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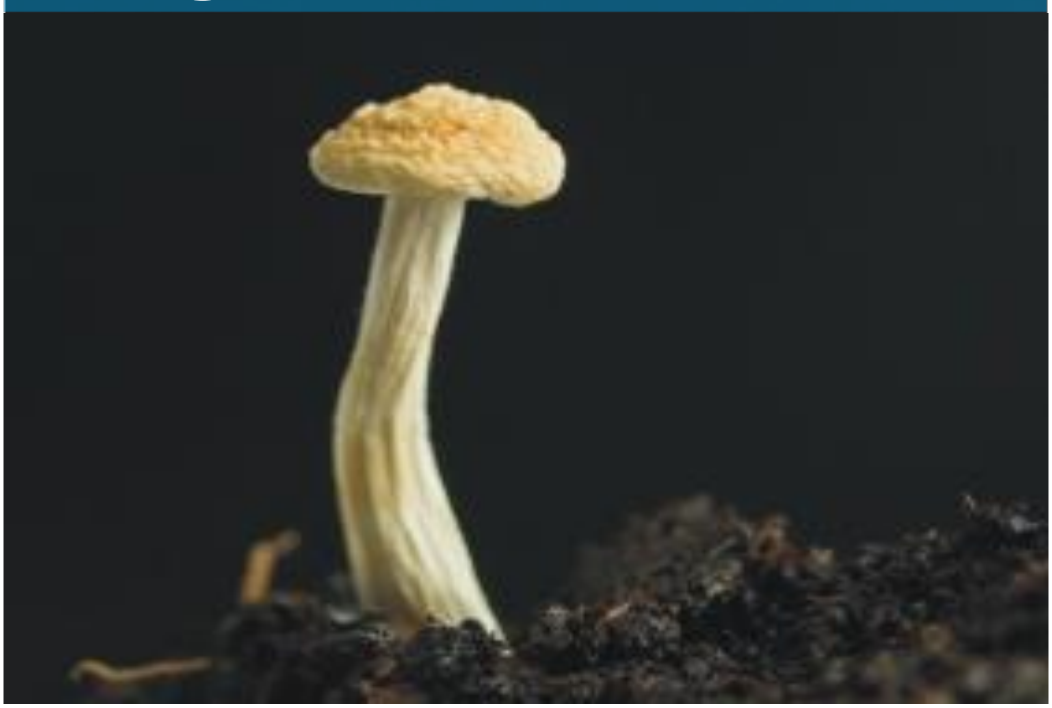

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Table of Content

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Full Length Research Paper

Occurrence of mycoflora, their association and production of aflatoxin B_1 in groundnuts

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Groundnut (*Arachis hypogaea* L.) is an important food crop in Africa which is a source of nutrients and income in rural areas of Zimbabwe. It is considered to be a crop highly susceptible to aflatoxin contamination. Accordingly, the objectives of this study were to understand the presence of mycoflora, their association and the level of contamination by aflatoxins of groundnut from various markets in Zimbabwe. Thirty groundnut samples were purchased randomly from Bulawayo (Shashe and Main market), Gweru (Kudzanayi and Kombayi markets) and Harare (Mbare and Highfield markets). Identification of various fungi was determined using the cultural method on Czapek Dox Agar. Fungi belonging to genera *Aspergillus*, *Mucor*, *Penicillium* and *Rhizopus* were isolated and characterised from six groundnut markets. *Rhizopus* species was the most dominant and negatively associated with other fungi species which is attributed to differences in environmental requirements or competition. *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger* and *Aspergillus parasiticus* were identified in groundnut samples with *A. flavus* being the dominant and found in all markets. The range of AFB_1 in groundnut samples analysed using a semi-quantitative immunochromatographic technique was within the safe limits for human consumption according to existing Zimbabwe (5 ppb) regulation. The presence of aflatoxigenic fungi (*A. flavus* and *A. parasiticus*) in groundnuts, however, means there is potential for aflatoxin production and fungal proliferation when conditions are favourable.

Key words: Aflatoxigenic, *Arachis hypogaea, Aspergillus* species, mycology.

INTRODUCTION

The impact of aflatoxin contamination on agricultural commodities is immense and production losses and trade has been severely affected. In developing countries due to lack of storage infrastructure, poor harvesting and handling techniques and lack of effective monitoring mechanisms aflatoxins occur frequently in various agricultural commodities (Negash, 2018). One of these crops is groundnut that is widely grown in semi-arid areas and prone to aflatoxin contamination. There is low production of groundnut in African countries because of unreliable rains, lack of inputs, use of retained seed, poor agronomic practices, pests and diseases (Ajeigbe et al., 2015; SNV, 2012). Among other challenges is the frequent recurrence of droughts and variable rainfall patterns. Drought increases the probability of aflatoxin contamination on groundnut at any stage of production

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cycle and thereafter affecting international exports from Africa. Warm climate and high humidity experienced in most tropical countries predispose crops to aflatoxin contamination (Pazderka and Emmott, 2010).

Groundnut is an important crop in the livelihoods of many Zimbabweans and comes second after maize. Majority of farmers grow groundnut during rainy season which is a risk factor during harvest and post-harvest handling that predisposes the crop to aflatoxin contamination. The ideal environmental conditions for aflatoxin production in stored seed are high temperatures up to 45°C, high humidity 65 to 90%, moisture in excess of 9%, damage by insect pests, rodents and lack of genetic inheritance in the host plant (Okello et al., 2010; Ncube and Maphosa, 2020).

Dube and Mtetwa (2015) showed that the majority of stakeholders involved in the groundnut value chain in Mutare, Zimbabwe had never heard about aflatoxins. Several researchers showed that most commodities were contaminated by aflatoxins in Zimbabwe especially groundnuts and maize (Nleya et al., 2018). Dried traditional foods in Zimbabwe were found contaminated by the aflatoxigenic fungus from Bulawayo markets (Dangwa et al., 2014). Similarly, Mupunga et al. (2014) observed that groundnuts from Bulawayo markets in Zimbabwe were contaminated with high levels of aflatoxin. Dube and Maphosa (2014) reported aflatoxin prevalence in groundnut samples collected from seven districts of the Matebeleland provinces in Zimbabwe. Aflatoxin results for groundnuts from Bulawayo showed that 17% of the samples were contaminated with total aflatoxins ranging from 6.6 to 622.1 ppb (Mupunga, 2013). Accordingly, there is need for more research and understanding the prevalence of the aflatoxigenic fungi and current levels of aflatoxin contamination of groundnut on the market. There has been no attempt to identify which fungal species are more prevalent in groundnut as well as their association. Accordingly, the knowledge of aflatoxigenic fungal diversity, their association and prevalence of aflatoxin contamination will lead to informed breeding for resistance and aflatoxigenic management.

MATERIALS AND METHODS

Collection of groundnut samples

Thirty samples of groundnuts were purchased from six open markets in three cities of Zimbabwe, Bulawayo (Shashe and Bulawayo main markets), Harare (Mbare and Highfield markets) and Gweru (Kombayi and Kudzanayi markets). These markets were purposively selected because they receive groundnuts from most places of the country. Five groundnut vendors were randomly selected from each market and raw, shelled 1 kg groundnut samples were collected per vendor. Samples collected represented the whole consignment and was done by collecting groundnuts from different sections of the sack. Collected samples were packaged in polyethylene bags, sealed, labelled and transported to Lupane State University Laboratory and kept in a cool refrigerator at 4°C.

Preparation of media

Czapek Dox Agar (CDA) (Thermoscientific, UK) was used to isolate and identify the fungi and was prepared according to manufacturer's instruction.

Fungal isolation

Isolation of fungi from groundnuts was done under laboratory conditions using Czapek dox agar. Groundnut samples were surface sterilised for one minute using 80% ethanol and air dried for 30 min. Sterilized and unsterilized samples were plated on petri-dishes (10 kernels per petri dish) containing CDA. Ten dried seeds were placed in each petri-dish and replicated three times. Plates were incubated at 25°C for 72 h and replicated three times in completely randomised design. After incubation, morphological and growth characteristics were observed under a microscope. Colony characteristics (colour, shape) that grew and number of seeds infected with the same type of fungus were recorded. The individual isolates were transferred to new CDA plates in order to obtain pure cultures. Inoculation was done using flame sterilised inoculating needle dipped into a spore formed of the suspected fungi. The Petri-dish containing the CDA medium was spot inoculated and incubated at 25°C for 72 h in an incubator. Slides were made for examination of morphological characters under a microscope and colony characteristics were recorded (Cappuccino and Sherman, 1999).

