 %), or in their natural state (29.4 %), often in combination with plants or other local resources, for the treatment of 16 different ailments. Administration routes included anal (38.9 %), cutaneous (28.4 %), oral (18.9 %) and auricular (13.7 %).

Conclusions: This study highlights the significant role of insects in traditional medicine in Côte d'Ivoire, identifying 10 medicinal insects used for 16 ailments. Further research is essential to evaluate the efficacy and safety of these remedies, contributing to the preservation and promotion of this traditional knowledge within a broader anthropological and ecological context.

Keywords: Traditional medicine, Africa, Entomology, Field survey, Therapeutic insects, Ethnomedecine

Background

Terrestrial biodiversity, encompassing a multitude of animals and plants, forms the cornerstone of a complex network of interactions that have a direct impact on human well-being, particularly in the realms of health and nutrition (Barbosa *et al.* 2018, Gahukar 2020). While plants have traditionally dominated remedies, ancestral medicinal practices have also explored, to some extent, animal resources and their derivatives. Among these resources, insects stand out due to their abundance and diversity, representing over 85% of animal biodiversity (Motte-Florac & Le Gall 2022). They have played a central role in indigenous healing methods for generations, providing alternative source rich in medicinal compounds and holding significant cultural importance in many societies (Costa-Neto 2005, Zhang *et al*. 2023). Exploring the use of insects in traditional medicine could lead to the discovery of new therapeutic sources, offering alternatives to traditionally used plants while addressing the health needs of the population in a more holistic manner.

The medicinal use of insects dates back to antiquity, recalled as early as the 16th century BCE in the Ebers Papyrus, an Egyptian medical treatise detailing several remedies derived from insects and arachnids (Weiss 1947). The book 'Insectotheology,' published in 1699, also bears witness to this ancient use of insects for therapeutic purposes (Berenbaum 1995). For millennia, silkworms (*Bombyx mori*) have been used in traditional Chinese medicine and the larvae of certain flies have been employed in the healing of infected wounds (Meyer-Rochow 2017, Zimian & Xiwu 1997).

The preventive or therapeutic use of insects is termed 'entomotherapy,' and the insects involved are referred to as 'medicinal insects' (Costa-Neto 2005, Devi *et al.* 2023). Currently, the number of insect species used for therapeutic purposes is estimated to exceed 1,000 in various regions worldwide (Siddiqui *et al*. 2023, Meyer-Rochow 2017). In China, around 300 species of medicinal insects have been documented alongside 5,700 other ingredients sourced from plants, animals, or minerals (Feng *et al.* 2009). Other regions of the world, such as India, Japan, Korea, Spain, Turkey, Africa, and South America, have also reported the significant use of insects in treating various illnesses (Choudhary *et al.* 2022, Meyer-Rochow 2017).
In West Africa, research on the therapeutic use of insects is limited. Of the three studies documented, two were conducted in Benin and one in Burkina Faso. In Benin, an initial study surveyed 150 individuals in Ouidah, identifying 13 species of medicinal insects used to treat 23 conditions (Hedanou 2017). Two years later, another study, conducted in the Southeast of Benin with 145 informants, documented 38 species of invertebrates, of which 64.7 % were insects and were used for treating 50 illnesses (Loko *et al*. 2019). In Burkina Faso, 60 traditional practitioners were interviewed across five locations in the Sudanese and Sudano-Sahelian zones, identifying 19 insect species used as remedies for 78 diseases and symptoms (Ouango *et al.* 2022).

Research in Côte d'Ivoire has revealed the use of insects for food purposes, with a list including 11 species consumed by over 60 % of the population (Boko *et al.* 2020, Ehounou *et al.* 2018, Niaba *et al.* 2012). Among these studies, one identified Bouaké and Daloa as among the most active centers for insect consumption and trade in Côte d'Ivoire (Boko & Angaman 2021). Hence, it is plausible that these insects could also be used for medicinal purposes in these regions, although specific studies are lacking regarding their usage in Ivorian traditional medicine. It is within this context that the present study was conducted, aiming to inventory insects used in therapy and assess the current practice of entomotherapy in three specific localities of Côte d'Ivoire: Bondoukou, Bouaké, and Daloa. This study aims to fill the knowledge gap regarding the traditional use of insects for medicinal purposes in these localities and contribute to a better understanding of this ancient yet often overlooked practice in Ivorian traditional medicine.

Materials and Methods

Study area

The study area encompasses three distinct cities: Bondoukou, Bouaké, and Daloa, situated in geographically diverse regions of Côte d'Ivoire (Figure 1). Bondoukou (8.03° N, 2.8° W) is the capital of the Zanzan district and the administrative center of the Gontougo region, an area characterized by a tropical climate. This province experiences high temperatures throughout the year, with a distinct dry season and a rainy season conducive to wooded savannah vegetation. Abundant precipitation contributes to fertile lands, thereby influencing the region's biodiversity. Bouaké (7.69° N and 5.03° W) the capital of the Vallée du Bandama district and the administrative center of the Gbêkê region shares similar characteristics with Bondoukou, with a tropical climate characterized by high temperatures year-round. Wooded savannah vegetation predominates in this region, where moderate precipitation defines the rainy season. Daloa (6.87° N, 6.45° W) from Haut-Sassandra region also experiences a tropical climate, characterized by constant high temperatures. However, this city is different from Bondoukou and Bouaké due to abundant annual precipitation that influences the diversity of its vegetation, primarily composed of tropical forests.

