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SPECIES DIVERSITY AND DISTRIBUTION OF USEFUL MUSHROOMS (*BASIDIOMYCOTINA, ASCOMYCOTINA*) IN AFRICA: AN EFFORT TO ADVANCE CONSERVATION AWARENESS

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ABSTRACT
The conservation of biodiversity of mushrooms in Africa has been a problem those concerned because no even the types, distribution and uses of the mushrooms is lacking continent-wide. This was complicated by the implied costs, lack of mycologists and political issues. An appraisal of macrofungi diversity in Africa was carried out using online literature. They were 959 mushroom species in Africa. Total number of mushrooms were highest in Central Africa (494 species: not exclusive counts) then Southern Africa (232 species), Eastern Africa (166 species), West Africa (155 species), and North Africa (38 species). Edible mushrooms were most abundant in Central Africa (447 spp.), East Africa (145 species), West Africa (97 species), Southern Africa (56 species), North Africa (26 species). The abundance of mushroom species (for the 2 leading countries in regions), in descending order of magnitude was as follows: DR Congo, South Africa, Nigeria, Cameroon, Ethiopia, Tanzania, Ivory Coast, Zimbabwe, Morocco and Egypt. While medicinal mushrooms were most abundant in West Africa followed by North Africa, Central Africa, East Africa, and Southern Africa in descending order of magnitude. The genus Agaricus had highest species diversity followed by Cantherellus, Russula, Lepiota, Lactarius, Amanita and finally Termitomyces. The most popular food mushrooms were Cantherellus congolensis (17 tribes in 11 countries), Amanita loosii (18 tribes in 8 countries) and Auricularia cornea (17 tribes in 7 countries). The most popular dual-purpose (food and medicinal/other use) mushrooms in descending order of popularity were as follows: Schizophyllum commone, Lentinus squarollus, Termitomyces microcarpus, Lentinus tuber-regium, Termitomyces robustus, Ganoderma lucidum, Volvariella volvacea, and least Termitomyces striatus. About 74.7% of the mushrooms were mentioned by only one source while 72.9% of the mushrooms were reported in only one country. It was concluded that documentation of mushrooms in Africa is not adequate.
KEY WORDS: *agroforestry, bioactive, macrofungi, mycophagy, nutriceuticals, truffles*

INTRODUCTION

Mushrooms have been known in Africa for eons. It is common knowledge that during the early Egyptian civilization, mushrooms were considered as the 'plant of immortality' and thus they were declared as 'food for royalty' hence no commoner was allowed to consume them (El Enshasy et al., 2013). Nevertheless numerous reports

from many parts of Africa presented the popular view that mushrooms are branded as 'meat for the poor' that should only be eaten by the less privileged.

Mycophagy had only of recent assumed greater importance in the diets of both rural and urban dwellers in Nigeria, unlike previously when their consumption was confined to rural dwellers (Okoro & Achuba, 2012). They however confirmed the view that mycophagy was still not popular in some parts of Nigeria due to the fact that mushrooms and fungi grow on decaying organic matter and waste substrates, coupled with another fact that some mushrooms are poisonous.

Wild mushrooms are now considered as vital components of the food, medicine and income source of rural people in different parts of the world (including Africa), which may help in alleviating poverty (Suciu et al, 2020, Kamou et al., 2015, Abdolgader et al., 2016, Mansour et al., 2019, Yoboue et al.,2020, Zeleke et al., 2020).

Mushrooms could serve as sources of food, medicine, enzymes and bioactive agents as well as in recreation and mythology/belief systems (Bouatia et al., 2018, Mansour et al., 2019, Zeleke et al., 2020). Moreover, mushrooms are important sources of proteins, vitamins, carbohydrates, amino acids and minerals that could be consumed instead of meat and fish.

Mushrooms were reported to be cheaper than beef, pork and chicken meat that contained similar nutrients and that Africa was very rich in edible species of mushroom which unfortunately had remained underutilized (Okoro & Achuba, 2012). Mushrooms are rich in protein, minerals, vitamins and essential amino acids (Sadler, 2003; Okoro & Achuba, 2012). Cultivation of edible mushrooms is an economically sound biotechnology for lignocellulose organic waste recycling which has dual purposes: the production of protein rich food and reduction of environmental pollution (Obodai et al., 2003, Okoro & Achuba, 2012).