Characterisation and identification of fungi

Identification was done using microscopic and macroscopic examination based on colony and morphological characteristics of pure cultures of the isolates. The micro morphological characteristics has been used for fungal identification including the shape of conidia heads, serration, the number of branching points between vesicle and philiades (uniseriate or biseriate), stripes (colour, shape, texture, and dimensions), vesicles shape and diameter, presence of metulae and conidia (Samson et al., 2014; Nyongesa et al., 2015). The *Aspergillus* consists of swollen conidiophore tips forming vesicle with philiades and metulae with chains of conidia. However, conidiophore tip of *Penicillium* lacks vesicles and has a number of metulae followed by philiades (Campos, 2019). The macro morphological features were used for identification of species based on the colony colour and texture (yellow green for *Aspergillus flavus* and dark or nearly ivy green for *Aspergillus parasiticus*) using the identification keys illustrated in a manual (Cappuccino and Sherman, 1999). However, the following characteristics of colonies were also considered; colony growth rates, texture, colour of mycelia, colony reverses and degree of sporulation (Samson et al., 2014; Nyongesa et al., 2015). Based on macro and micro morphological characters, the following species were identified, *A. flavus, Aspergillus fumigators*, *Aspergillus niger*, *A. parasiticus*, *Mucor* species, *Penicillium* species, and *Rhizopus* species. Different *Aspergillus* species with varying morphologies were identified. Macro and micro morphological characteristics were used for fungal identification from genus to species level together with taxonomic keys (Cappuccino and Sherman, 1999; Samson et al., 2014; Nyongesa et al., 2015).

Semi-quantitative detection of AFB_1 using immunochromatographic technique

AFB_1 Rapid Test based on competitive lateral flow immunochromatographic assay (Krska and Molinelli, 2009) was performed as a semi-quantitative step to identify whether aflatoxins

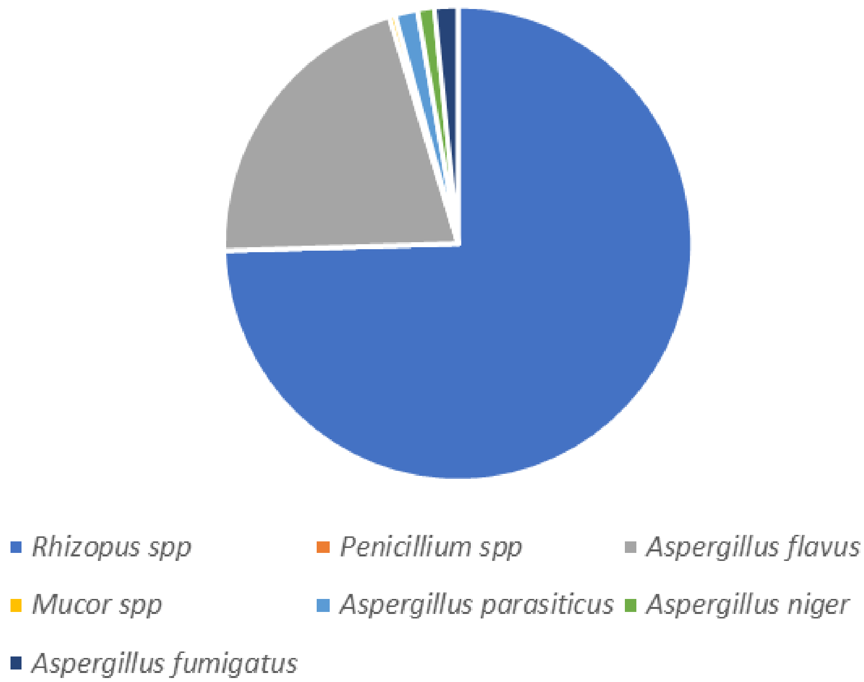

Figure 1. Fungal diversity isolated from groundnut in the major markets of Zimbabwe.

AFB_1 were present. This method has a lower limit of 5 ppb for AFB_1. Thirty samples of groundnuts were brought to the laboratory and each sample was mixed thoroughly to achieve complete homogenization. About 10 g of groundnuts were picked from each sample and grounded to the particle size of the instant coffee using the pastel and mortar. A 2 g groundnut sample, 2 ml of pure water, 8 ml of ethyl acetate were added into a 15 ml centrifugal tube and mixed for 10 minutes. After emulsification, the sample was centrifuged for 5 minutes at 4000 rpm. About 4 ml of supernatant (ethyl acetate layer) was transferred into a 250 ml beaker and evaporated to near dryness and diluted in water. The results of AFB_1 test were interpreted within 5–10 minutes after placing the droplets into the assay hole (Krska and Molinelli, 2009).

Data collection

Genus and species of fungi found growing on the surface of groundnuts samples collected from six groundnut markets were recorded together with their frequency of occurrence (Algabr et al., 2018). The percentage frequency of occurrence was calculated using the following formula:

% Frequency = Number of seeds on which fungi are growing / Total number of seeds × 100

Experimental design and statistical analysis

The experimental design used in this research is a 6×2 factorial replicated three times arranged in Completely Randomised Design (CRD). The two factors were divided into two categories which are markets and sterilisation. Principal component analysis was used to detect fungal species association and level of importance. All data were analysed using Genstat 13 (Payne et al., 2010).

RESULTS

Incidence of fungal contamination in groundnuts

Prevalence of fungal species significantly differed ($p<0.05$) across the six markets. *Rhizopus* species were the most prevalent fungus followed by *A. flavus* (Figure 1).

A. flavus was found in both sterilised and unsterilised groundnut from the six markets (Table 1). *Rhizopus* spp. were isolated from both non-sterilised and surface sterilised samples of five groundnut markets with a higher percentage of non-sterilised than in sterilised groundnut samples. *Penicillium* species were found in Harare Mbare market and isolated in 0.6% of surface sterilised groundnuts. Bulawayo Shashe market was the only market were *Mucor* spp. (4%) was found in non-sterilised groundnuts.

Principal component analysis of fungal distribution in groundnut samples of six markets of Zimbabwe

The principal component biplot analysis showed high correlations between *A. flavus* and *A. fumigatus* and *A. parasiticus* and *Penicillium* spp. as evidenced by the same direction dimension vectors and small angles between them (Figure 2). *A. flavus* and *A. parasiticus* were the most prominent fungal species as shown by the long vector. *Rhizopus* was negatively associated with all

Table 1. Fungal species (%) isolated from groundnuts using CDA method.

Market	BS	BS	BM	BM	GK	GK	GKo	GKo	HM	HM	HH	HH
State of seed	n-s	s-s	n-s	s-s	n-s	s-s	n-s	s-s	n-s	s-s	n-s	s-s
Rhizopus spp.	75	67	-	-	66.6	40.6	82.6	80	90	84	68.3	80.6
Penicillium spp.	-	-	-	-	-	-	-	-	-	0.6	-	-
Mucor spp.	4	-	-	-	-	-	-	-	-	-	-	-
Aspergillus flavus	27	11	26	18	38	33.3	30	26	10	8	7.3	6
Aspergillus parasiticus	2	-	3	-	-	-	-	-	-	0.6	3	0.6
Aspergillus fumigatus	0.7	-	8	2.7	1.3	1.3	-	-	0.6	-	-	-
Aspergillus niger	0.67	-	2.6	-	0.6	-	-	-	-	-	-	2

BS - Bulawayo Shashe, BM - Bulawayo Main, GK - Gweru Kudzanayi, GKo - Gweru Kombayi, HM - Harare Mbare, HH- Harare Highfield, n-s - not sterilised, s-s - surface sterilised.