The selection of these regions was motivated by several criteria, including demographic diversity, cultural differences, medicinal practices, and dietary habits, such as insect consumption among the residents (Boko & Angaman 2021). Furthermore, these areas are characterized by a pronounced cosmopolitanism, hosting communities with diverse dietary and medicinal traditions (Ehounou *et al.* 2018, Gogbé 2011). These urban centers thus provided a diverse range of cultural and environmental contexts for the conducted study.

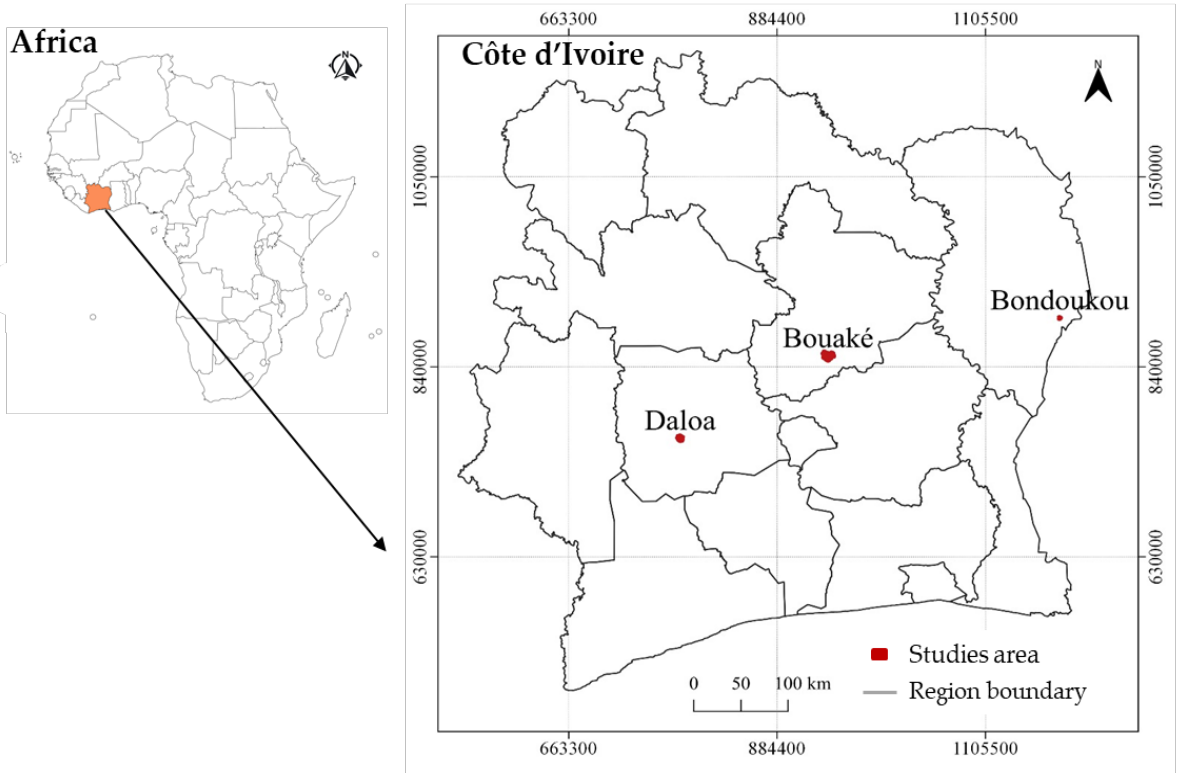

Figure 1. Map of the study area showing the three surveyed localities

Ethical considerations

The ethical points addressed included obtaining informed consent from participants, ensuring confidentiality and anonymization of personal data, as well as respecting local traditions and preventing exploitation. This protocol was formally approved by Université Jean Lorougnon Guédé and community leaders, ensuring that the study adheres to ethical standards. Each participant was carefully informed about the study's objectives, methodology, and the use of collected data. Their voluntary and informed consent was obtained before their participation.

Data collection

A comprehensive field survey was carried out within households located in the three cities indicated above between March and August 2022. A systematic approach was employed, involving a randomized selection of households from diverse neighborhoods, ensuring a well-rounded representation. Key informants, aged over 18, were selected from within these households. The primary objective of this survey was to evaluate the prevailing understanding and application of entomotherapy, collate an inventory of insects utilized as remedies, and gain insight into the diverse methodologies of preparation, administration, as well as the perceived motivations and outcomes associated with these practices.

A structured questionnaire, designed to cover a wide range of topics, was administered to the participants. In addition to gathering sociodemographic information such as gender, age, ethnicity, occupation, and level of education, the form also addressed the following aspects: types of insects used, treated pathologies, methods of preparation and administration, conditions of use, as well as user feedback categorized by their satisfaction levels (unsatisfied, somewhat satisfied, satisfied, and very satisfied). Individual interviews primarily conducted in French with the assistance of a competent interpreter were employed when necessary to accommodate local languages. Additionally, a sheet containing photographs illustrating certain medicinal insects and their products was provided to complement the questionnaire. The responses obtained were meticulously collected in accordance with the questionnaire to ensure precise and exhaustive data collection. Lastly, the mentioned insect specimens were collected and preserved in alcohol for identification in close collaboration with Dr. Tano Kevin, entomologist at the Jean Lorougnon Guédé University of Daloa, Côte d'Ivoire (Scholtz 2016).