A complete lack of documentation on the interest of West African people (especially in Benin Republic) in the genus *Cantharellus*, as a food stuff, is in direct contrast to what this genus represent for inhabitants of Central and Eastern Africa especially in Madagascar (De Kesel et al., 2011). It was largely observed that the mycoflora of the African continent had remained mostly unknown, coupled with mycophobia that may be in existence. Thus the communities have largely not benefitted from macrofungi diversity.

In El Kala National Park (North Eastern Algeria) with the exception of the most priced mushroom species, the precise information on the ecology and the biogeographical distribution of macrofungi associated with peat lands is very rare (Djelloul and Samraoui, 2011). Wild truffles were recognized as nutrient-rich food in many countries worldwide but information on their nutritional values and phytochemical composition is highly limited (Bouatia et al., 2018).

It was reported that based on the Hawksworth six:one-fungus-to-plant-species ratio, known fungal diversity in West Africa represented 11.4% of the expected

mushroom diversity in the region, however, for some selected six West African countries, the known fungi species diversity was less than two percent (Piepenbring et al., 2020). These researchers affirmed that 45.3% of the fungi species in the checklist they compiled were cited only once for West Africa and 66.5% of the fungi species were reported only for a single country.

Scientific information about species diversity and distribution is indispensable for nature conservation and sustainable management of natural resources (Piepenbring et al., 2020). These researchers lamented that such data were not available for fungi especially in tropical regions like West Africa. Documentation of ethnomycological knowledge on edible fungi is inadequate in West Africa (Fadeyi et al., 2017). For instance, Kane et al. (2020) reported that there was no data on fungi diversity (especially on macrofungi) from Niokolo Koba National Park in Senegal. This was the general outcry all over Africa due to the obvious scarcity of information on macrofungi.

It is very common to read in most of the research from Africa about discovery of new species in different countries now and then. This could be a problem created by lack of any checklist of any sort. This status quo may be due to differences in official languages and lack of visibility of some publications, even at that how comes no cross references are encountered that cited such publications if they exist. Thus any checklist produced would be considered a working list based on current needs and no checklist may be complete for the foreseeable future.

Moreover, many publications are in exotic prestigious subscription journals aimed at the few well-funded researchers, oblivious of the needs of students, non-funded researchers, poor policy makers, consumers, macrofungi entrepreneurs/enthusiasts and non-profit non-governmental conservation organizations. This is a disservice to diversity conservation efforts of many concerned parties in the face of climate change and deforestation. The situation will get worst with the current rate of deforestation in Africa (e.g. Cameroon and Nigeria have lost more than two-third of their forests). This means mushroom habitat loss and possible extinction of the unique mushrooms of Africa. This is coupled with the fact that mushroom germplasm collection is hardly mentioned in Africa.

In this vein, this review was carried out with the objective to systematically document the identity, uses and distribution of African mushrooms to date. Companion standalone datasets were produced which may be useful for those who don't have time or skills to dig out the details of some mushrooms. It was hoped that this review would help us to accept or reject the hypothesis that documentation of the diversity of African mushrooms is up to date and adequate.

MATERIALS AND METHODS

Criteria for selection and compiling the datasets

This assessment is not strictly a research on the systematics of mushrooms of Africa. Thus a reader may be satisfied with reading only this assessment or go for the free detailed datasets for listing of species of the macrofungi encountered and the sources/references, etc. Duplication of information was avoided so as to make it easy to sort out details on each macrofungus continent-wide and from multiple sources.

The problem of how to avoid repeating synonyms in these datasets was always present but all literature available were utilized to ensure that synonyms were reduced as much as possible. This is true when one considers for example that *Auricularia auricular-judae* (which is an older name) has 9 synonyms with one synonym that came decades after this name. One may thus wonder whether the nine synonyms are/are not established or officially acknowledged by the official body in-charge of fungi taxonomy. Yet this name is most popular and highly accepted by researchers globally. The reason why the same organism is being rediscovered/renamed over and over, could point to the lack of any checklist of any sort.

The listing of any species was done only once, and countries where it exists were listed in the datasets (as obtainable in literature). This is beside the phenomenon of new species being created *en masse* due to advances in molecular biology from existing species. Definitely this review was borne out of necessity.