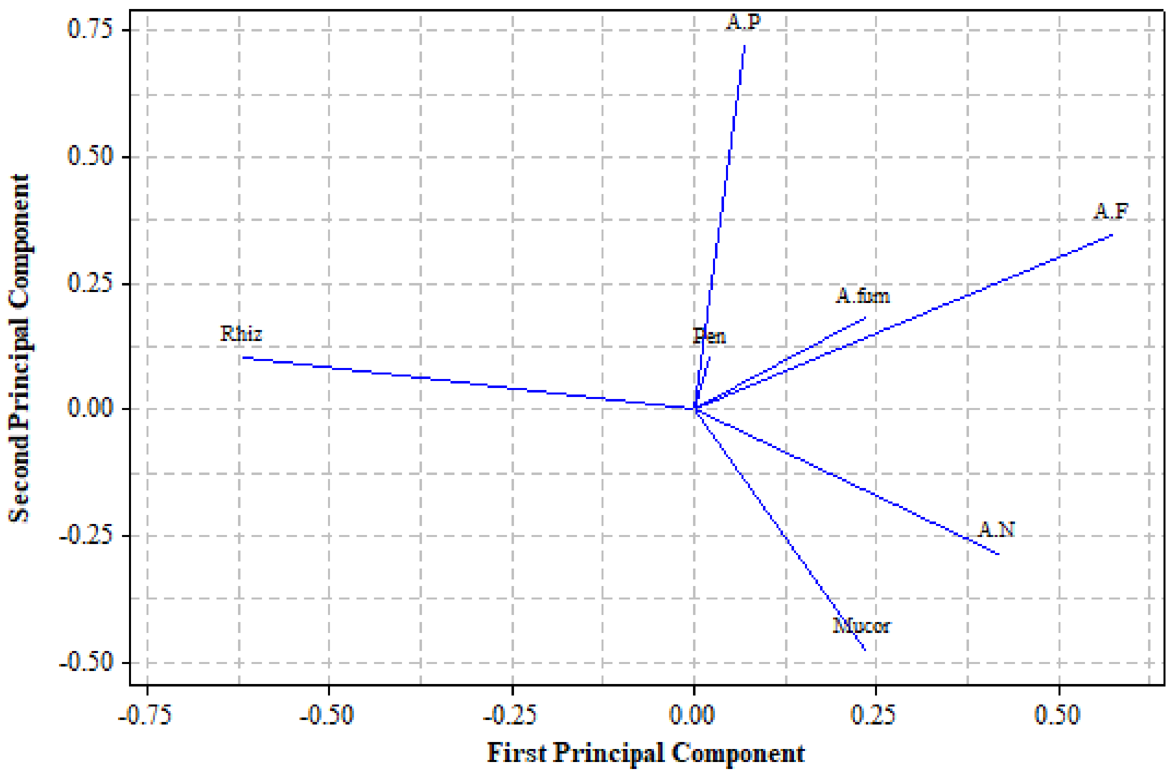

Figure 2. Biplot analysis of six fungal species observed from 30 groundnut samples collected from six major markets of Zimbabwe.
Rhiz - *Rhizopus*, Pen - *Penicillium*, A.fum - *A. fumigatus*, A.F - *A. flavus*, A.N - *A. niger*, -, A.P - *A. parasiticus*.

the other aflatoxigenic fungi with negative vector loadings (Figure 2).

Four principal components were important (eigen value >1) and explained 68% of the total variation. The first principal component explained 23% of the variation and was strongly positively associated with *A. flavus* and negatively associated with *Rhizopus* (Tables 2 and 3).

In the second, third and fourth principal components explaining 38%, 53% and 68% of variance respectively *A. parasiticus* had the highest positive loading (Table 2). These results suggest the high prevalence of the two fungal species, that is, *A. flavus* and *A. parasiticus*.

The results obtained in thirty groundnut samples collected from all six major markets of Zimbabwe, showed that AFB_1 was not detected after analysis. This showed that AFB_1 level was below the cut-off point of 5 ppb (Table 4). The results of each sample were recorded as positive or negative.

Table 2. Eigen analysis of the correlation matrix of six fungal species occurring in 30 groundnut samples collected from main markets in Zimbabwe.

Eigenvalue	1.5918	1.0866	1.0607	1.0114	0.9157	0.7584	0.5754
Proportion	0.227	0.155	0.152	0.144	0.131	0.108	0.082
Cumulative	0.227	0.383	0.534	0.679	0.809	0.918	1.000

Table 3. Rotated component matrix of six fungal species from 30 groundnut samples collected from main markets in Zimbabwe.

Fungal species	**PC1**	**PC2**	**PC3**	**PC4**
Rhizopus spp.	-0.618	0.104	0.074	-0.012
Penicillium spp.	0.023	0.101	-0.027	0.971
Mucor spp.	0.233	-0.476	0.344	0.036
Aspergillus flavus	0.574	0.347	0.012	0.075
Aspergillus parasiticus	0.069	0.720	0.501	0.146
Aspergillus niger	0.416	-0.285	0.245	-0.088
Aspergillus fumigatus	0.235	0.181	-0.751	-0.145

Table 4. Semi-quantitative detection of AFB_1 (cut-off point of 5 ppb) in groundnuts from major markets of Zimbabwe.

Source/Market	**AFB1 (≥5 ppb)**
Bulawayo Shashe	Not detected
Bulawayo Main	Not detected
Gweru Kudzanayi	Not detected
Gweru Kombayi	Not detected
Harare Highfield	Not detected
Harare Mbare	Not detected

DISCUSSION

Occurrence of mycoflora in six selected groundnut markets in Zimbabwe

Different types of fungi were found in groundnuts sourced from six selected markets of three major cities of Zimbabwe which are Bulawayo Shashe, Bulawayo Main, Gweru Kombayi, Gweru Kudzanayi, Harare Mbare and Harare Highfield. The presence of *Aspergillus* spp. (*A. flavus, A. parasiticus, A. niger, A. fumigatus*), *Mucor* spp., *Penicillium* spp. and *Rhizopus* spp. in groundnuts have also been reported (Mupunga, 2013; Njoroge et al., 2016). Abuga (2014) isolated *Mucor, Penicillium, Rhizopus* and *Aspergillus* spp. with different frequencies on groundnut seeds. Other studies done in Kenya, Nigeria and Yemen also revealed the occurrence of *Aspergillus, Mucor, Rhizopus* and *Penicillium* spp. in groundnuts and other products (Menza and Muturi, 2018; Salau et al., 2017; Tobin-west et al., 2018). This suggests that conditions that favour one fungal species may support another species as well (Bayman et al., 2002). Results of the present study revealed higher fungi occurrence on groundnut from Bulawayo Shashe market and the lowest was found in Gweru Kombayi market. The variations could be caused by poor storage, poor sanitation and handling by the vendors though groundnuts are prone to aflatoxin contamination (Tobin-west et al., 2018). Groundnuts from all the six markets were stored in uncovered sacks exhibiting them to consumers thereby being exposed to airborne fungal spores.

Surface sterilisation was done to determine the presence of internal fungi in groundnuts and gave variable results. In all instances *A. flavus* was not affected by surface sterilisation suggesting that it was not superficial but had established itself in the groundnuts (Bayman et al., 2002). Presence of fungi was observed on both sterilised and non-sterilised groundnuts from all markets with non-sterilised having high frequency compared to sterilise suggests a high risk of aflatoxin.

Prevalence and association of *Aspergillus* spp. in selected groundnut markets

All selected groundnut markets from Bulawayo, Gweru and Harare were contaminated with at least two or more of *Aspergillus* spp., *A. flavus, A. parasiticus, A. niger* and *A. fumigatus*. In this study, *A. flavus* was identified in all groundnut markets showing that most groundnut species grown are susceptible to contamination from *Aspergillus* spp. (Salau et al., 2017). There were differences in occurrence of *Aspergillus* among Bulawayo, Harare and Gweru markets because of different weather conditions. There was high contamination from hot and dry climatic conditions prevalent in Bulawayo and Gweru compared to low incidence of fungi to cool and wet areas of Harare. However, the risk of aflatoxin is present countrywide given that *Aspergillus* spp. mainly *A. flavus* and *A. parasiticus* are considered as aflatoxin producers (Boli et al., 2014). Previous studies revealed that *A. flavus* is mostly prevalent in foods including groundnuts and contains aflD toxigenic genes producing aflatoxin frequently in dry weather conditions (Menza and Muturi, 2018). *A. parasiticus* rarely occurred (0.3 - 6%) in these selected markets and furthermore was reportedly not a challenge on stored groundnuts (Bediako et al., 2019). *A. niger* had high occurrence in non-sterilised groundnuts from Bulawayo Main, Bulawayo Shashe and Gweru Kudzanayi while *A. fumigators* was detected in groundnuts from Bulawayo main market (8%). Bediako et al. (2019) reported that *A. niger* does not produce aflatoxins, it produces other toxins such as ochratoxin A and malformins. This study showed that some groundnuts are contaminated with *Aspergillus* and the predominant species was *A. flavus*. The presence of *Aspergillus* spp. in groundnuts exposes human to aflatoxin making it unsafe for consumption. Al-Amodi (2016) suggested that presence of these fungi causes groundnut seed to decay, reduces germination and causes damage of stored groundnuts. The widespread distribution of *A. flavus*, *A. niger*, *A. fumigatus* and *A. parasiticus* shows their importance on stored groundnuts in Zimbabwe. Even distribution of *A. flavus* across all selected markets implies that management strategies should be implemented on all markets under investigation. From this study *A. flavus* was more prevalent in the samples collected from six markets while *Mucor* and *Penicillium* spp. were less prevalent. *Rhizopus* was always negatively associated with other fungi species which can be due to differences in environmental requirements or competition. This was however contrary to Bayman et al. (2002) who observed a positive association of *A. flavus* and *A*. *niger* in tree nuts.