Data Analysis

The data collected in this survey were initially analyzed using Sphinx software, version 4.5. Subsequently, these processed data were exported to Microsoft Excel (version 2016) for further analysis within the R 4.2.2 environment via RStudio. Various R packages such as questionr, gtsummary, ggplot2, and GGally were utilized to generate contingency tables. Independence tests between variables were conducted using the chi-square test ($\chi 2$), while Pearson's chi-square residuals were calculated to more accurately determine proportions affected by statistically significant differences.

Additionally, a precise methodology was followed to transform the data into Use Reports (Chellappandian *et al*. 2012). For instance, when an informant recommended the use of a specific species, such as 'A' to treat disease 'x', it resulted in the drafting of a single Use Report (UR). However, if this informant advocated for 'A' in treating both 'x' and 'y' diseases, it led to the creation of two distinct reports.

Results

Sociodemographic characteristics of the participants

The study involved a total of 612 participants distributed as follows: 208 in Daloa, 303 in Bouaké and 101 in Bondoukou (Table 1). These participants aged between 19 and 80 years old, had an average age of 42.5 years and a median age of 43 years. They belonged to 32 distinct ethnic groups, grouped into five categories, among which the Akans (29.73 %) and the Voltaics (25.32 %) were the most represented. Specifically, the Baoules (21.0 %), Agnis (3.4 %), and Abrons (2.1 %) were the most represented groups among the Akans, while the Senoufos (8.5 %), Lobis (7.0 %), and Koulangos (6.5 %) predominated among the Voltaics. Furthermore, other ethnic groups such as the Mandés (Malinkés, Bambaras, and Dioulas) and the Krous (Bétés, Yacoubas, Wès, Didas, and Gouros) were recorded in significant numbers, accounting for 20.3 % and 13.9 % respectively. The group of foreigners (non-Ivorian citizens), consisting of individuals from countries in the West African sub-region, namely Burkina Faso, Mali, Guinea and Benin, accounted for 10.8% (n=66) of the surveyed sample. The participants belonged to various professions, and over a third of them (34 %) had not received any formal education.

Table 1. Socio-demographic profile of 612 participants across three localities in Côte d'Ivoire

Characteristics	Frequency	Percent (%)
Gender		
Male	303	49.5
Female	309	50.5
Age		
18-30 years	111	18.1
31-45 years	262	42.8
46-60 years	181	29.5
Over 60 years	58	9.4
Educational level		
Illiterate	208	34.0
Primary school	137	22.4
Secondary school	164	26.8
University	103	16.8
Ethnic group		
Akan	182	29.7
Mandés	124	20.3
Voltaïque	155	25.3
Krous	85	13.9
Foreigners	66	10.8
Occupation		
Farmer	93	15.2
Merchant	148	24.2
Artisan	104	17.0
Student	56	9.1
Unemployed	113	18.5
Retired	11	1.8
Civil servant	87	14.2
Locality		
Bondoukou	101	16.5
Bouaké	303	49.5
Daloa	208	34.0

Knowledge of entomotherapy among the surveyed individuals

Among all the study participants, only 87 individuals, comprising 14 % of the sample, possess knowledge about insects used for medicinal purposes or entomotherapy. A statistical analysis employing the chi-square test revealed a significant association between this knowledge and the geographical location of the respondents ($\chi2$ = 27.145, df = 2, p-value = 1.275×10^{-6}): individuals from the Bondoukou region exhibit a higher level of information (30.7 %) compared to other regions (Figure 2). Furthermore, this disparity in knowledge is noteworthy concerning age ($\chi2$ = 8.347, df = 3, p-value = 0.03936), ethnicity ($\chi2$ = 20.208, df = 4, p-value = 0.0004542) and the respondents' occupations ($\chi2$ = 15.011, df = 6, p-value = 0.02017). For instance, older individuals seem to possess a more comprehensive understanding, with rates of 18.2 % for the age group of 46 to 60 years and 20.7 % for those over 60 years old. Regarding ethnicity, the Voltaic and Akan groups stand out with respective knowledge levels of 22.6 % and 17 %. Regarding occupations, farmers and unemployed individuals are the most informed displaying rates of 22.8 % and 19.5 %, respectively. An interesting observation was that a higher proportion of individuals with knowledge about medicinal insects belonged to the non-schooled category (illiterate). Finally, participants indicated that their knowledge about medicinal insects primarily comes from familial transmission (71 %) and social circles (29 %).

