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Review

African palm ethno-medicine

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ABSTRACT

Ethnopharmacological relevance: This study is the first to demonstrate the breadth and patterns of the medicinal applications of African palms. It sheds light on species with the potential to provide new therapeutic agents for use in biomedicine; and links the gap between traditional use of palms and pharmacological evaluation for the beneficial effects of palm products on human health. Last but not least, the study provides recommendations for the areas that should be targeted in future ethno-botanical surveys.

Aim of the study: The primary objective of this survey was to assemble all available ethno-medicinal data on African palms, and investigate patterns of palm uses in traditional medicine; and highlight possible under-investigated areas.

Materials and methods: References were found through bibliographic searches using several sources including PubMed, Embase, and Google Scholar and search engines of the State and University Libraries of Aarhus, National Library of Denmark and Copenhagen University Libraries, Harvard University Libraries, and the Mertz Library. Information about ethno-medicinal uses of palms was extracted and digitized in a database. Additionally, we used an African palm distribution database to compute the proportion of palm species that have been used for medicinal purposes in each country.

Results: We found 782 medicinal uses mentioned in 156 references. At least 23 different palm species (some remained unidentified) were used medicinally in 35 out of Africa's 48 countries. The most commonly used species were *Elaeis guineensis*, *Phoenix dactylifera*, *Cocos nucifera*, and *Borassus aethiopum*. Medicinal uses were in 25 different use categories of which the most common ones were *Infections/Infestations* and *Digestive System Disorders*. Twenty-four different parts of the palms were used in traditional medicine, with most of the uses related to fruit (and palm oil), root, seed and leaf. Palms were used in traditional medicine mostly without being mixed with other plants, and less commonly in mixtures, sometimes in mixture with products of animal origin. Future ethno-botanical surveys should be directed at the central African region, because palm species richness (and plant species richness in general) is particularly high in this area, and only few ethno-botanical studies available have focused on this region.

Conclusion: The wide time span covered by our database (3500 years) shows that African palms have been used medicinally by many societies across the continent from time immemorial until today. Most medicinal use records for African palms were found in two categories that relate to most prevailing diseases and disorders in the region. By analyzing ethno-medicinal studies in one database we were able to demonstrate the value of palms in traditional medicine, and provide recommendations for the areas that should be targeted in future ethno-botanical surveys.

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1. Introduction

Species of the Palm family (Arecaceae) have played a prominent role for traditional cultures as a source of medicines. They are used throughout tropical and subtropical regions to cure a series of diseases and disorders (Ali, 1999; Bellomaria and Kacou, 1995; Betti, 2004; El-Kamali and Khalid, 1998; Hamill et al., 2003; Nadembega et al., 2011; Zambrana et al., 2007). Likewise, palms support other functions of daily life as they provide raw materials for consumption, construction, manufacture of utensils, etc. (Burkill, 1997; Byg and Balslev, 2001; Johnson, 2011; Lee and Balick, 2008; Macía, 2004; Macía et al., 2011).

Medicinal uses of palms have been reviewed thoroughly for South America (Sosnowska and Balslev, 2009; Macía et al., 2011). As yet, no such survey has been conducted for the African continent. Even though, palm diversity in Africa is relatively poor compared to South America and Asia, the African palm flora has extensive populations of several species and a variety of local uses (Burkill, 1997; Tuley, 1995).

In Africa up to 80% of the human population uses traditional medicine for the management of prevailing diseases (WHO, 2002). Primary health care is practically synonymous with traditional medicine in rural areas. Also, urban residents supplement the care they receive in clinics and hospitals with treatment from traditional healers (Fasola, 2006; Oreagba et al., 2011). Some traditional palm-derived medicines have proven to be pharmacologically effective and we cite a range of pharmacological reports validating traditional use. Yet, countless healing properties of palms remain to be investigated through meticulous laboratory trials.

There is a need to link the gap between existing ethno-medicinal data and potential pharmacological studies to fully investigate beneficial effects of palm-derived medicines on human health.

The primary objective of this bibliographical survey was to combine ethno-medicinal data on African palms, and investigate patterns of palm uses in traditional medicine. We were particularly interested in answering the following questions:

- Which African palm species are most often used for medicinal purposes?
- Which conditions are most commonly treated with medicines derived from palms?
- Which palm parts are most used in traditional medicine?
- How are the remedies prepared and applied?
- What are the distribution and geospatial patterns of medicinal palm uses across the African continent?

We believe that answering these questions will help to identify palm species that have the potential to be explored in future laboratory trials. We also hope to highlight eventual under-investigated areas.

2. Materials and methods

2.1. Data collection

The study embraces ethno-medicinal uses of palms on the African continent. Apart from palms native to Africa the introduced but now naturalized *Areca catechu* and *Cocos nucifera* are included (Tuley, 1995). We found 156 scientific papers and books that provided information on medicinal uses of African palms, dating back to the ancient *Papyrus Ebers* from 1550 BC (described in Ebbell, 1937) and ending up in very recent publications (Vossen et al., 2014). Information was extracted and digitized in a database (Appendix A). References were found through bibliographic searches using several sources including PubMed, Embase, and Google Scholar and search engines of the State and University Libraries of Aarhus, National Library of Denmark and Copenhagen University Libraries, Harvard University Libraries, and the Mertz Library.

Medicinal use record was characterized by each distinctive activity/disorder, plant part used, mode of preparation, application, country of use or ethnic group mentioned for a certain palm species in every publication. Almost all information found was traced back to the primary references; this proved to be important because some of the secondary references did not precisely reflect the information found in the primary sources. Care was taken not to duplicate the same palm use records when they were cited in secondary references and it was unfeasible to access and review the primary source. In case of books searches where the references to primary sources of information were not always given directly in the text, each encountered use record was crosschecked with the bibliography of the book to prevent duplicating the records.