The range of AFB_1 in groundnut samples analysed in this study were within the safe limits for human consumption according to existing Zimbabwe (5 ppb) regulation (Table 2). Though groundnuts were reported as a good substrate for aflatoxins producing fungi, the results showed that none of the thirty groundnut samples from six major markets of Zimbabwe contained any detectable levels of AFB_1 (≥5 ppb). In contrast with Mupunga et al. (2014), Dangwa et al. (2014), and Siwela et al. (2011) reported high contamination levels of aflatoxins in Zimbabwean groundnuts. Previous studies on aflatoxin in groundnuts from Bulawayo showed that 2/18 contaminated samples had detectable levels of AFB_1 above 4 ppb the maximum allowable limit set by the EU and Codex Alimentarius Commission (7 ppb) (Mupunga, 2013; Kamika et al., 2014). The levels of AFB_1 were below the cut-off point of 5ppb this might be because the conditions were not conducive for aflatoxin production. Furthermore, previous studies have shown that the interaction of *A. flavus* with other fungal species decreases its aflatoxin production or degrades it (Mann and Rehm, 1976; Mislivec et al., 1988). The presence of aflatoxigenic fungi (*A. flavus* and *A. parasiticus*) in groundnuts, however, means there is potential for aflatoxin production and fungal proliferation when conditions are favourable. Though levels were low, chronic exposure to aflatoxins remains a health concern (Williams et al., 2004; Okoth and Kola, 2012).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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REFERENCES

Abuga I (2014). Isolation and identification of fungi associated with groundnut seeds sold at Aleoro central market. Biological Sciences 1:56-62.

Ajeigbe AH, Waliyar F, Echekwu AC, Kunihya A, Motagi BN, Eniaiyeju D, Inuwa A (2015). A farmer's guide to profitable groundnut production in Nigeria. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Kano, Nigeria.

Al-Amodi MO (2016). Fungi associated with seeds of Ashford variety of groundnut grown in Yemen and its disinfection in vitro using sodium hyplochlorite. Global Sciences 5:3414-3422.

Algabr HM, Alwaseai A, Alzumir MA, Taresh SA (2018). Occurrences and frequency of fungi and detection of mycotoxins on poultry rations in Yemen. Bulletin of the National Research Centre 42:32.

Bayman P, Baker JL, Mahoney NE (2002). *Aspergillus* on tree nuts: incidence and associations. Mycopathologica 155:161-169.

Bediako KA, Dzidzienyo D, Ofori K, Offei SK, Asibuo JY, Amoah RA,Obeng J (2019). Prevalence of fungi and aflatoxin contamination in stored groundnut in Ghana. Food Control 104:152-156.

Boli ZA, Zoue LT, Koffi-nevry R, Koussemon M (2014). Fungal contamination and mycotoxins, occurrence in peanut butters marketed in Abidjan district (Côte d'ivoire). Food and Environment Safety 13(3):267-275.

Campos CA (2019). Characterization of *Aspergillus* section *Flavi*: molecular markers as tools to unmask cryptic species, PhD Thesis, Université Paul Sabatier, Toulouse.

Cappuccino JG, Sherman N (1999). Microbiology: a laboratory manual. New York: Addison Wesley Longman.

Dangwa N, Mwenje E, Dhlamini Z, Siwela AH (2014). Molecular characterisation of aflatoxigenic *Aspergillus* species in dried traditional foods in Zimbabwe. Advances in Bioresearch 5:29-36.

Dube L, Mutetwa M (2015). Assessment of aflatoxin awareness by players in groundnut value chain: The case of Dora in Mutare, Zimbabwe. International Journal of Innovative Research and Development 4:90-100.

Dube M, Maphosa M (2014). Prevalence of Aflatoxigenic *Aspergillus* spp. and Groundnut resistance in Zimbabwe. Journal of Agriculture and Veterinary Science 7:8-12.

Kamika I, Mngqawa P, Rheeder JP, Teffo S, Katerere DR (2014). Mycological and Aflatoxin Contamination of Peanuts Sold at Markets in Kinshasa, Democratic Republic of Congo, and Pretoria, South Africa. Food Additives and Contaminants: Part B: Surveillance. doi: 10.1080/19393210.2013.858187.

Krska R, Molinelli A (2009). Rapid test strips for analysis of mycotoxins in food and feed. Analytical and Bioanalytical Chemistry 393:67-71.

Mann R, Rehm HJ (1976). Degradation products from aflatoxin B1 by *Corynebacterium rubrum*, *Aspergillus niger*, *Trichoderma viride* and *Mucor ambrigus*. European Journal of Applied Microbiolology 2:297-306.

Menza NC, Muturi MW (2018). Occurrence of aflatoxigenic *Aspergillus* spp in peanut varieties in Busia and Kisii central districts, Kenya. Open Journal of Medical Microbiology 8:98-108.

Mislivec PB, Trucksess MW, Stoloff L (1988). Effect of other toxigenic mold species on aflatoxin production by *Aspergillus flavus* in sterile broth shake culture. Journal of Food Protection 51:449-451.

Mupunga I (2013). A Comparative Study of Natural Contamination with Aflatoxins and Fumonisins in Selected Food Commodities from Botswana and Zimbabwe Masters Thesis, University of South Africa, South Africa.

Mupunga I, Lebelo SL, Mngqawa P, Rheeder JP, Katerere DR (2014). Natural occurrence of aflatoxins in peanut and peanut butter from Bulawayo, Zimbabwe. Journal of Food Protection 77:1814-1818.

Ncube J, Maphosa M (2020). Current state of knowledge on groundnut aflatoxins and their management from a plant breeding perspective: Lessons for Africa. Scientific African 7:1-7.

Negash D (2018). A review of aflatoxin: occurrence, prevention, and gaps in both food and feed safety. Nutritional Health and Food Engineering 8:190-197.

Njoroge SMC, Kanenga K, Siambi M, Waliyar F, Monyo ES (2016). Identification and Toxigenicity of *Aspergillus* spp. from Soils Planted to Peanuts in Eastern Zambia. Peanut Sciences 43:148-156.

Nleya N, Adetunji MC, Mwanza M (2018). Current status of mycotoxin contamination of food commodities in Zimbabwe. Toxins 10:89.

Nyongesa BW, Okoth S, Ayugi V (2015). Identification key for *Aspergillus* species isolated from maize and soil of Nandi country, Kenya. Advances in Microbiology 5: doi: 10.4236/aim.2015.54020.

Okello DK, Kaaya AN, Bisikwa J, Were M, Oloka HK (2010). Management of Aflatoxins in Groundnuts: A manual for Farmers, Processors, Traders and Consumers in Uganda, Available At: https://www.researchgate.net/publication/260247426 (accessed 4 March 2020).

Okoth SA, Kola MA (2012). Market samples as a source of chronic aflatoxin exposure in Kenya. African Journal of Health Sciences 20:56-61.

Payne RW, Harding SA, Murray DA, Soutar DM, Baird DB, Glaser AI, Channing IC, Welham SJ, Gilmour AR, Thompson R, Webster R (2010). The Guide to GenStat Release 13:2. Statistics. VSN International, Hemel Hempstead, UK.

Pazderka C, Emmott A (2010). Groundnut case study. Available at: chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20Development/0610casestudy_groundnut.pdf. Accessed 28/2/2020.

Samson RA, Visagae CM, Houbraken J, Hon SB, Hubka V, Klaassen CHW, Perrone G, Seiffet KN, Susca A, Tanney JB, Varga J, Koscube S, Szigeti G, Yaguchi T, Frisvad JC (2014). Phylogeny identification, nomenclature of the genus *Aspergillus.* Mycology 78:141-173.

Salau IA, Shehu K, Kasarawa AB (2017). Morphological Characterization of Mycotoxigenic Fungi Contaminating Groundnut Products in Sokoto State. Research in Pharmacy and Biosciences 4:1-7.

Siwela AH, Mukaro KJ, Nziramasanga N (2011). Aflatoxin carryover during large scale peanut production. Food and Nutrition Sciences 2:105-108.

SNV (2012). Groundnuts Subsector study: Report of a study commissioned by SNV Zimbabwe. https://snv.org/cms/sites/default/files/explore/download/zimbabwe_groundnuts_sub-sector_study_report.pdf, accessed 1/05/2020.

Tobin-West MD, Dimkpa SON, Osakwe JA (2018). Isolation and Identification of Fungi Associated with Raw Groundnut Seeds Sold at Four major markets in Port Harcourt Metropolis, Rivers State. Biology, Agriculture and Healthcare 8:29-34.