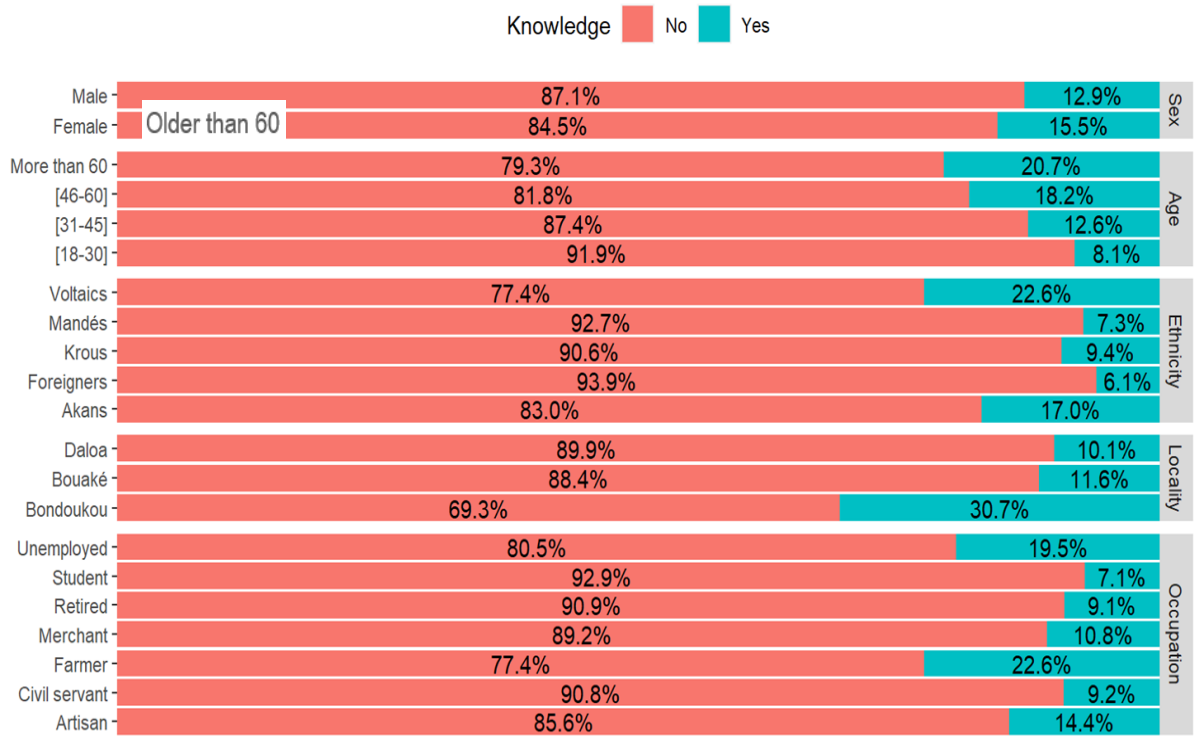

Figure 2. Entomotherapy awareness level based on gender, age group, ethnicity, locality, and occupation of surveyed individuals

Practice of entomotherapy among the surveyed individual

Among the subset of respondents with knowledge of medicinal insects, nearly half (n=42, 48 %) claimed to have previously used this form of therapy. However, this practice is not regular in the majority of cases, as most of these users have resorted to entomotherapy once or twice in their lifetime, representing 42.5 % and 37.5 % of the respondents, respectively. A minority, comprising 20 % of those who tried this method, reported using it three times or more for medical purposes.

Despite this, the use of insects for medicinal purposes was generally well received by the users. A vast majority of individuals who underwent this therapy, around 65.85 %, expressed satisfaction with 24.39 % even describing it as 'very satisfactory'. However, a small proportion of the sample, approximately 9.75 %, considered this approach to be somewhat unsatisfactory.

It is important to note that no adverse effects were reported for insects other than ants. Respondents who used ants to treat childhood illnesses reported that prolonged treatments lasting over a month could lead to severe behavioral changes in the child, notably marked restlessness.

Medicinal insects inventoried and their therapeutic benefits

In total, 10 species of medicinal insects were reported by the 87 respondents familiar with the use of medicinal insects (Table 2). Among these, an overwhelming majority of 74 individuals mentioned only one species, 10 mentioned two different species, and only three respondents were able to identify up to three species of medicinal insects.

The listed species are distributed among six orders and eight distinct families. Among these orders, Hymenoptera stands out as the most prolific with three notable families: Apidae (*Apis mellifera*, UR=15), Sphecidae (*Sceliphron* sp., UR=12), and Formicidae (*Camponotus* sp., UR=36; *Oecophylla longinoda*, UR=10; *Dorylus* sp., UR=2). Other cited insects belong to the orders Blattodea (*Periplaneta americana*, UR=20), Coleoptera (*Rhynchophorus phoenicis*, UR=3), Isoptera (*Macrotermes subhyalinus*, UR=2), Hemiptera (*Cicada orni*, UR=1) and Mantodea (*Mantis religiosa*, UR=2).

It is noteworthy that most insects, mentioned a limited number of times (UR < 3), are specifically associated with only one of the studied localities (Figure 3). For example, the praying mantis (*Mantis religiosa*, UR=2) is exclusively mentioned in Bondoukou, while *Macrotermes subhyalinus* (UR=2) is solely cited in Daloa. Furthermore, insects like *Dorylus* sp. (UR = 2) and *Cicada orni* (UR =1) are reported only in the city of Bouaké. Only five species, namely *Apis mellifera*, *Sceliphron* sp., *Periplaneta americana*, *Camponotus* sp. and *Oecophylla longinoda*, were mentioned jointly in all three localities, although their occurrences vary considerably. However, despite these disparities, these insects are used for similar medicinal purposes, regardless of the location.