2.2. Data preparation

Palm nomenclature follows the *World Checklist of Palms* (Govaerts et al., 2014), and author names are included in Appendix A. *Borassus* sp. aff. *flabellifer* was updated to *Borassus akeassii* following Bayton (2007). When the scientific name of the palm was not mentioned by the author we attempted to identify the species by the part used. For example, it was assumed that palm oil and palm kernel oil were extracted from the native African oil palm *Elaeis guineensis*, since processing of the fruits for edible oil has been traditionally practiced in Africa for thousands of years (Johnson, 2011; Tuley, 1995). Medicinal uses referring to “coconut” were assigned to *C. nucifera* given the palm is naturalized to the African continent, and there are no other palm species with fruits of similar morphology (Tuley, 1995). Medicinal uses referring to “date” were assigned to date palm *Phoenix dactylifera* since this is the only *Phoenix* sp. occurring in Egypt where the uses came from (Govaerts et al., 2014). Some palms remained unidentified, such as those used for palm wine, which can be produced from several

species including *E. guineensis* and species of *Hyphaene*, *Raphia* and *Phoenix reclinata* (Johnson, 2011).

The information on plant parts used was standardized following Dransfield et al. (2008). When oil was given as a palm part it was assigned to fruit, and when specified as palm kernel oil it was assigned to seed. For sap we specify the origin as stem-sap, flower-sap, etc. Concerning palm wine used as a remedy, we assumed the sap was collected from the cut flower (flower-sap), following the typical practice for palm wine production. The same approach of subcategories was applied for inflorescence.

Country names that are no longer used today, but found in the older literature, were updated to the current names (Fig. 3A).

2.3. Database structure

Data were organized in an excel-spreadsheet (Appendix A). A separate medicinal use record was made for each discrete activity (e.g., hemostatic)/disorder (e.g., hemorrhage), palm-part used, preparation, application, country of use, ethnic group for each palm species in each publication. If more than one palm part was used to treat a disorder and it was not specified whether the parts were used together or separately, the uses based on each part was treated as a separate use record. Preparation methods were divided into three subcategories depending on whether the palm species was used individually, in mixture with other plants, or in mixture with animal parts. Whenever preparation of a palm remedy was not indicated, the use record was treated as individual preparation. In cases where the remedy contained more than one palm species the record was duplicated for each palm species in the mixture and only used quantitatively for the analysis of the number of palm species (marked in the database).

Medicinal uses were organized according to palm species and categories of health disorders following the *Economic Botany Data Collection Standard* (Cook, 1995). Three additional categories were added to the analysis: *Cultural Diseases and Disorders*, *Ritual/Magical Uses*, and *Veterinary Medicines* (Gruca et al., 2014a). This approach entailed duplication of some medicinal use records, but allowed highlighting the significance of the spiritual framework surrounding traditional medicine. Duplicated palm uses were only used for quantifying different use categories and were not included in the quantitative analysis of palm remedies (e.g., the number of palm species, palm parts used, etc.) where each palm remedy was treated as a unit. Each duplicated palm use was marked in the database.

Data for native palm species richness per country across Africa was extracted from a comprehensive database of African palm distribution records (Blach-Overgaard et al., 2010, 2013). The database includes 5569 records derived from multiple sources. Most records are derived from digitalized herbarium records, but private databases and observations, literature surveys and even Google Earth have provided large quantities of data entries in the database. Information on species names combined with the name of country in which the species has been collected or observed was used to sum up the number of species available in each country (species richness). As the database only includes naturally occurring species in Africa we added the countries in which *C. nucifera* is found according the *World Check List of Palms* (Govaerts et al., 2014).

We used the African palm distribution database to compute the proportion of palm species that have been used for medicinal purposes in each country. As *A. catechu* is not included in the African palm distribution database or is registered in Africa by the *World Checklist of Palms* we removed this species from the calculated proportions. We further calculated the proportion of unique medicinal use categories per country out of the total number of use categories registered for the entire continent.

The medicinal palm database was created and analyzed in MS Excel 14.0.0. The maps were created using ArcGIS 10.2.2 (ESRI, Redland, CA).

3. Results and discussion

3.1. Palm species

In total we found 782 medicinal use records for 23 different palm species belonging to 11 genera (some records were only assigned to genus and some to unidentified palm species) (Table 1).

The most used palm, *E. guineensis* (the African oil palm), is native to Africa, but planted throughout the tropics for its oil-rich fruits that are a major source of vegetable oil globally (Balslev et al., 2008; Wahid et al., 2005). The native range of the second most used palm, *P. dactylifera* (date palm), remains uncertain because it has been cultivated for thousands of years, and it is difficult to distinguish between wild and planted populations. The primary use of date palms is for their nutritious fruit (Dransfield et al., 2008; Johnson, 2011). The origin of the third most commonly used palm, *C. nucifera* (coconut), is also not clear, as it is the most widely cultivated palm of all (Dransfield et al., 2008). Two independent origins of coconut cultivation have been proposed in the Pacific and Indian Ocean basins, respectively (Gunn et al., 2011). In the Americas *C. nucifera* is the most commonly used medicinal palm species (Sosnowska and Balslev, 2009) and it is on the US Food and Drug Administration's list of approved nature-derived drugs (Zhu et al., 2011). Commercially, *E. guineensis*, *P. dactylifera* and *C. nucifera*, are the most important species in the palm family (Barrow, 1998).