Williams JH, Phillips TD, Jolly PE, Stiles JK, Jolly CM, Aggarwal D (2004). Human aflatoxicosis in countries: a review of toxicology, exposure, potential health consequences, and interventions. American Journal of Clinical Nutrition 80:1106-1122.

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Knowledge on utilization of wild mushrooms by the local communities in the Selous-Niassa Corridor in Ruvuma Region, Tanzania

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The present study focused on documentation of wild mushroom species used by the local communities in the Selous-Niassa corridor in Namtumbo district, Ruvuma region, Tanzania. Qualitative and quantitative data were collected by interviewing 50 local informants from different localities in the Selous-Niassa wildlife corridor in Namtumbo district. The data documented include types of wild mushroom species, taxonomical information, social-demographic information, indigenous knowledge and uses. The majority of participants in the hunting of wild mushrooms were females aged between 31 and 45 years who were literate peasants with primary education only. The knowledge about edibility of wild mushroom species was mainly transferred to others by old women whereby those eaten by insects and wild animals or do not form much foam during cooking were considered edible. A total of 32 edible and inedible wild mushroom species belonging to thirteen genera and eleven families were documented. Among the documented wild mushrooms, 34.38% were edible, 25% were medicinal and edible, 31.25% did not have known uses, 6.25% were medicinal only and 3.12% were poisonous. The fidelity level (FL) and informant consensus factor (ICF) of the 32 collected wild mushroom species ranged from 50 to 100% and 0.33 to 0.91, respectively. The documentation of wild mushroom species in communities is important for conservation, transfer of knowledge and information regarding their uses across one generation to another. This study provides information that may, in the future, be used for cultivation, pharmacological, and drug discovery studies to improve public healthcare.

Key words: Utilization, ethnomycological survey, edible mushrooms, medicinal mushrooms, indigenous knowledge, mushroom hunters.

INTRODUCTION

Traditional knowledge on mushrooms is a subject of great significance that unveils the relationships between humans and fungi in a given environment, both in the past and present (Molares et al., 2019; Sitotaw et al., 2020). These natural resources in developing countries, particularly in tropical countries, contribute to an important socioeconomic and ecological role in communities' lives, especially in rural areas. Among these resources are wild edible and medicinal mushrooms that are valuably used globally, although they are neglected in some African countries (Njouonkou et al., 2016). Rural communities in Tanzania use wild mushroom for culinary purposes, nutraceuticals (Teke et al., 2018), medicine, and other uses during the beginning of the rainy season (Härkönen et al., 2003). The existing frequency of deforestation, burning of forest or bush, and overexploitation of both timber and non timber goods (Kinge et al., 2017) are most threatening wild mushroom diversity in Tanzania (Härkönen et al., 2003).

Mushrooms are distinctive large fruiting body macrofungi, which are large enough to be seen with the naked eye and can be picked by hand mostly from *Basidioomycota* and *Agaricomycetes* phylum. Mushrooms are broadly grouped into four categories: edible, inedible, medicinal, and poisonous. Macrofungi are cosmopolitan, heterotrophic organisms that are unique in their nutritional value and ecological requirements that occupy important significance in the biodiversity of the world (Hawksworth, 2012; Vishwakarma et al., 2017). Worldwide, there are about three million fungi of which only 140,000 species are macrofungi and to-date, only 14,000 (10%) are classified as mushroom species. Among these species, about 50% (7000 species) possess varying degrees of edibility, and more than 3000 species from 31 genera are edible while less than (1%) are poisonous (Dutta and Acharya, 2014). The most edible wild mushrooms reported in Tanzania are from the genus *Cantharellus* and *Termitomyces,* while among well-known poisonous mushrooms are from the genus *Amanita* (Härkönen et al., 2003).

Traditional knowledge on the uses of mushrooms has been transmitted orally from one generation to the next across societies globally in both past times and present. This indigenous knowledge includes different uses, belief and perception on wild mushrooms (Molares et al., 2019). Romans perceived them as the "Food of the Gods". Ancient Greek beliefs suggest mushrooms have strength and life force providing capacity, particularly for the warriors when they were in battle. Ancient Chinese and Japanese consider mushrooms as the gifts of the God Osiris and the people belonging to ancient India and Iran used mushrooms in their ritualistic performances (Dutta and Acharya, 2014).

In tropical Africa, knowledge of traditional uses of mushrooms and their diversity documentation is scarce. However, some research done on documentation of fungi in Central, East, and West Africa has shown that there is a great diversity of edible and medicinal mushrooms. The number of macrofungal species in Cameroon is estimated at 50,000 species, of which only 1,050 are known. In sub-Saharan Africa, around 300 edible mushrooms have been identified, particularly in Central and Southern Africa (Soro et al., 2019). In addition to the limited information on the macrofungi diversity in tropical regions, very little is known about their ethnomycological knowledge and its importance in Africa countries (Debnath et al., 2019; Njouonkou et al., 2016). In Tanzania, wild mushrooms are among high diversity natural resources which are not well documented. However, about 100 species of wild mushrooms are documented in different regions of Tanzania (Tibuhwa, 2013; Härkönen et al., 2003).

Mushrooms are filamentous fungi with fruiting bodies showing a huge number of pharmacological aspects in human health. They are considered one of the delicious foods and are commonly produced worldwide. These macrofungi are a rich source of nutrients and bioactive compounds such as proteins, carbohydrates, vitamins, fibers, minerals, low lipid contents, and essential amino acids. They also have huge medicinal properties including antibacterial, antiviral, antioxidant, anticancer, and hypocholesterolemic activity (Panda and Tayung, 2015; Venkatachalapathi and Paulsamy, 2016; Hussein and Tibuhwa, 2020; Kinge et al., 2020). The medicinal properties are thought to be due to the presence of diverse secondary metabolites. Mushrooms accumulate different types of secondary metabolites, including alkaloids, phenolic compounds, polyketides, terpenes, steroids, and others (Venkatachalapathi and Paulsamy, 2016; Hussein and Tibuhwa, 2020; Kinge et al., 2020).

The tropical regions in Africa have the highest diversity of macrofungi that has not been completely exploited (Kinge et al., 2017). Tanzania is among the tropical regions in Africa which have rich biodiversity but poorly unexplored. The communities in various tribes in Tanzania including the Haya, Nyamwezi, Sukuma, Hehe, Bena, Makua, and Makonde use macrofungi for various purposes including food, traditional medicines, and rituals. Some tribes such as Chagga, Maasai, and Meru lack knowledge on mushroom traditional uses (Härkönen

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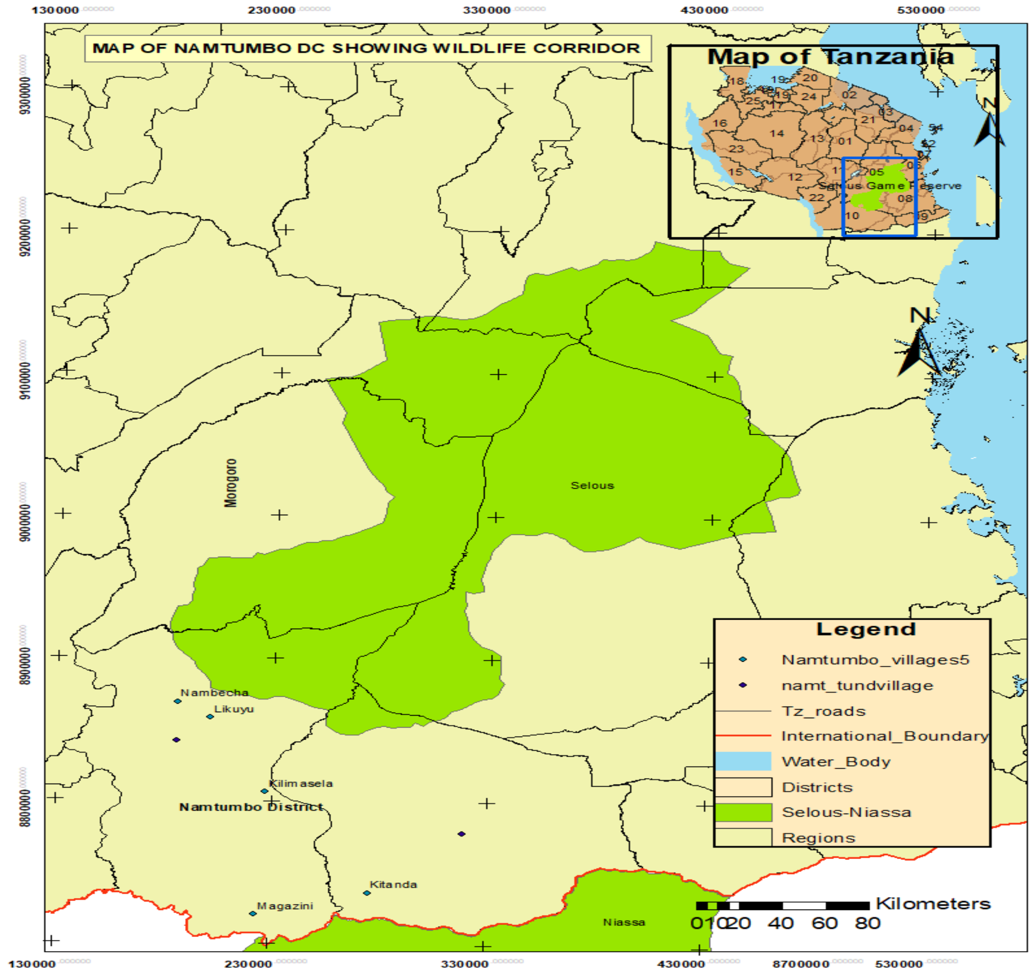