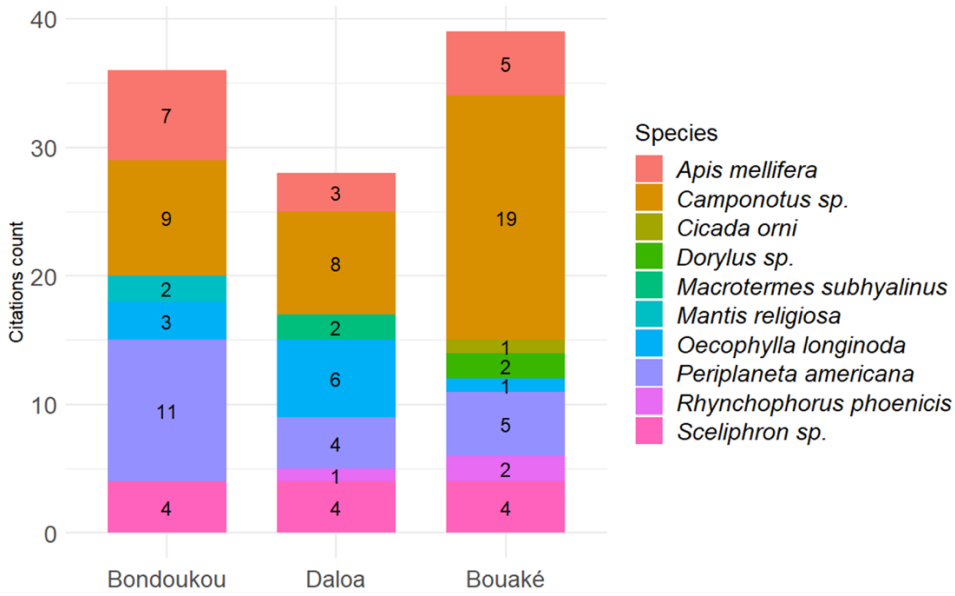

Figure 3. Species citations count across different localities

All of these mentioned insect species and their derivatives are used to treat sixteen different pathologies and symptoms. For instance, infusions derived from black ants and driver ants (*Camponotus* sp. and *Dorylus* sp.) are administered to children to strengthen their immunity and improve their mobility. The infusion made from *Oecophylla longinoda* is known to alleviate various ailments such as cough, fevers, and vomiting. Moreover, it has been reported that regular consumption of this dried insect, combined with raw cassava contributes to the treatment of tremors. Additionally, a poultice made from cockroach (*Periplaneta americana*) is applied to the umbilical cord of newborns to prevent infections and speed up healing. This paste is also used to treat earaches and boils. Palm weevil larvae (*Rhynchophorus phoenicis*), commonly known as "anonkplin" in the Baoulé language, are consumed in various forms to facilitate childbirth. Furthermore, hemolymph extracted from these larvae is mixed with crushed palm heart and applied to treat burns. Other insects such as the termite queen *Macrotermes subhyalinus*, the cicada (*Cicada orni*) and the praying mantis (*Mantis religiosa*) have specific applications in treating hemorrhoids, toothaches and sprains, respectively.

In addition to the insects themselves or their parts, some insect-derived products were also mentioned. Honey, produced by bees (*Apis mellifera*), is used to alleviate sore throats, coughs, and stomach ulcers. The nest of the mason wasp is also used as a remedy for sprains and swelling (Figure 4). It is kneaded with shea butter and applied to the affected area.

Table 2. Medicinal insects and their therapeutic uses reported in the three surveyed localities from Côte d'Ivoire citations count across different localities Medicinal insects and their therapeutic uses reported in the three surveyed localities from Côte d'Ivoire

Order	Scientific name	Organ or product used	Common name	Vernacular name (Ethnic group)	Use Report (UR)	Preparation Method	Combined With	Route of administration	Therapeutic application
Blattodea									
	Periplaneta americana	Whole (11) Hemolymph (9)	Cockroach	Dalèq (Senoufo)	20	Pulverize into paste or Squeeze to extract hemolymph	Shea butter	Topical (poultice, auricular)	Earache (13) Scar formation (5) Boil (2)
Coleoptera									
	Rhynchophorus phoenicis	Whole (2) Hemolymph (3)	Palm weevil	Anonkplin (Baoulé)	3	Prepared as a soup or swallowed raw	Heart of palm	Oral Topical	Childbirth (2) Burn (1) Cough (1)
Hemiptera									
	Cicada orni	Whole	Mountain cicada	-	1	To chew the live insect with one's teeth.	None	Oral	Toothache (1)
Hymenoptera									
	Apis mellifera	Honey	Bee (Honey)	Wongô (Koulango)	15	Raw form	None	Oral (9) Topical (6)	Cough (5) Scar formation (5) Ulcers (3) Stomachache (2)
	Camponotus sp.	Whole	Little black ant	Tih-trè (Bété)	36	Grind the ants, steep them in warm water for 15 minutes, strain, and administer	Medicinal plants	Anal purging	Infant motor skills (13) Fever (11) Immunity (5)
	Dorylus sp.	Whole	Harvester ant	Danhan (Tagbana)	2	Grind the ants, steep them in warm water for 15 minutes, strain, and administer	Medicinal plants	Anal purging	Immunity (2)
	Oecophylla longinoda	Whole	Red ant	Kacahadjé (Baoulé)	10	Dry the ants, grind them into powder, add the powder to the water, and then filter.	Raw cassava (1)	Oral (4) Anal (6)	Cough (4) Fever (3) Vomiting (2) Tremor (1)

	Sceliphron sp.	Nest	Mason wasp	Kalankâ tièl (Lobi)	12	Mixing the nest with shea butter and applying it to the affected area	Shea butter	Topical (massage or poultice)	Sprain (8) Swelling (4)
Isoptera	*Macrotermes subhyalinus*	Whole	Termite queen	Louh (Bété)	2	Raw form	None	Oral (swallow)	Hemorrhoid (2)
Mantodea	*Mantis religiosa*	Whole	Praying mantis	Assi Congo (Baoulé)	2	Walk the live praying mantis over the affected area	None	Apply to the affected organ	Sprain