The extensive use of the most commercial palm species in traditional medicine is driven by various factors. Their cultivation makes them widespread and easily accessible. Abundance and height are the most important characteristics that determine palm use in Ecuador (Byg et al., 2006). More salient species are easier to locate, attract more attention, and are prone to experimentation (Byg et al., 2006). In northwestern South America palm species for which traditional knowledge is widely shared are also the most useful, widespread, common, and therefore widely available palms (Cámara-Leret et al., 2014). The top three medicinal species also have a well-recognized importance as sources of raw materials for consumption, building, and other functions of daily life, and due to their great usefulness they may also be expected to add value in the field of medicine. However, it has to be kept in mind that there are well-defined criteria that are specific for each culture, which leads to the selection of a plant to be used as a medicine (Campos and Ehringhaus, 2003; Heinrich, 2000). Thus, local knowledge about medicinal properties of available species is not necessarily equal in all regions in which they occur. In the study of geospatial patterns in traditional knowledge in northwest South America — a region with high bio-cultural diversity — it was found that most traditional knowledge on medicinal uses of palms is not shared among countries, cultural groups, tribes, communities, or even individuals within them (Cámara-Leret et al., 2014). One species can replace the use of another in a different cultural context, depending on the cultural preferences and history. For example, although *C. nucifera* is valuable on tropical coasts of Asia and the Pacific Ocean, it has much less importance in West Africa where many of its uses are replaced by the native oil palm (Burkill, 1997). This might be an explanation to the widespread use of *B. aethiopum* in traditional medicine. Even though it is not cultivated and does not have a major commercial value, it is distributed across sub-Saharan Africa where, depending on area, it can substitute medicinal uses of the top three commercial species.

In comparison with American palms where 106 (=20%) out of 542 species are used medicinally (Sosnowska and Balslev, 2009),

Table 1
List of palms used in traditional medicine in Africa, including number of medicinal use records and use category(-ies) for each of them.

Palm species[a]	No. of medicinal use records	Use categories[b,c]
Elaeis guineensis	258	**1**, 2, 3, **4**, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 23, 24
Phoenix dactylifera	113	1, **2**, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 22, 23, 25
Cocos nucifera	70	**1**, **2**, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 17, 18, 19, 20, 21, 23, 25
Borassus aethiopum	70	**1**, 2, 3, 4, **5**, 6, 7, 8, 9, 10, 11, 16, 17, 21, 23
Hyphaene thebaica	37	**1**, 2, 3, 6, 7, 9, 10, 12, 13, 14, 19, 24, 25
Phoenix reclinata	32	1, **2**, 3, 4, 7, 9, 15, 16, 17, 18, 19
Areca catechu	24	**1**, 2, 3, 8, 15, 18, 21
Borassus akeassii	22	1, 2, **3**, 5, 6, 7, 8, 18
Chamaerops humilis	16	2, 13, 15
Laccosperma secundiflorum	14	1, 2, 3, 8
Raphia hookeri	14	1, 2, 4, 6, 7, 10, 12, 14, 20
Raphia vinifera	11	1, 2, 4, 6, 11
Raphia sudanica	7	1, 2, 9, 10, 19
Raphia spp.	6	1, 6, 7, 8, 11, 14
Hyphaene coriacea	5	2, 3, 4, 22
Hyphaene petersiana	5	1, 5, 9, 15
Calamus spp.	4	2, 8, 9
Eremospatha haullevilleana	4	1, 2, 7, 10
Eremospatha macrocarpa	4	1
Raphia mambillensis	3	7, 22
Raphia monbuttorum	3	1, 2, 10
Calamus deerratus	2	17, 23
Hyphaene compressa	2	1
Eremosphata sp.	1	1
Hyphaene guineensis	1	10
Laccosperma laeve	1	3
Unidentified palm species	61	1, 2, 3, **4**, 5, 9, 10, 12, 18, 20, 21

[a] Nomenclature follows *World Check List of Palms* (Govaerts et al., 2014) where authors' names for the species can be found.
[b] 1. Infections/infestations. 2. Digestive system disorders. 3. Genitourinary system disorders. 4. Ritual/magical uses. 5. Respiratory system disorders. 6. Pain. 7. Inflammation. 8. Skin/subcutaneous cellular tissue disorders. 9. Injuries. 10. Pregnancy/birth/puerperium disorders. 11. Muscular-skeletal system disorders. 12. Circulatory system disorders. 13. Endocrine system disorders. 14. Poisonings. 15. Veterinary medicine. 16. Nervous system disorders. 17. Nutritional disorders. 18. Sensory system disorders. 19. Blood system disorders. 20. Cultural diseases and disorders. 21. Mental disorders. 22. Neoplasms. 23. Abnormalities. 24. Il-defined symptoms. 25. Metabolic system disorders. The categories follow the *Economic Botany Data Collection Standard* (Cook, 1995) with the addition of Cultural Diseases and Disorders, Ritual/Magical Uses, and Veterinary Medicines following Gruca et al. (2014a).
[c] In bold: most common categories (i.e., more than 20 use records).

we found the proportion of African palm species used medicinally to be higher (23 (=34%) of 65). Therefore, despite much higher palm species richness in the Neotropics, the value of African palms in traditional medicine should not be underestimated based on lower species richness.

While we cannot be certain that all palm uses reported in our study are still applied, the wide time span covered in our database confirms that at least some of them have been practiced throughout the years until today. For example, the ancient *Papyrus Ebers* mentions that dates (*P. dactylifera*) were used against cough in Egypt — and more recent reports mentions it as effective against various respiratory disorders such as asthma (Gill, 1992), sore throat (Ziyyat et al., 1997), bronchitis (Vall Hmeyada, 2009), and tonsillitis (Khalid et al., 2012). Also, decoction from the roots of *B. aethiopum* was reported 85 years ago as used against asthma (Chevalier, 1930) and the same application was confirmed in Ghana a few years ago (Mshana et al., 2000). As the environment is changing human cultures evolve, local people gain new knowledge on plants and their properties not only vertically (from generation to generation) but also horizontally (e.g., from the peers of neighboring ethnic groups) bringing recent innovations to the local ethno-pharmacopeias. New species are constantly described and this review cites the first report on medicinal uses of *B. akeassii* (Yaméogo et al., 2008) which until recently was confused with *B. aethiopum* and *B. flabellifer* (Bayton et al., 2006).

3.2. Use categories

Medicinal palm uses belonged to 25 different categories (some remained unspecified) (Fig. 1).