Figure 1. Map of Namtumbo district showing the study site in the Seleous-Niassa Wildlife Corridor.

et al., 2003). However, in other Tanzanian communities ethno-mycology knowledge is scarce due to a low level of documentation. There is no strong purposeful effort in Tanzania to update the wild mushrooms status. Therefore, the present study documented the edible, inedible, and medicinal mushroom species used by community groups in the Selous-Niassa corridor in Namtumbo district, Ruvuma region, Tanzania.

MATERIALS AND METHODS

Study area

The study was conducted at the Selous-Niassa corridor in Namtumbo district, located in the Ruvuma region. The region is located in the Southern part of Tanzania (Figure 1). The Selous-Niassa Wildlife corridor in the Ruvuma region of Southern Tanzania extends roughly from 10° S to 11°40' S. The corridor has a total area of about 10,000 km^2. The larger part of the area of the corridor is found in the Namtumbo district while the other area is found in the east part of the Tunduru district. The corridor is bordered by Selous in the North and the Niassa in Mozambique along the Ruvuma River in the South. The collection was done in Likuyuseka, Nambecha, Kilimasera, Kitanda, and Magazini village in the Namtumbo district.

Ethnographic background and climate

According to the 2012 Population Census, the Namtumbo district human population is 201, 639 people (98,335 male and 103,304 female), whereby population density is 11 people per km^2 (2012 Census; URT, 2013). Mean annual rainfall is about 1230 mm. The rainfall in the corridor decreases from 1200-1300 mm in the Northern part to 800 mm per year in the Southern part along the Ruvuma River. The mean annual temperature is about 21°C (Bloesch and Mbago, 2008).

Dominant ethnic groups within the 29 villages in Namtumbo district are the Yao followed by Ndendeule who settled in the Northern part and a small group of the Ngoni tribe. The community's economy in these three ethnic groups depends on small-scale farming of crops including maize, beans, and paddy for food, with few cash crops which include cashew-nuts, sesame, and tobacco. Livestock keeping is poorly developed but in the corridor area, livestock keeping is not completely ranched (Bloesch and Mbago, 2006, 2008).

Selection of informants and interviews

The entry point to the communities was through village government leaders, who were requested to provide information about individuals in their communities with experience in the identification and collection of wild mushrooms. Resulting from the list that was provided by the village leaders, individuals who appeared to be more knowledgeable about wild mushrooms were selected for detailed interviews. The selected interviewees signed an informed consent form before participating in detailed interviews. Two interview rounds were done, and for each round there were 25 interviewees (10 from the Ndendeule tribe, 10 from the Yao tribe, and 5 from the Ngoni tribe), making a total of 50 interviewees. The selection of respondents focused on people who, in the community, have exceptional knowledge on the use of wild mushrooms for food and medicine. The interviews were conducted in five villages in the local languages; Ngoni, Ndendeule, and Yao depending on the ethnic groups. The information which was enquired from the interviewees included; whether wild mushrooms had any importance to their livelihoods, the seasons when mushrooms are available, uses of mushrooms, and how collectors acquired knowledge about wild mushrooms. Others were: how to differentiate edible and poisonous wild mushrooms; whether they use any of the wild mushrooms for medicinal purposes; and whether there are specific people in their communities who specialized in the collection of wild mushrooms.

The collection of wild mushroom samples was done during rainy seasons in four sessions based on availability; February to March both in 2019 and 2020. The initial identification of the wild mushroom species was done in the field according to Härkönen et al. (2003), where vernacular names and putative scientific names of the wild mushroom species were documented. The collected wild mushroom species were authenticated at the Department of Molecular Biology and Biotechnology, University of Dar es Salaam. Voucher specimens were kept at the Herbarium of the Institute of Traditional Medicine, Muhimbili University of Health and Allied Sciences.

Data analysis

Wild mushrooms data were summarized using descriptive statistics to identify the number and percentage, socio-demographic information, indigenous knowledge on edibility, uses, genera, and families of wild mushrooms used in the community. Relative frequency of citation (RFC), fidelity level (FL), and informants consensus factor (ICF) were determined for quantitative data analysis.

RFC signifies the local importance of each species in a study area. The RFC was determined by:

$$RFC = \frac{FC}{N}$$

where FC is the number of informants citing a useful species and N is the total number of informants in the survey.

FL is the ratio of informants who mentioned the uses of particular species in the surveyed area. FL was determined using the formula:

$$FL = \frac{N_p}{N}$$

where ‘Np’ is the number of informants that claimed the use of a particular species for a particular use and ‘N’ is the total number of informants citing the species for any uses.

ICF determines the homogeneity of information given by respondents. ICF was determined by:

$$IFC = \frac{\text{Nur-Nt}}{(\text{Nur-1})}$$

where Nur is the number of use reports from informants for a particular mushroom use category and Nt is the number of taxa or species category of wild mushroom species.

Ethics approval and consent to participate

The study was awarded Ethical clearance by the Muhimbili University of Health and Allied Sciences Institutional Review Board (Ethical clearance No. Ref.No.DA.282/298/01, Dated, 26th October 2019). Permission to conduct the study in the Namtumbo district was sought from all authorities from the district to the village level. All informants gave prior informed consent before they were interviewed.

RESULTS

Documentation of mushrooms species

A total of 32 mushroom species belonging to thirteen genera and eleven families were documented (Table 1). The most represented wild mushroom families were Russulaceae (10 species) and Cantharellaceae (5 species), followed by Boletaceae (4 species), Clavulinaceae (3 species), and Agaricaceae and Auriculariaceae (2 species). The other families documented and represented by one species each include Amanitaceae, Garnodermataceae, Marasmiusmiaceae, Polyporaceae, and Suillaceae. Among the 32 documented wild mushrooms, 11 (34.38%) were edible, 10 (31.25%) inedible, 8 (25%) were both medicinal and edible species, 2 (6.25%) were medicinal only and 1 (3.12%) poisonous.

Socio-demographic information of informants

A total of 50 wild mushroom hunters and collectors including 29 (58%) women and 21 (42%) men participated as informants. Twenty were Ndendeule, twenty were Yao and ten were Ngoni. The age distribution of the wild mushroom hunters were 20-30 years 4 (8%), 31-45 years 21 (42%), 46-55 years 18 (36%), 56-65 years 4 (8%) and above 65 years 3 (6%). More than half of the respondents 31 (62%) had primary school education, while 19 (38%)

Table 1. Indigenous and conventional characterization of mushrooms.