Thus this appraisal was carried out using only internet based visible research publications specifically on mushrooms from Africa. Only research publications that had any relation with macrofungi and their utilization in Africa were reviewed. The sub-headings in this review were based on availability of published research findings online and their visibility on the internet to the targeted readers, rather than on preconceived subheadings. Some publications could be missed out then when utilizing these criteria, due to lack of visibility, language of publication as well as not being online at all.

This present assessment is a summary of six-region based assessments produced prior to this one. It was observed that even at regional level, some countries had no visible mushroom publications online. This could be tied to lack of interest or knowledge of these supposedly 'scary poisonous deadly' mushrooms. Even within the same country, publications tended to come from only certain regions where researchers may be interested or based. Thus more mushroom species may hitherto be discovered. The dearth of mycologists in some countries was also suspected to be the cause of any imbalance that may be palpable.

Publications on macrofungi exist in Africa in a spasmodic format that cannot be utilized as a reference checklist especially by non-experts on mycology. Moreover, this state of affairs may lead to the current over-production of synonyms of species. Due to availability of data, systematical evaluation of the quality and amount of work

that has been carried out so far in mycology in Africa was carried out. The grouping of the literature available into regions was carried out based on accepted geographical grouping of the countries within Africa.

The inclusion of species of macrofungi in the checklists depended on identification to species (specific epithet) or below it. Genera names were included if no species was identified for the genus, but they were dropped once any species of the genus was identified. Thus it may seem that the final number of mushrooms encountered was small. Synonyms were removed and only one (the most popular one left) based on common usage by researchers cited.

Analysis of the datasets

The data generated from the datasets included data on different uses, spatial distribution pattern, references or researchers working who worked on the mushroom in each area, tribes and countries covered where the mushrooms are found. The data were subjected analysis using SPSS 23 (IBM version) and descriptive statistics were used to present the results.

RESULTS AND DISCUSSION

They were 959 species of mushrooms all together, with 429 species having no specified uses (Fig. 1). The highest number of mushroom species were found in Central Africa (494 species, not exclusive counts) followed by Southern Africa, Eastern Africa, West Africa and North Africa in descending order of magnitude.

The distribution of mushroom diversity among the regions of Africa based on uses (edible mushrooms i.e. used for food/(food and medicine and or mythology and or recreation)) were most abundant in Central Africa, followed by East Africa, West Africa, Southern Africa and finally North Africa in descending order of magnitude (Fig. 2). Dual purpose mushrooms (used for medicine/medicine and other uses) were most abundant in West Africa (37 spp.) followed by North Africa, Central Africa, East Africa, Southern Africa in descending order of magnitude (Fig. 2).

The comparison of mushroom diversity among the regions of Africa based on highest number of species in the leading countries in the regions determined. Based on the two leading countries in the regions (i.e. two countries per region) of Africa; DR Congo accounted for 414 species followed by South Africa, Nigeria, Cameroon, Ethiopia, Tanzania, Ivory Coast, Zimbabwe, Morocco and Egypt in descending order of magnitude (Fig. 3). The most abundant genera of mushrooms in Africa based on the number of species in each genus were determined (Fig. 4). It was observed that *Agaricus* (74 spp.) had the highest species diversity followed by *Cantherellus, Russula, Lepiota, Lactarius, Amanita* and *Termitomyces* genera, while 9 other genera had more than 10 species each.

The most popular food mushrooms (sole purpose) were *Cantherellus congolensis* (17 tribes/ 11 countries) followed by *Amanita loosii* then *Auricularia*

cornea in descending order of popularity (Fig. 5). Meanwhile the most popular dual purpose (Food and (medicine and or mythology and or recreation)) mushroom species were *Schizophyllum commone* (30 tribes/ 16 countries) followed by *Lentinus squarollus, Termitomyces microcarpus, Lentinus tuber-regium* (syn. *Pleurotus tuber-regium*), *Termitomyces robustus, Ganoderma lucidum, Volvariella volvacea,* then *Termitomyces striatus* in descending order of popularity.