Our review shows that palms are mostly used for treating conditions in the category *Infections/Infestations*. This corresponds to the distribution of burden of diseases in the African region where infections and parasitic diseases embody the highest percentage (42%) (WHO, 2014). The category was mostly represented by ailments caused by parasites including gastro-intestinal worms and parasitic protozoa (malaria). Most African countries are exposed to 80–100% risk of malaria (Global Malaria Mapper, 2014), and the persistence of disease is due to inadequate vector control and drug resistance (WHO, 2006). We encountered 18 medicinal uses of palms to treat malaria, however, this number may be higher once we take into consideration conditions mentioned only by their symptoms, such as high fever or headache, which are difficult to associate with one particular disease, but could potentially be linked to malaria. Other group of diseases present under the *Infections/Infestations* category was bacterial infections mainly related to sexually transmitted diseases, which are a major health issue in many parts of Africa (Naidoo et al., 2014; WHO, 2012). Although we did not record any direct link of medicinal uses of palms to HIV/AIDS, according to the *Atlas of African Health Statistics* it is the leading cause of burden of disease (WHO, 2014). It is possible that some of the medicinal palm uses may be indirectly linked to HIV/AIDS incidence, given that it increases the prevalence and severity of parasitic, bacterial and viral diseases (Abd El Bagi et al., 2004; Babatunde et al., 2010; Naidoo et al., 2014). For example, it has been recorded that *C. nucifera* fruit was applied on the skin to cure skin rashes associated with HIV/AIDS in Kenya (Nagata et al., 2011).

The second most common medicinal category that palms were used for was *Digestive System Disorders*. We expect that in most African regions ailments in this category are also associated with infestations. That is because the symptoms of parasitic diseases very often include gastro-intestinal disturbances such as diarrhea,

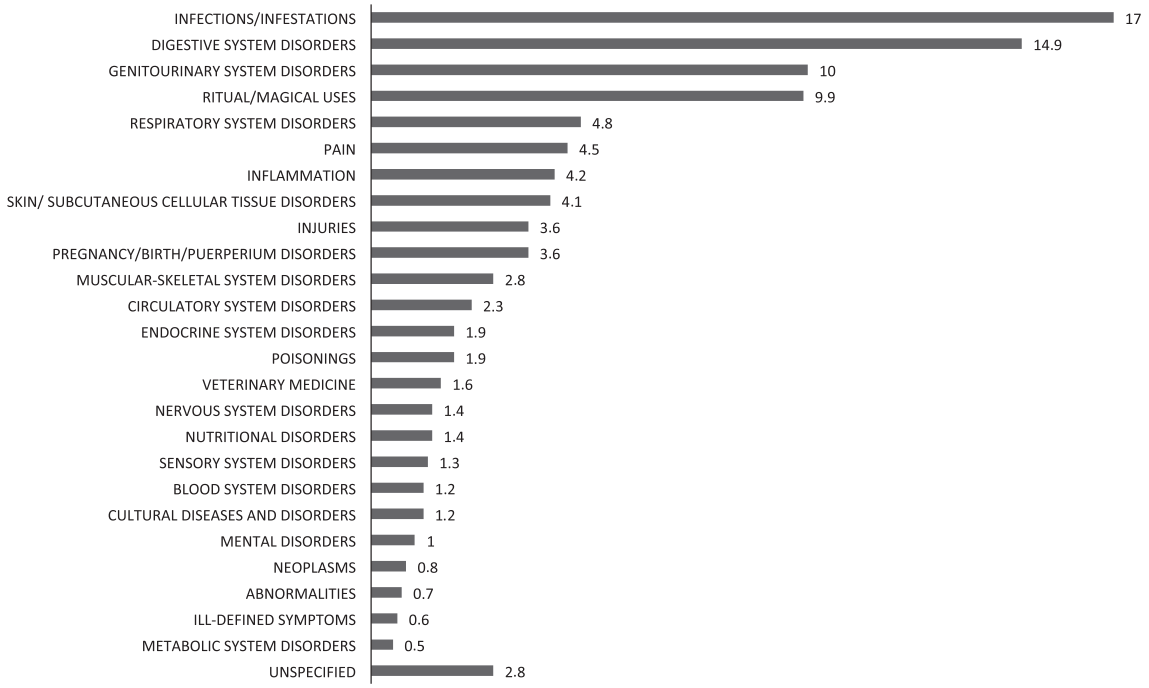

Fig. 1. Percentage (%) of all medicinal use records per use category for African palm species.

dysentery, colic, bowel obstruction, constipation, or jaundice (Abd El Bagi et al., 2004) — and these are ailments that palms were mostly used for under *Digestive System Disorders*. Gastrointestinal disorders were the most frequent ailments treated by palms in America (Sosnowska and Balslev, 2009).

The third and fourth most common use categories for palms were *Genitourinary System Disorders* and *Ritual/Magical Uses*. In the former, palms were mostly used in aphrodisiac preparations, to treat impotence and infertility, as well as menstrual and urinary disorders. In Africa, the stigma of infertility is often associated with profound negative social repercussions, marital instability, and polygamy (Dyer, 2007). It is mostly women who carry the burden of infertility and they can even be accused of witchcraft (Dyer, 2007; Moyo, 2013). Also, men who do not become family patriarchs tarnish their public image, as they are deemed weak and ineffective (Moyo, 2013). Therefore, impotence and infertility are not only seen as physical health limitations, but very often are social and spiritual issues, both in rural and urban areas (Hollos and Larsen, 2008). From this point of view, it is logical that the treatment is sought mostly in traditional medicine (Stekelenburg et al., 2005).

It is noteworthy that once *Ritual/Magical Uses* were added to the analysis, this category was the fourth most prominent among the 25 categories for which palms were used. Palm-derived medicines were reported to work not only upon diseases of the body, but also directly upon people's psyche and emotions. This reflects how important palms are in the spiritual framework of traditional medicine. It is often difficult to evaluate whether the medicine applied has actual active biological compound(s) or its efficiency is mostly based on the "meaning effect" (Moerman and Jonas, 2002). In some recorded rituals, palms played a central role as sacred objects, for example in oracles, offerings, healing ceremonies. In other cases, palms were added as a support to other powerful ingredients, for example palm oil used as a medium to blend and make the healing mixture coherent. Similar palm uses were previously recognized in the study of American palm ethnomedicine under the category of *Social Uses* likewise showing the cultural importance of palms in the healing process (Sosnowska and Balslev, 2009). Local beliefs on health and illness should always be taken into consideration to provide culturally appropriate health care. This is where traditional medicine is many times more adequate and preferred by local people to more impersonal Western approach (Tabuti et al., 2003). The ritual uses of African palms have been thoroughly described and discussed by Gruca et al. (2014b).