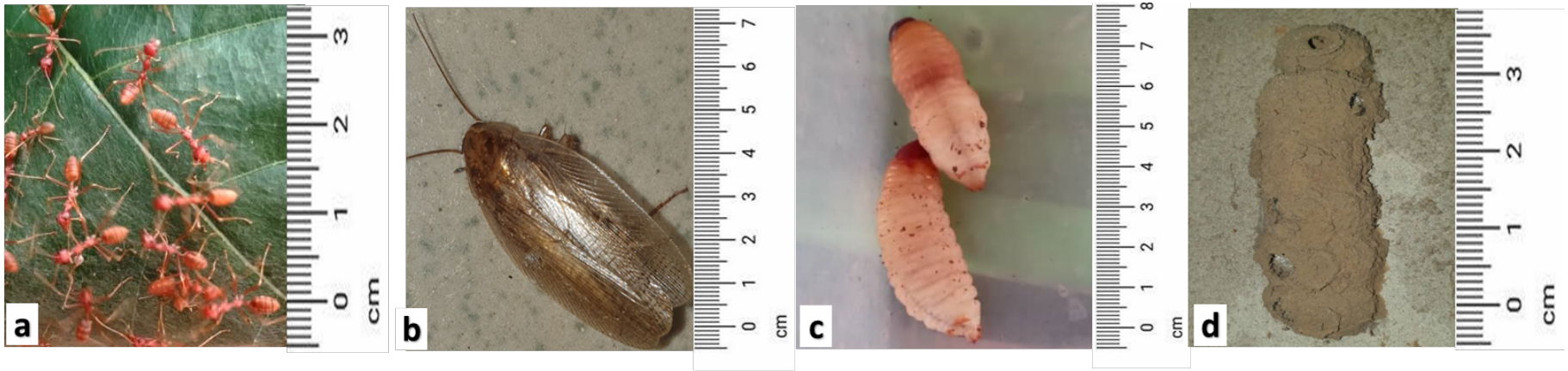

Figure 4: Photographs of the most cited medicinal insects found in the three localities. **a**: *Ocoephylla smargdina*; **b**: *Periplaneta americana*; **c**: *Rhynchophorus phoenicis*; **d**: *Sceliphron* sp. nest

Forms of use and administration route

The majority of mentioned medicinal preparations rely on the use of the whole insect (65 %). However, the use of other products such as hemolymph (9.7 %), nest (11.6 %) or honey (14.6 %) have been also reported. These components are used individually or in combination with other local products, including medicinal plants or shea butter. Insect-based remedies are employed in the form of infusion (43.1 %), crushed (21 %) or in their raw state (29.4 %). In other cases, they are used alive (3 %) or consumed as soup (3 %) (Figure 5). These diverse preparations are generally administered anally (38.9 %), topically (28.4 %), orally (18.9 %), and auricularly (13.7 %). However, differences can be observed between the methods of administration and the various medicinal preparations. For instance, administration through the anal route or purging is exclusively reserved for infused forms. To create these infusions, ants, combined with medicinal plants, are ground on a stone and steeped in warm water for about 15 minutes. The liquid is then filtered through cloth and administered into the child's rectum using an enema syringe or a bulb syringe. Raw extracts or crushed forms are applied topically or auricularly. Conversely, oral administration is used for different preparations, except for crushed forms.

Discussion

The use of insects for medicinal purposes remains relatively unknown in the various regions surveyed. Indeed, only 14% (n=87) of the surveyed population is aware of this therapy. These findings, though modest, indicate the existence of this practice in the traditional healthcare systems of local populations, reflecting a similar trend observed in many other African countries, especially in the West African sub-region, including Burkina Faso, Benin, and Nigeria (Lawal & Banjo 2007, Loko *et al*. 2019, Ouango *et al.* 2022).

The irregularity observed in the practice of entomotherapy is often attributed to the seasonal availability of certain species of medicinal insects. The challenges associated with this seasonal availability are illustrated by comments collected during the survey, such as "they are not easily found" or "they are difficult to collect". Thus, the unavailability of medicinal species during certain seasons limits access to essential medicinal insects, thereby hindering the continuity of traditional treatments. Local populations adapt their medicinal practices based on the availability of insects, demonstrating a deep understanding and adaptation to natural cycles (Lawal & Banjo 2007). For example, in Nigeria, Fasoranti and Ajiboye (1993) reported that termites, particularly valued for their medicinal properties, are more abundant during the rainy season. Similarly, in Benin, Loko *et al*. (2019) noted that caterpillars and grasshoppers, used to treat various illnesses, are mainly available during the rainy months, thus influencing their incorporation into traditional medicinal practices. A better understanding of these seasonal dynamics could contribute to improving the documentation and preservation of traditional medicinal practices, while also enabling better management of the natural resources used in entomotherapy.

It is noteworthy that residents of Bondoukou appear to have a better understanding of entomotherapy, likely due to the traditional medical practices within the local Voltaic community (Silue 2021). This observation underscores the importance of intergenerational transmission of traditional medical knowledge in African cultures. Furthermore, this community, originating from the former Republic of Upper Volta, now Burkina Faso, where the practice of entomotherapy has been documented (Ouango *et al*. 2022), has likely preserved this medical practice over time through migration and settlement in new regions. This dynamic highlights the resilience and persistence of medical traditions, even in the face of social and environmental changes. These findings underscore the importance of cultural and historical contexts in perpetuating traditional medical practices, including entomotherapy, across borders and generations in Africa.