Scientific name	Vernacular or local name (Tribe)	Family name	Morphology description	Edibility/ Medicinal application	Habitant	Fruiting period
Afroboletus luteolus (Heinem.)Pegler & T.W.K.Young	Nakatunu/ Nakangoma /chikoko (Yao), Mandondo and (Ngoni)	Boletaceae	Dark grey-brown globose the convex cap	Inedible	Mountains forest and miombo woodland	March
Afrocantharellus platyphyllus Eyssart and Buyck	Kungurukwetiti (Yao), Unguyugu uapanakate (Ndendeule) and and Karungeya (Ngoni)	Cantharellaceae	Smooth red at the centre and orange-yellow at margin cap, convex (regularly wavy and irregularly funnel-shaped). Pale to bright yellow gills.	Edible and highly valued	Miombo woodland	Late December, January, and march
Afrocantharellus symoensii Heinem.,Bull.Jard.bot.etat.Bruk.	Chipatwe cha njano or Kungurukweti or Upatewe (Yao), Unguyugu (Ndendeule and Karungey a (Ngoni)	Cantharellaceae	Unevenly red and orange color mixture of a cap, Smooth, thin, depressed at Centre, convex at the margin when young, strongly funnel-shaped when matured. Light yellow or orange-yellow gills.	Edible and highly valued	Miombo woodland	Late December, January, and March
Agaricus spp.	Ulundi or Uhanga (Ngoni)	Agaricaceae	Smooth softy whitish brown and brown colour concentrated at the centre, convex then the flat cap. Whitish then dark white gills.	Edible and highly valued	On termites' hills	Late December, January, and March
Amanita masasiensis Hark. and Saarim	Kogongooro (Ndendeule), Nakajongolo Janjaro(Yao) and Ugongoro (Ngoni)	Amanitaceae	Smooth, slightly sticky yellow-orange darker at the centre, convex then flat cap. Yellow coloured gills.	Edible but not highly valued. Treatment of wound when dry	Miombo woodland	Late December, January, and March
Auricularia delicate (Mont.) Henn.	Mangaukau (Ngoni), Uyoga hindi (Swahili)	Auriculariceae	Ear shaped, Pale to dark brown upper surface and whitish lower surface	Edible and highly valued. Rheumatic pain, injuries, skin inflammation, hemorrhoids, and hemoptysis.	On decaying wood mainly on mountain forest	March to April
Auricularia polytricha (Mount.) Sacc.	Mangaukau (Ngoni), Uyoga hindi (Swahili)	Auriculariceae	Cup-shaped then ear-shaped or folded, Pale brown upper surface	Edible and highly valued. Rheumatic pain, Skin inflammation, and conjunctivitis	On decaying wood mainly on mountain forest	March to April
Boletus Spectabilisi simus Watling	Magomoyakarunga (Yao) (Madondo and (Ngoni)	Boletaceae	Rough orange-yellow or reddish yellow convex cap.	Edible but not highly valued. Alleviate cold symptoms	Degraded miombo woodland	March
Boletus spp.1	Maoloko (Yao),Mandondo (Ngoni)	Boletaceae	Rough greenish-brown or light greenish violent upper surface of the cap	Edible but highly valued	Miombo woodland	March

Table 1. Contd.

Boletus spp.2	Maoloko (Yao),Mandondo and (Ngoni)	Boletaceae	Thick, soft smooth convex to flat yellow or greenish-yellow upper and lower surface of the cap	Inedible	Miombo woodland	March
Cantharellus congolensis Beeli	Chipatweche, (Yao), Unguyugu kakalu (Ndendeule) and Unguyugu mtitu (Ngoni)	Cantharellaceae	Fairly thick brownish fuliginous, convex with central depression cup and brown gills	Edible but not highly valued	Miombo woodlands growing in groups	Late December, January, and March
Cantharellus cf floridula Heinem.	Unguyugu njano (Ndendeule) Chipatwe cha njano (Yao) and Karungeya (Ngoni)	Cantharellaceae	Very thin, Smooth funnel-shaped cap with expanded margin, intensive red at the centre, lighter and light-reddish gills	Inedible	Miombo woodland	Late December, January, and March
Cantharellus isabelinus Var. isabellinus Heinem.	Unguyugu upanake (Ndendeule), Upatwe or Chipatwe cha njano (Yao) Unguyugu njano (Ngoni)	Cantharellaceae	Soft brownish yellow with tiny brown and white flesh cap. Convex with slightly depressed in the middle of the cap (irregularly funnel-shaped) and pale-yellow gills	Edible and highly valued Clean liver, improve vision, regulate the breath, nourish the lung and for diuresis	Miombo woodlands	Late December, January, and March
Chlorophyllum molybdites (G. Mey)	Uhinda (Ndendeule)	Agaricaceae	White with pale brown scales, subglobose then flat cap. White then pale or yellowish-green coloured gills	Poisonous	Bushland vegetation	January to, March
Clavulina sp.1	Ndeuzyalamu like spinach (Yao)	Clavulinaceae	Pale white or cream coloured upper and lower surface	Edibility not known. Improve heartbeats and other heart conditions, treatment of cancer, relief of stomach pain	Soil with degraded woods	February to March
Clavulina sp.2	Ndeuzyamu (Yao)	Clavulinaceae	Soft thick pale white or cream when young and black at edge surface when matured	Edibility not known. Improved heart condition, treatment of cancer, relief of stomach pain	Soil with degraded woods	February to March
Clavulina wisoli R.H,Peterson	Ndeuzyalamu (Yao)	Clavulinaceae	Smooth coloured with a faint pinkish-grey tint. Brush like	Edible. Improve heartbeats and other heart condition, relieve stomach pain, skin infection	Degraded Brachystegia species	February to March
Gastromycetes spp.	Uyoga mayai	Arachniaceae	Yellow or greenish with small brown scales globose with 2-4cm diameter attached to the ground by a thick mass of mycelial strands.	Edible and highly valued	Growing partly buried in soil under different tree species	March

Table 1. Contd.

Humphreya eminni	Not known	Garnodermataceae	Cream, ochraceous to orange-brown upper surface cap	Inedible	Miombo woodland	March
Lactarius densifolius Verbeken and Karhula	Upowa (Ndendeule), Nakazoku (Yao) and Upowa (Ngoni)	Russulaceae	Smooth cream or pale brown convex with a slight central depression cap. Very thin pale cream coloured gills	Edible and highly valued Strengthen weak body condition, condition stomach condition, relieve pain, nourish lungs regulate breath and used in the treatment of cancer	Miombo wood	Late December to March
Lactarius tanzanicus Karhula and Verbeken	Unguyugu nakakuru (Ndendeule), Uyoga mchenga or Upatwe (Yao)	Russulaceae	Bright orange convex then uplifted cap. Dark with brown spots	Inedible	Miombo woodland	Late December to March
Lactarius denigricans Verbeken and Karhula	Kancheke or Likangandunda (Ndendeule) and Upowa (Ngoni)	Russulaceae	Smooth white with black spots or brownish black which convex slightly depressed cap. White with black gills	Edible	Miombo woodlands	Late December to March
Lactarius edulis Verbeken and Buyck	Uboa (Yao) and Nakahuko (Ndendeule	Russulaceae	Rough with cracks whitish brown or ochraceous cream, darker at the centre with convex then uplifted cap. Ochraceous cream gills	Edible and highly valued	Miombo woodland	Late December to March
Lactarius heimi Verbeken	Kikawa (poison) (Ndendeule)	Russulaceae	Smooth pale brownish-orange convex with central depression which then uplifted cap. Yellowish white gills	Inedible	Miombo woodland	Late December to March
Lactarius Kabansus Regler	Kambalakata/ Umbulakata (Ndendeule), Nakambalakata/ Kungulokwetiti (Yao) and Kambarakata (Ngoni)	Russulaceae	Smooth blackish-brown convex with central depression which then uplifted cap. Dark buff-yellow-white gills.	Edible but not highly valued	Miombo woodland	Late December to March
Lactarius medusae Verbeken	Not known to Ndendeule, Yao, and Ngoni	Russulaceae	Tall, applanation to slightly depressed pale greyish purple to a brown cap. Pale cream coloured gills	Edible but not highly valued	Mimbo woodland	Late December to March
Lactarius pumilus Verbeken	Unguyugu kachoko (Ndendeule) and Upatwe (Yao)	Russulaceae	Golden yellow to an orange-yellow convex then slightly depressed cap. Pale orange gills.	Inedible	Miombo woodland	Late December to March
Lactarius xerampelinus Karhula and Verbeken	Chitutazanga (Yao) and not known (Ndendeule)	Russulaceae	Dark red-brown convex with central depression then depressed to funnel shape cap. Pale cream gills	Edible highly valued	Miombo woodland	Late December to March

Table 1. Contd.

Marasmius bekolacongoli Beeli,	Not known	Marasmiusmiaceae	White with dull lilac-colored depression, central rough and greyish lilac, edge wavy thin like a paper upper cap. Sordid cream white lower side.	Inedible	On ground debris in different types of forest	February to March
Polyporus moluccensis (Mont.) Ryvarden	Ngaha (Ngoni)	Polyporaceae	Convex to a flat brownish upper surface	Edible and. Skin treatment highly valued	Decaying wood during moist period	March
Russula aff. roseovelata Quél.	Upoa (Ndendeule),	Russulaceae	Rough greyish-brown or white with brown spots, convex becoming applanate with shallow depression cap. White gills.	Inedible	Miombo woodland	January to March
Suillus spp.	Dito (Ndendeule)	Suillaceae	Smooth purple convex cap	Inedible	Miombo woodland	March

were uneducated.