3.3. Palm parts used

In total we distinguished 24 different palm parts used in medicines. Most medicinal use records were linked to the fruit, which is also most commonly used for medicinal purposes in the Americas (Sosnowska and Balslev, 2009). Of these, almost half were related to palm oil extracted from *E. guineensis* fruits. Second most popular fruits were dates from *P. dactylifera*. The following parts in order of use frequency were root, seed, and leaf (Fig. 2). Again *E. guineensis* was the most common species for those palm parts and was followed by: *Borassus aethiopum* and *Cocus nucifera* of which the root was used, and *C. nucifera* and *A. catechu* of which the seeds were used. Other palm parts used included flower-sap (in form of palm wine), stem, sap, bud, shoot, inflorescence, palm heart, resin, flower, leaf-fiber, terminal bud sap, male inflorescence, petiole, leaf sap, thorn, entire palm tree (used in rituals), stem sap, radicle, plumule, and spine.

3.4. Preparation and posology

Out of 782 medicinal use records palms were the only ingredient in 68% of the cases. Some palms were used in mixture with other plants (27%), few were used in mixture with products of animal origin (1%) and in mixtures with both plants and animal parts (4%) in order to achieve the best results. Preparations included: decoctions, macerations, infusions, ointments, as well as raw, dried, roasted, and pulverized plant material. In some preparations palms were the fundamental components, and in others they were used as secondary ingredients such as palm oil or palm wine used as medicine carriers or excipients. Palm remedies were applied both internally: drunk, eaten, chewed, or smoked; and externally by: rubbing, embrocation, unction, scarification, baths, drops, massage and poultice.

Even though we achieved an overview of the diversity of ways in which palm medicines are prepared and applied, there was

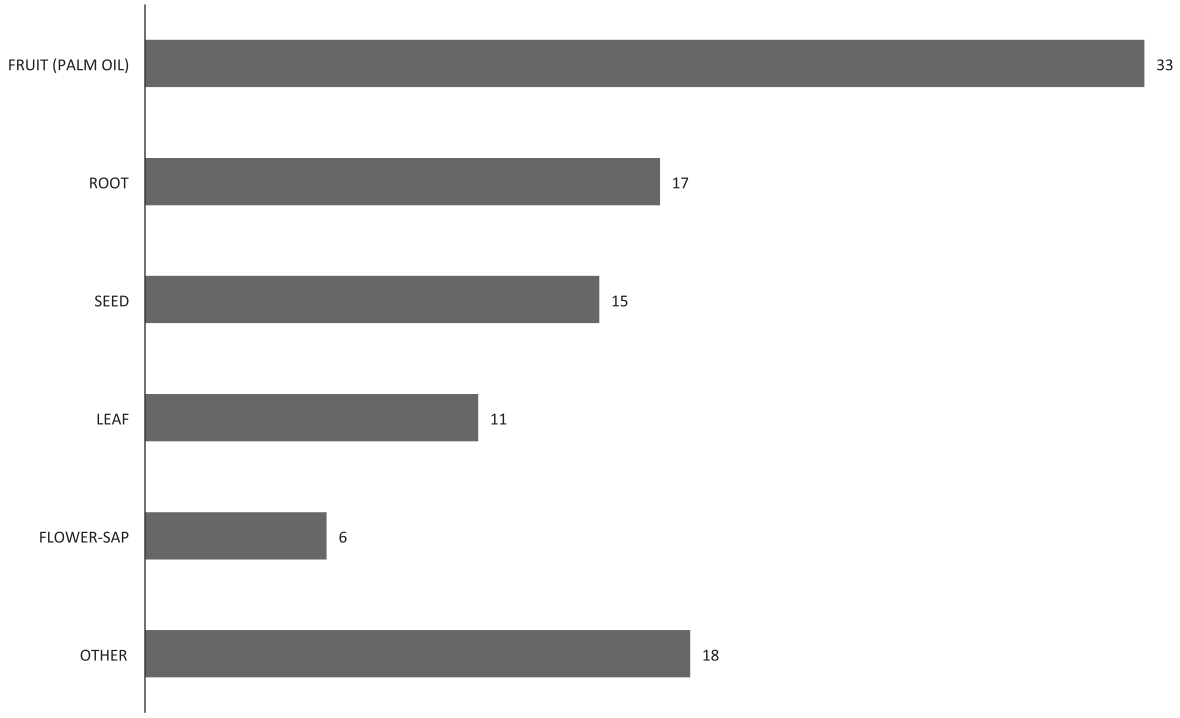

Fig. 2. Percentage (%) of the most common palm parts used in traditional African medicine.

missing information for almost one-third of the use records in terms of preparation and for almost half of the records related to medicinal applications. Many ethno-botanical studies published today include raw lists of plants used medicinally, only indicating which parts are used for what ailments, a problem also noted by Farnsworth (1990). Detailed preparation and application are rarely mentioned. These types of studies do not reveal the ideas underlying the use of the cited medicines nor do they explain why certain plants were selected. It is necessary to include precise medicinal indication for each species in future ethno-botanical studies in order to be able to reproduce the traditional preparations and understand their modes of actions. For example, individuals of the same species collected at different localities, in different seasons, even various times of the day and night or at different stages of growth might have strikingly different levels of active compounds (Jayanthy et al., 2013). In Senegal and Congo, the root decoction of *E. guineensis* was recorded as medicine to prevent abortion when a woman is threatened by miscarriage (Berhaut, 1988; Bouquet, 1969). In Ivory Coast the root in form of ash mixed with salt and fresh pericarp oil was used as ecbolic, which hastens labor or abortion (Kerharo and Bouquet, 1950). Comprehensive information about both the collection and handling of each palm remedy needs to be meticulously recorded.