The distribution of medicinal insects in this study reveals a predominance of Hymenoptera, with 5 out of 10 identified species. This trend is found in various African cultures, highlighting the considerable therapeutic importance of Hymenoptera. For example, in Burkina Faso, Ouango *et al*. (2022) identified 8 species of Hymenoptera among the 19 medicinal insects recorded in the provincial communities of Houët and the Indian Ocean. In Cameroon, Tamesse *et al.* (2018) reported that ants and bees are commonly sold by traditional healers and used to treat various diseases, including rheumatism, chickenpox, spleen inflammation, umbilical hernia, mumps, cramps, and weak bones. This therapeutic importance of Hymenoptera is not limited to Africa. In India, among the Nagas, Mozhui et al. (2021) documented that Hymenoptera represent 20% of the 11 orders of medicinal insects. Similarly, in South America, Costa-Neto (2005) recorded 9 distinct orders of medicinal insects in the traditional medicine of Bahia, Brazil, among which 22 species were Hymenoptera.

To better understand the sociocultural context of the use of immunity in the use of ants in children, we further discuss our results here. The use of ants (*Camponotus* sp.*, Dorylus* sp. and *Oecophylla longinoda*) infusions for enemas in children is based on the belief that this practice offers protection against childhood diseases and promotes rapid mobility acquisition, thereby preventing developmental delays. Mothers associate the sickly nature and motor difficulties of walking-age children

with a weakened immune system. This belief is expressed through phrases such as "he/she is always sick" or "he/she is too calm." Ants, combined with medicinal plants, are crushed on a stone and infused in warm water for about 15 minutes. The liquid is then filtered through cloth and administered into the child's rectum using a syringe or enema bulb. This practice is believed to purify the child's body, thereby promoting psychomotor development.

This practice exhibits points of convergence with other cultures. For instance, it has been reported that the Arawaks in Guyana encouraged stings from *Paraponera clavata* (the bullet ant) on their babies to stimulate early walking (Costa-Neto 2005). Loko *et al.* (2019) reported the use of the ant *Oecophylla longinoda* in the treatment of hypertension and body pains in Benin, while among the Nagas, a boiled decoction of *Oecophylla smaragdina* is orally administered to treat cough and fever (Mozhui *et al.* 2021). In China, ant medicine is renowned for its effectiveness in treating various issues related to the liver, sexual function, and cancer (Choudhary *et al*. 2022). The medical importance of these animals and their use in different traditional pharmacopeias around the world are crucial aspects to consider for new advancements in pharmacology.

The therapeutic use of the American cockroach, *Periplaneta americana*, in the treatment of skin conditions such as boils, earaches, and wound healing, is a well-established traditional medicinal practice due to its potential antibacterial effects. This approach finds logical justification in the lifestyle of cockroaches, which thrive in often unsanitary conditions, enabling them to develop a natural immunity against bacteria (Dossey 2010). Despite the occasionally folkloric perceptions associated with its use, scientific studies have revealed that the hemolymph of *Periplaneta americana* contains bioactive compounds, notably antimicrobial peptides, which demonstrate effective antibacterial activity against pathogens such as *Escherichia coli* and *Micrococcus luteus* (Basseri *et al.* 2016, Martin & Channe 2020). These findings support the traditional use of the American cockroach in folk medicine and highlight its real therapeutic potential, while paving the way for further research to better understand its mechanisms of action and clinical efficacy.

The larvae of the species *Rhynchophorus phoenicis*, also known as palm weevils, are cited for the treatment of cough and burns. Similar uses have been reported among certain Indian tribes, where they are used to relieve cough and body pains (Posey 2003). In Benin, the adults of this species are used to treat headaches, dental caries, and fever (Loko *et al.* 2019). A recent study demonstrated that the hemolymph extracted from the larvae of this species possesses antibacterial activity against six strains, including *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* spp. (Kambou *et al*. 2023).

The therapeutic use of the queen termite *Macrotermes subhyalinus*, noted for the treatment of hemorrhoids, aligns with its broader applications in traditional medicine. Queen termites are highly prized in African pharmacopeias for their aphrodisiac effects (Motte-Florac & Le Gall 2022). Among various communities such as the Nagots in Benin, the Wolofs in Senegal, and the Shonas in Zimbabwe, these queens are recognized for enhancing virility. Concurrently, among the Yorubas in Nigeria and the Kabayes in Togo, they are reputed to improve female fertility (Motte-Florac & Le Gall 2022). In China, it has been observed that some people, intrigued by their aphrodisiac properties, consume them with a bit of alcohol or soak them in alcohol before ingestion (Durst et al. 2010). The convergent use of queen termites in Asia and Africa to improve general health, fertility, or as an aphrodisiac could be attributable to their richness in ecdysteroids. These compounds have the ability to stimulate protein synthesis in humans and may offer anabolic effects, thereby enhancing physical performance and endurance (Lupoli 2010).

The cicada (*Cicada orni*) and the praying mantis (*Mantis religiosa*) are also used by some of the surveyed individuals to respectively treat toothaches, earaches and sprains. In a review of insects used as remedies in different human cultures, the use of cicada *Huechys sanguinea* was also reported to alleviate migraines and ear infections in various Chinese provinces (Fujian, Guangdong, Guangxi, Jiangsu, Sichuan, Zhejiang) (Bairagi 2019). Another author mentioned the use of the praying mantis as a remedy, although it is more commonly associated with the treatment of other conditions such as fever, beriberi, toothaches, as well as hair and respiratory problems (Meyer-Rochow 2017).

Just as insects in their entirety or their components, certain derivatives from insects are used for therapeutic purposes. A notable example is honey, a product crafted by bees, widely recognized for its numerous healing properties. Surveyed populations utilize it to treat coughs and stomach ailments, uses supported by scientific evidence of effectiveness (Meyer-Rochow 2017, Balas 2015). Nowadays, honey is included in the composition of various pharmaceutical products due to its antimicrobial, antitumoral and anti-inflammatory properties (Balas 2015, Fauzi *et al.* 2011). However, it is important to note that these results primarily come from in vitro studies and animal models, and further research is needed to confirm these effects in humans.