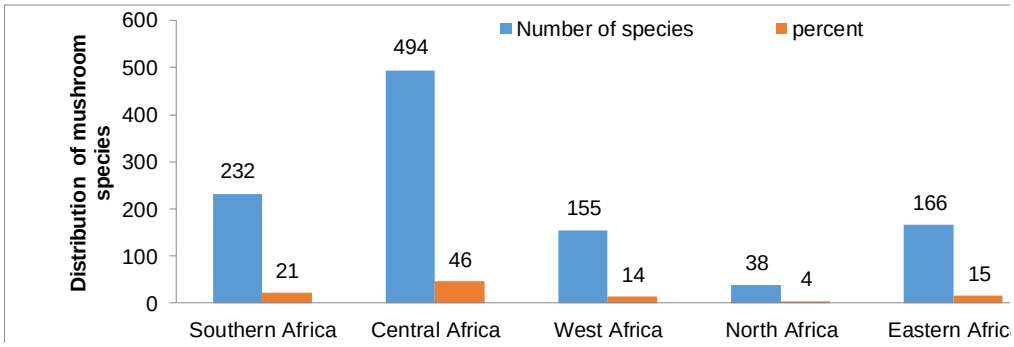

FIG. 1. The general distribution of mushroom species diversity among the regions of Africa

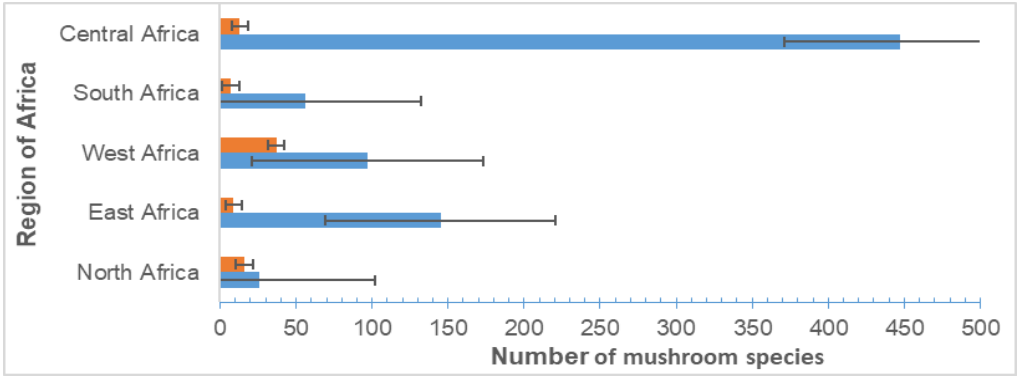

FIG. 2. The distribution of mushroom species diversity among the regions of Africa based on uses

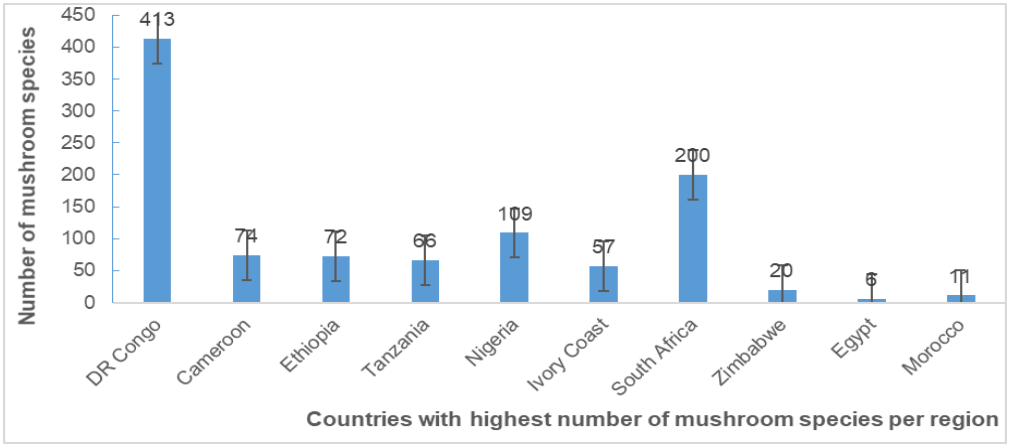

FIG. 3. The comparison of mushroom species diversity among the regions of Africa based on highest number of species in the leading country in each region