3.5. Medicinal palm uses distribution

Medicinal palm uses were recorded for 35 of the 48 African countries (Fig. 3B). Most references to medicinal palm uses were found in the three neighboring countries: Nigeria, Cameroon, and Benin. The highest number of use records came from Nigeria, which was the most studied country, followed by Senegal, Cameroon and Benin. It was noteworthy that over 50 medicinal use records came from Liberia where only one source of information (Harley, 1970) was found. Much data came from classic anthropological work that embraced the entire native African tribe, and the best accounts of traditional medical practices come from those authors who spent years among the local people. Although it is demonstrated which of the countries are most likely understudied, it is also apparent that not only the number of references but also the type of source matters (Fig. 3B). Relatedly, Egypt showed high number of medicinal use records, however, almost all of them came from the ancient source — *Papyrus Ebers* — that embraces herbal knowledge dating back to ca. 1550 BC.

Liberia and Egypt (next to Nigeria) were also countries where the most of unique use categories were recorded, although only two and four palm species were used in these countries, respectively (Fig. 3C). The highest number of palms species used medicinally was found in Senegal, Nigeria, Cameroon, Togo, and Ghana.

In relation to the number of palms available we found that only a low proportion of palms was used in Angola, Democratic Republic of Congo, Gabon, Equatorial Guinea, Cameroon, Ivory Coast, Liberia, Sierra Leone. The highest proportion of available palms were in northern Africa (Fig. 3D). However, in this climatic zone the biodiversity is low and available resources are more likely to be fully exploited (Fig. 3D). For example, in Egypt the few available palm species supplied traditional medicines belonging to over 60% of the recorded use categories (Fig. 3C).

In western and central Africa biodiversity is high (Barthlott et al., 2007), and it can be expected that many other plant families substitute or complement medicinal uses of palms. For example, in the most investigated country — Nigeria (Fig. 3B) — still less than half of the available palm species were used in traditional medicines (Fig. 3D). Nevertheless, most of the medicinal palm uses and unique use categories were still recorded from western coastal areas (Fig. 3C). The diversity of medicinal uses of palms can be explained by two complementary factors. On one hand, the high species richness in these areas allows access to a wide array of potential resources. On the other hand, the great diversity of ethnic groups favors equally diverse ethno-botanical knowledge. We found evidence of palms used medicinally by 46 ethnic groups in West Africa, however, many publications did not mention the ethnic group and we expect the ethnic diversity to be much higher than what appears from our database. If we take linguistic diversity as a proxy of cultural diversity, western coastal Africa is where the highest density of languages occurs (Stepp et al., 2004). For example, Nigeria where the diversity of medicinal palm uses was the highest has also the