In addition to honey, the nests of mason wasps are also used as therapeutic agents to treat sprains and swelling. In comparison, nests of potter wasps, *Eumene sp.*, have been reported to be used by the Mishings and the Bodos and other Assamese tribes from India to alleviate headaches and burns. The pharmacological properties of wasp nests come from the constituent elements of the nest, particularly the clay and the wasp saliva (Wenzel 1998). Clay is highly valued for its diverse pharmacological properties, particularly in reducing inflammation and alleviating pain associated with sprains (Lefief-Delcourt 2012). As for wasp saliva, it consists of a complex mixture of chemical compounds such as enzymes, proteins, and biogenic amines, possessing various biological properties such as analgesic, anti-inflammatory or antimicrobial effects (Beaudouin *et al.* 2022).

The diversity observed in insect-based medicinal formulations is also reported in various communities, such as those in the Plateau department in Benin, among the Yoruba people in Nigeria, and among the Nagas in northeast India (Lawal & Banjo 2007, Loko *et al.* 2019, Mozhui *et al.* 2021). This variety of practices highlights the importance of biodiversity in traditional medicines, especially when combining insects with other local resources such as plants. This approach demonstrates a deep understanding of nature and interactions between different species, thus strengthening the connection between humans and their environment (Barbosa *et al.* 2018).

The surveyed populations have developed specific preferences regarding the application of insect-based remedies. Topical application is preferred for targeted conditions, likely because it allows direct contact with the affected area (Barbosa *et al.* 2018). On the other hand, anal administration is preferred for treating more systemic health issues or for overall health maintenance. This practice is commonly used in Côte d'Ivoire for administering traditional remedies, notably to treat digestive disorders and infertility problems (Ambe *et al.* 2015, Moyabi *et al.* 2021, Yapi & Zirihi 2015). Additionally, it becomes an alternative for children when oral administration is impossible, especially in cases of refusal or vomiting.

In most cases, these remedies are administered by the mothers or grandmothers of the children, considered as the custodians of this ancestral knowledge, thus passing down these practices from generation to generation. However, a reported adverse effect of this practice involving ant infusions is that prolonged treatments, exceeding, for example, three months, can make the child very restless and difficult to control in the future. This observation underscores the importance of examining the long-term effects and socio-behavioral implications of administering traditional remedies through unusual routes such as anal administration.

In modern biomedical practices, anal administration is contraindicated in cases of rectal lesions, in immunocompromised individuals, and often requires dosage adjustment as well as special precautions in children to prevent trauma (Santé (AFSSAPS) 2009). However, it is interesting to note the points of convergence between these traditional practices and modern biomedical practices. For instance, rectal or anal administration is recommended for severe nausea, vomiting, or swallowing difficulties, as well as for local treatments of inflammatory rectal conditions or hemorrhoids (Macy *et al.* 2023, Kestenbaum *et al*. 2014). This method also offers the advantage of rapid absorption of active ingredients, thus bypassing potential degradation of drugs by digestive enzymes and the liver (first-pass effect) (Hahn *et al*. 2000). These convergences and divergences between traditional practices and biomedical approaches underscore the importance of understanding the socio-cultural contexts and local perceptions of health and disease for effective and respectful medical care of traditions.

In summary, although entomotherapy is relatively underutilized in the studied areas, it represents a potential medicinal resource deserving increased scientific attention for documentation and preservation. These findings underscore the need for further research to document these traditional knowledge systems while exploring their pharmacological potential (Kutalek and Kassa 2005).

Conclusion

This is the first study focusing on the use of insects in traditional medicine in Côte d'Ivoire. Among the 612 participants from the localities of Bondoukou, Bouaké, and Daloa, only 14 % (N=87) identified at least one insect species used for medicinal purposes, with a maximum of three insects mentioned per person. These respondents use 10 medicinal insects to treat 16 different pathologies and symptoms. These insects are used in the form of infusions (43.1 %), powders (21 %), or whole (29.4 %), often combined with plants or other local resources. Regarding administration, these insects are generally used anally (38.9 %), topically (28.4 %), orally (18.9 %), or auricularly (13.7 %). Although not common in these regions, this practice is present in Ivorian pharmacopeia and highlights the importance of preserving traditional medical practices within the

community. The diversity of insects, their therapeutic applications, and the different methods of preparing and administering remedies highlight the potential pharmacological properties of medicinal insects.

The use of insects in traditional medicine provides a unique perspective on the potential therapeutic benefits that these organisms can offer, justifying increased attention and research in the field of entomotherapy. Exploring the taboos or religious restrictions related to the use of insects in medicine in future research could provide an interesting perspective, as it may reveal important nuances in ethnomedicinal practices. However, thorough pharmacological and clinical studies are needed to evaluate the effectiveness and safety of remedies based on medicinal insects. This research could pave the way for integrating these traditional practices into modern healthcare, offering new perspectives for the treatment of various conditions. Since medicinal insects are directly collected from nature, systems for breeding medicinal insects should be considered to promote the conservation of insect biodiversity and ensure their sustainable use in traditional medicine.

Declarations

List of abbreviations: UR: Use Report

Ethics approval and consent to participate: Verbal prior informed consent was obtained from each informant during the survey.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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