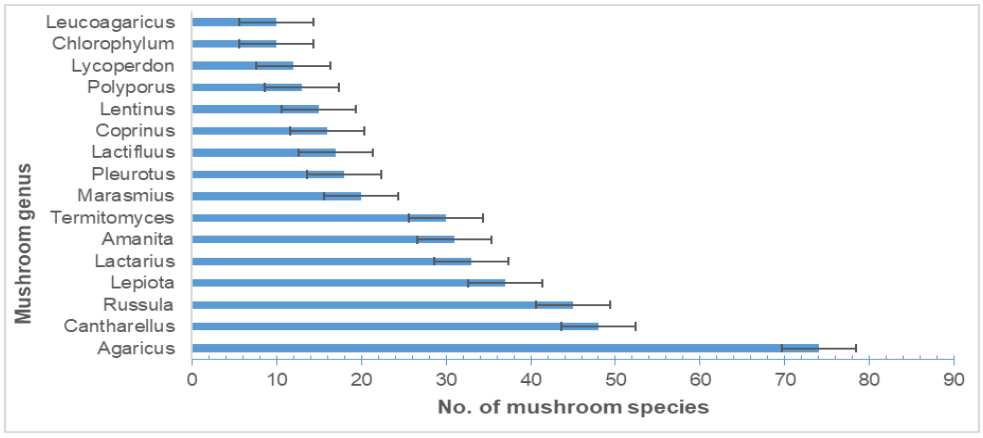

FIG. 4. The most abundant genera of mushrooms in Africa based on the number of species in each genus

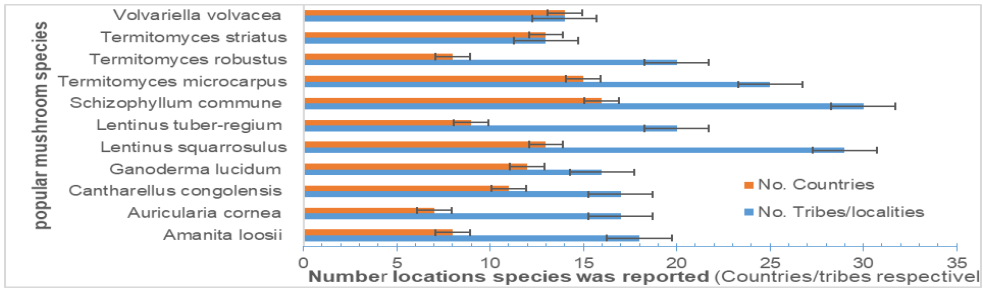

FIG. 5. The most popular species of mushrooms based on the number of localities and or on number of countries in Africa

The outcomes showed that 74.7% of the mushrooms were mentioned by only one source while 72.9% of the mushrooms were reported in only one country. This finding that the distribution of mushrooms in Africa is not uniform and that only a single author tends to report on most of the mushrooms corroborated the findings by Piepenbring et al. (2020) who reported that 45.3% of the fungi species in the checklist they compiled were cited only once for West Africa and 66.5% of the fungi species were reported only for a single country.

The statements by Yoboue et al. (2020), Zeleke et al. (2020) that wild mushrooms are now vital components of the food, medicine and income source of rural people in different parts of the world (including Africa) which enable people to overcome poverty thus they corroborated the findings of this review that all regions of Africa use mushrooms as food and as medicine.

Another foreseeable limitation was the frequent official removal of species from one genus to another with or without renaming them. If mushroom species were identified but no use mentioned, the species was placed on a different list from those with specified uses. In this appraisal correction of names did not go beyond correction of obvious taxonomic mistakes since the process of official authentication of such names may be ongoing or the evidence for the validity of such names may not be immediately visible on-line.

CONCLUSION

An assessment of the mushrooms / macrofungi of Africa was carried out using online literature. It showed that mycophagy and use of mushrooms as source of medicine were rampant in all regions of Africa. The review showed that the distribution of mushrooms in Africa was uneven hence some species may become extinct if the restricted habitats they occupy, becomes unavailable due to change in land use activities. It was noted that mushrooms of Africa were diverse and could thus offer much potential for sourcing medicinal bioactive agents. The outcomes revealed that 74.7% of the mushrooms were mentioned by only one referenced source while 72.9% of the mushrooms were reported in only one country. Thus the hypothesis that documentation of mushrooms in Africa is adequate was rejected.

Data availability statement: The datasets linked to this manuscript are available on demand.

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