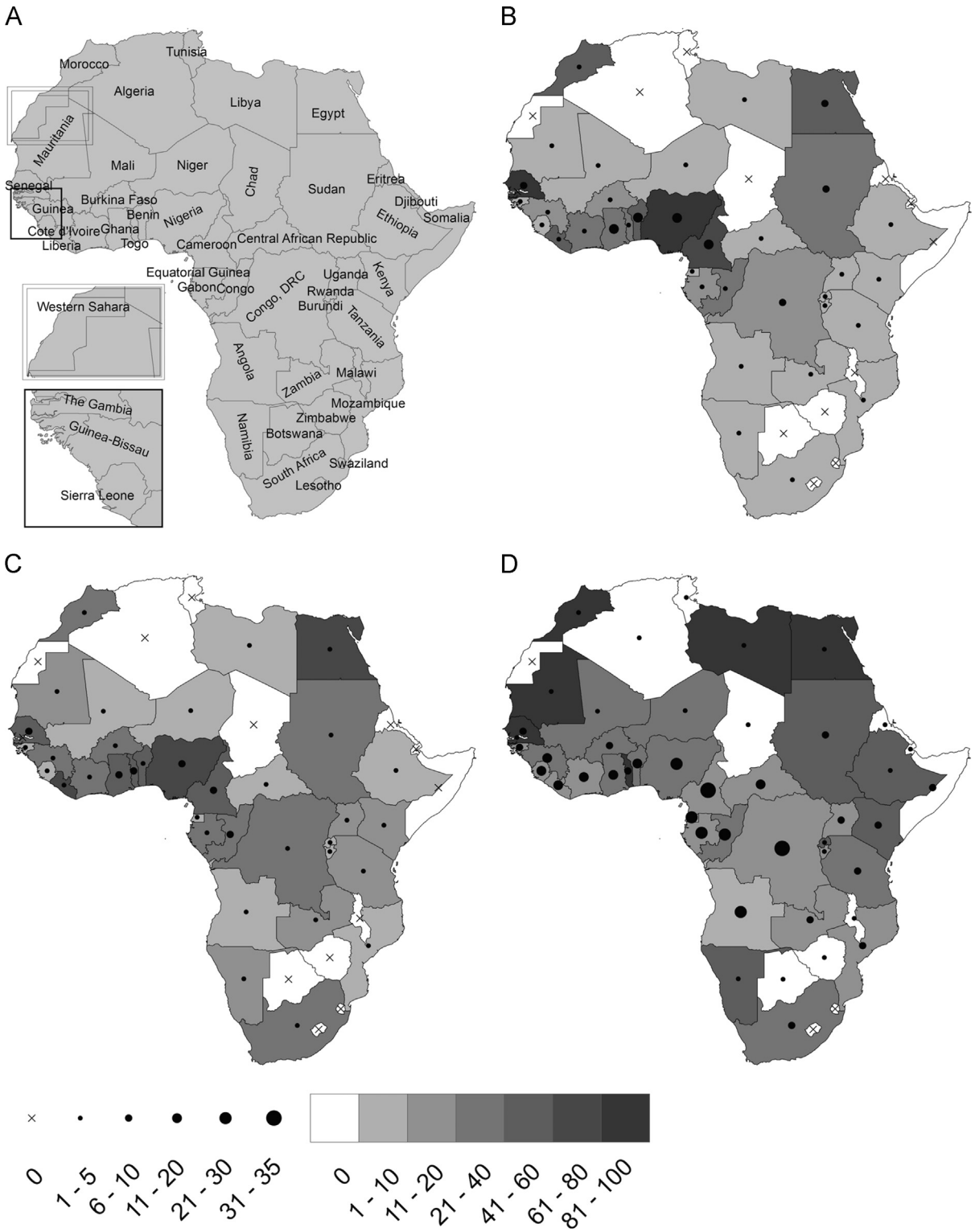

Fig. 3. Country-level spatial patterns of medicinal uses of palms across Africa (B)–(D): (A) overview map of the African countries, (B) number of medicinal use records related to the number of references, (C) the proportion of unique medicinal use categories out of the total of 25 use categories recorded, and related to the number of palm species used medicinally and (D) the proportion of palm species used medicinally out of the number of available palms related to the overall palm species richness. Color gradient (gray) indicates number of medicinal use records (B) or proportions expressed in % (C) and (D). Dots indicate numbers of references (B) or number of palm species (C) and (D)

highest number (522) of different languages spoken on the African continent (Ethnologue, 2014). If *there is an inextricable link between biological and cultural diversity* (Declaration of Belem, 1988), we would also expect a linkage between cultural diversity and the diversity in traditional ethno-botanical knowledge.

In other areas, like central Africa, we could not easily determine how many of the available palm species were used medicinally, as there were only few ethno-botanical studies available (Fig. 3B). Some of the areas with high species richness were certainly under-investigated. For example, although the Democratic Republic of Congo is rich in

Table 2
Pharmacological validations related to some ethno-medicinal uses of the most popular palm species in traditional medicine in Africa: *Elaeis guineensis*, *Phoenix dactylifera*, *Cocos nucifera*, and *Borassus aethiopum*.

Palm species	Ethno-medicinal uses	Pharmacological validation
Elaeis guineensis	Decoction from young palm leaf and palm heart was drunk in Nigeria for treatment of gonorrhea (Ainslie, 1937). In Rwanda, a spoonful of palm oil was heated and applied on the tongue and gums to treat candidiasis in children (Kamilindi, 1950).	*In vitro* as well as *in vivo* studies have shown that the leaf extract exhibits excellent antimicrobial activity, effective against both the bacterial and fungal infections; and especially against the yeast *Candida albicans* that is the most abundant species affecting humans (Chong et al., 2008; Vijayarathna et al., 2012).
	The powder from the leaves was used in Ghana to treat chronic wounds (Agyare et al., 2009). The juice from young petioles was used to treat cuts in Gabon (Walker, 1953). A drink prepared from powdered leaves was applied in Benin as a hemostatic (Adjanohoun et al., 1989).	*E. guineensis* leaf extract was shown to have potent wound healing capacity promoting a better wound closure and improved tissue regeneration (Sasidharan et al., 2012).
	Decoction from the leaf was administrated orally to treat liver diseases in Morocco (El-Hilaly et al., 2003).	Methanol extract from the leaves was proven to be an effective hepatoprotective agent (Sasidharan et al., 2009).
	Decocted roots were ingested to treat malaria in Ghana (Asase et al., 2010).	The ethanol leaf extract was shown to be highly active against the chloroquine-resistant strain of *Plasmodium falciparum* (Annan et al., 2012). It might be that the same compounds responsible for antiplasmodial activity are also found in the roots.
Phoenix dactylifera	The fruit was used in Nigeria to treat liver disorders (Gill, 1992).	The aqueous dates extract was proven to have hepatoprotective activity, and suggested as a prophylactic as well as support treatment against liver toxicity (Ahmed et al., 2008).
	Dates were eaten in Sudan and Mauritania to treat constipation (El-Kamali and Khalid, 1998; Khalid et al., 2012; Vall Hmeyada, 2009). In Morocco dates were eaten in in case of both diarrhea and constipation (Hmamouchi, 1999).	It has been shown that depending on the extract preparation non-dialyzed (ethanol and water) or dialyzed, date fruit extracts significantly increase or decrease gastrointestinal transit in a dose dependtent manner, respectively (Al-Qarawi et al., 2003).
	Dates were used to treat the “purulency in the belly” in ancient Egyp (Ebbell, 1937).	The aqueous as well as ethanolic extracts of dates were shown to be effective in ameliorating the severity of gastric ulceration (Al-Qarawi et al., 2005).
	Dates were used in traditional treatment of diabetes in Morocco (Tahraoui et al., 2007; Ziyyat et al., 1997).	Dates have low glycaemic index and therefore may be useful in glycaemic and lipid control of diabetic patients (Miller et al., 2003).
	Phoenix dactylifera pollen grains were used traditionally in Sudan and Libya to increase fertility (Khalid et al., 2012; Le Floc'h, 1983).	It has been recently investigated and concluded that date palm pollen can be used in managing sexual dysfunction, both as an aphrodisiac as well as treatment for male impotency (Abedi et al., 2014).
Cocos nucifera	In Nigeria, ground coconut fruit was applied to wounds (Adetutu et al., 2011). In Kenya the fruit was applied on the skin to cure skin rashes associated with HIV/AIDS (Nagata et al., 2011).	The study of extracts obtained from the coconut husk fiber revealed antimicrobial activity against *Staphylococcus aureus*, which is a common cause of skin infections (Chakraborty and Mitra, 2008; Esquenazi et al., 2002).
	Coconut shells were calcined, pulverized, mixed with Shea (*Vitellaria paradoxa* C.F.Gaertn.) butter and applied twice daily for several days to treat herpes in Ghana (Mshana et al., 2000).	The crude husk fiber extract showed inhibitory activity against herpes simplex virus (Esquenazi et al., 2002).
	Coconut milk that was ingested in case of diarrhea in Sierra Leone (Krüger and Krüger, 1985).	Antibacterial activity of husk extracts from *C. nucifera* has been proven against bacterial *Vibrio* species, which commonly cause gastroenteritis (Akinyele et al., 2011).
	Coconut shell was used in the treatment of fungal skin diseases in West Africa (Oliver-Bever, 1983).	The husk fiber showed antifungal activity (Venkataraman et al., 1980).
	Cocos nucifera was used to overcome the nerves pains in Cameroon (Dibong et al., 2011).	Aqueous extract from the husk fiber of *C. nucifera* possesses antinociceptive properties (Alviano et al., 2004; Rinaldi et al., 2009),
	Coconut oil was in Nigeria as a dressing for burns and scalds (Gill, 1992).	The oil extracted from *C. nucifera* seed has proven to be an effective burn wound healing agent (Srivastava and Durgaprasad, 2008)
Borassus aethiopum	Male flowers of *B. aethiopum* were applied topically to treat impetigo in Ghana (Mshana et al., 2000). In Senegal, the stamens were mixed with Shea butter and used to heal wounds (Sambou et al., 1992). In Benin, the powder from male inflorescences was mixed with Shea butter and applied on the skin to treat fungal diseases (Aké Assi et al., 2006).	Male inflorescences' extracts displayed weak antibacterial activity, but the results supported the ethno-medicinal use of *B. aethiopum* for the treatment of fungal diseases (Sakandé et al., 2012).

palm species and extremely rich in natural resources in general, its political instability has historically limited the potential for exploration. According to Global Peace Index (2014) it is still one of the least peaceful countries in the World (just before Central African Republic). Based on Fig. 3B and D we could recommend the future ethno-botanical surveys to be directed at central African region in countries as Angola, Democratic Republic of Congo, Central African Republic, Congo, Gabon, Equatorial-Guinea, as well as in some of the west coast countries such as Gambia, Guinea-Bissau, Ivory Coast, Liberia, Sierra Leone. It is likely though, that other factors such as diseases outbreaks will limit the possibilities of investigation in some of the countries.

For 13 African countries we did not encounter any medicinal palm uses. These were: Algeria, Botswana, Chad, Djibouti, Eritrea, Gambia, Lesotho, Malawi, Somalia, Swaziland, Tunisia, Western Sahara, and Zimbabwe. Even though ethno-botanical literature exists for some of the countries, it is very limited (Chinemana et al., 1985; Hassan-Abdallah et al., 2013; Kambizi and Afolayan, 2001; Maroyi, 2011; Morris, 1986; Motlhanka and Nthoiwa, 2013; Ndamba et al., 1994; Samuelsson et al., 1991, 1992; Sewani-Rusike, 2010; Volpato et al., 2012). It might be simply because palms do not occur in these countries, or the palm richness is low (Fig. 3D). It can also be the case that palms are not used traditionally in medicine, or there are no studies documenting palm uses in the field.

4. Pharmacological studies confirming ethno-medicinal uses of palms

Several recent studies have documented the pharmacological bases for traditional uses of palms. Here we present scientific validations related to some ethno-medicinal uses of the most popular palm species in traditional medicine in Africa.

It is noteworthy that the above-mentioned pharmacological studies were conducted based on knowledge of traditional uses of palms. It has been shown in general that most useful drugs derived from plants have been discovered by follow-up on ethno-medicinal uses and that their modern uses are for treating the same (or related) conditions (see Fabricant and Farnsworth, 2001). *E. guineensis* was traditionally mostly used in the *Infections*/*Infestations* category, and *P. dactylifera* was mostly used to treat *Digestive System Disorders* — and these types of medicinal properties were validated pharmacologically for both species (Table 2). Though the top three palm species and their medicinal properties were quite extensively evaluated, there are still countless healing properties of palms that remain to be investigated through precise laboratory trials, not necessarily related to the most widespread and commercial species. For example, we gathered the same amount of traditional medicinal use records for *B. aethiopum* as for *C. nucifera*, yet we found only one study validating the traditional uses of the former. Thus, the medicinal potential of *B. aethiopum* clearly requires further investigation.

As The Organisation of African Unity recognized that traditional medicine *is the most accessible and affordable means of health treatment for most Africans* (Dibong et al., 2011) — ethno-pharmacological research should contribute to development of improved therapeutic options for the regions where the plants are used and prepared under local conditions (Heinrich, 2000). Alternative therapies are also necessary to face the increasing challenge of handling infectious and parasitic diseases that so heavily affect Africa. Drugs commonly used to treat microbial infections are becoming ineffective because many pathogens and parasites have already developed multi-drug resistance (Adebayo et al., 2012; Akinyele et al., 2011; Esquenazi et al., 2002).

5. Conclusion

We recorded 23 palm species used in traditional medicine in Africa. The wide time span of our database (3500 years) shows that African palms have been used medicinally by many societies across the continent from time immemorial until today. This study is the first to demonstrate the breadth of the medicinal applications of African palms. Among a variety of uses, most medicinal use records for African palms were found in two categories that relate to most prevailing diseases and disorders in the region: *Infections*/*Infestations* and *Digestive System Disorders*. We also link the gap between traditional use of palms and pharmacological evaluation for the beneficial effects of palm products on human health. By analyzing ethno-medicinal studies in one database we were able to demonstrate the value of palms in traditional medicine, and shed light on species with the potential to provide new therapeutic agents for use in biomedicine. These promising species are not necessarily the most widespread and commercial ones. We have also presented a novel insight into the merits of palms, not only in natural products research, but also with respect to anthropological aspects of traditional medicine, by highlighting the role of palms in healing rituals and ceremonies, which are often an inextricable part of culturally adequate health care. Last but not least, we examined patterns of medicinal palm uses across Africa in relation to palm species richness; and based on this we provide recommendations for the areas that should be targeted in future ethno-botanical surveys.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at: http://dx.doi.org/10.1016/j.jep.2015.02.050.

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