Indigenous knowledge on wild mushrooms

All the informants recognized wild mushrooms as a source of low-cost food, but only 16 (32.32%) recognized wild mushrooms as a source of medicines and 1 (2%) reported that some of the wild mushrooms are used for recreational and ritual functions. Knowledge on wild mushrooms is transmitted from generation to generation by elderly people and mushroom hunters. Three criteria are used for wild mushroom identification; wild mushrooms that are eaten by insects and wild animals are recognized as edible wild mushrooms; wild mushrooms, which foam during cooking, or those which produce latex are classified as inedible. Some are out rightly recognized as poisonous wild mushrooms.

Harvested wild mushrooms are either consumed immediately or preserved for future use. Preservation of wild mushrooms for long-term use is done by drying in the sun, smoking, and salting. The wild mushrooms are also boiled followed by drying in the sun as an alternative preservation method.

Relative frequency of citation (RFC) and fidelity level (FL)

The FL of the 32 collected wild mushroom species ranged from 50 to 100% (Table 2). The wild mushroom species with high FL were *Agaricus* species, *Cantharellus isabelinus, Afrocantharellus platyphyllus, Afrocantharellus symoensii, Lactarius denigricans, Lactarius edulis, Lactarius pumilus, Lactarius tanzanicus, Amanita masasiensis, Gastromycetes* species, *Auricularia delicata,* and *Auricularia polytricha*. The RFC index authenticates the frequency of citation of wild mushroom species for various uses. RFC of reported species ranged from 22 to 100% (Table 2).

The species with high RFC were *Agaricus* spp., *C. isabelinus, A. symoensii, Lactarius kabansus, Lactarius medusa, L. tanzanicus, A. masasiensis, Clavulina wisoli, Gastromycetes* spp., *A. delicata,* and *A. polytricha*.

Informant consensus factor (ICF)

The ICF value for selected Tanzanian wild mushrooms ranged between 0.33 and 0.91 (Table 3). A higher ICF value found in this study showed practically high reliability of informants in using relatively few species in a particular use category. ICF were categorized into five groups on the basis of the use of informants' reports: edible, medicinal, inedible, both edible and medicinal as well as poisonous.

DISCUSSION

In this study, it has been established that wild edible mushroom species are significant non-timber natural resources of food supplements in the Namtumbo district, and this was found to be a

Table 2. Relative frequency citation (RFC) and fidelity level (FL).

Scientific name	RFC (%)	Major use	FL (%)
Afroboletus luteolus	66	Inedible	97.00
Afrocantharellus platyphyllus	84	Edible	97.60
Afrocantharellus symoensii	100	Edible	100.00
Agaricus spp.	100	Edible	95.70
Amanita masasiensis	92	Edible	95.70
Auricularia delicate	88	Edible	97.70
Auricularia polytricha	94	Edible	95.50
Boletus Spectabilis imus	34	Inedible	58.80
Boletus sp.1	22	Inedible	81.80
Boletus sp.2	54	Inedible	59.30
Cantharellus cf floridula	6	Inedible	46.00
Cantharellus congolensis	68	Inedible	76.50
Cantharellus isabelinus	96	Edible	100.00
Chlorophyllum molybdites	48	Poison	75.00
Clavulina spp.1	22	Inedible	100.00
Clavulina spp.2	26	Inedible	100.00
Clavulina wisoli	92	Edible	73.90
Gastromycetes spp.	90	Edible	86.00
Humphreya eminni	28	Inedible	100,00
Lactarius densifolius	24	Inedible	83.30
Lactarius tanzanicus	94	Inedible	100.00
Lactarius denigricans	84	Inedible	100.00
Lactarius edulis	80	Edible	92.50
Lactarius heimi	46	Inedible	56.50
Lactarius Kabansus	96	Edible	85.40
Lactarius medusae	92	Inedible	85.40
Lactarius pumilus	64	Inedible	100.00
Lactarius xerampelinus	86	Edible	86.10
Marasmius bekolacongoli	24	Inedible	83.30
Polyporus moluccensis	34	Edible	50.00
Russula aff. roseovelata	32	Inedible	93.80
Suillus spp.	28	Inedible	100.00

Table 3. Informant consensus factor (ICF).

User category	Citations		Species		IFC
	User citation	% of user citation	Number of species	% species	
Food	132	73.33	11	34.38	0.91
Inedible	24	13.37	10	31.25	0.61
Medicinal	03	1.67	02	6.25	0.33
Food/Medicinal	18	10.00	08	25.00	0.58
Poisonous	03	1.67	01	6.25	0.33

common feature among the three tribes living in the district.

According to the literature, this is a common phenomenon for rural communities in developing and developed countries who use mushrooms to maintain health and increase longevity since ancient times (Panda and Tayung, 2015). Ethnic groups in other parts of Tanzania also use wild mushrooms for food including the

Coast, Iringa, Mara, Morogoro, Ruvuma, Shinyanga, Tabora, and Tanga regions (Tibuhwa, 2018). Some ethnics in Tanzania use mushroom species to promote healthy recovery of mothers after childbirth, malnutrition in children and elders, treatment of stomach pain as well as management of heart conditions (Haärkönen et al., 2003). In the Namtumbo district, wild mushrooms of the genus *Cantharellus* are the most eaten wild mushrooms followed by the genus *Lactarius*. The genus *Cantharellus* is the most consumed species in most ethnic groups in Africa including Burundi, Cameroon, and Congo (Kamalebo and Kesel, 2020). Most edible wild mushrooms in India are of the genus *Lactarius* and *Cantherallus* (Kumar et al., 2017).

Wild mushrooms are collected during the rainy season by different ethnic groups in the Selous- Niassa wildlife corridor in Namtumbo district since this is when wild mushrooms grow and they disappear shortly after the rainy season in mid-December to late January and late February to early April. The same practice has been observed among other tribes in Tanzania including Bena, Makua, Hehe, Ngoni, Nyamwezi, Nyika, and Sambaa (Haärkönen et al., 2003). The collected wild mushrooms are used as food for about 2 to 3 weeks, after which period most of these tribes preserve wild mushrooms for food by drying them while still raw or they boil the wild mushrooms and dry them in the sun. The present study has established that the Yao, Ndendeule, and Ngoni tribes in the Namtumbo district use the same methods for wild mushroom preservation.

Wild mushrooms gathering or hunting by other Tanzanian ethnic groups are gender-oriented particularly by women for food and commercial purposes (Tibuhwa, 2013, 2018). Wild mushroom activities including collection, selling, processing, and preservation are dominated by women, in Njombe and Mufindi (Chelela et al., 2014). The same was observed in the Namtumbo district; where women are the main wild mushroom collectors and hunters. This seems to be the trend in many societies (Garibay-Orijel et al., 2012). Women worldwide especially in developing countries are the main collectors, traders, and possess knowledge of wild mushroom use such as for food, medicines, and recreational purposes (Haärkönen et al., 2003; Garibay-Orijel et al., 2012; De Leon et al., 2016; Fui et al., 2018). In Mexico (Ruan-Soto, 2006), Nigeria and Brazil (Oso, 1975; Prance, 1984; Teke et al., 2018), and the Philippines (Tantengco and Ragragio, 2018) most wild mushroom sellers and gatherers or hunters are women above 40 years of age.

In this study, it was observed that knowledge about wild mushrooms is transferred to younger generations by the women collectors, and elderly women constitute a big knowledge resource that is important for the transfer of this knowledge to young generations. Knowledge on the identification of wild mushrooms, folk taxonomy, habitat, phenology, and preparation methods are transferred orally in the Namtumbo district and, in other indigenous communities in Tanzania. This shows that if efforts are not made to document knowledge on these wild mushrooms, knowledge will eventually disappear with time and the embedded economic potential may not be realized. The role of elders, especially women (mothers), in transferring this knowledge from one generation to another has been previously underscored (Sitotaw et al., 2020). Tanzanian children are taken by their mothers to identify edible from inedible and pick edible wild mushrooms for food. This knowledge is not taught in schools in rural areas where these wild mushrooms grow (Härkönen et al., 2003).

The tribes in the Namtumbo district determine the edibility of wild mushrooms by morphological charters, growth habitats, and whether eaten by wild animals or insects through observation. Similar methods of edibility identification have been reported in other tribes of Tanzania (Tibuhwa, 2018) and elsewhere in the developing countries (Basumatary and Gogoi, 2016; Teke et al., 2018; Mérida Ponce et al., 2019). Wild mushrooms with mild tastes, thick flesh, and eaten by tortoise or rodents are edible (Fui et al., 2018). The wild mushrooms changing color to red during cooking, yellowish or blackish after touching or cutting, and give a burning sensation on the tongue when tasted raw are considered inedible (Fui et al., 2018; Sitotaw et al., 2020). The three tribes living in the Selous- Niassa wildlife corridor use the related methods for inedibility identification of wild mushrooms.

High values of FL validate potential traditional mushrooms for specific use while low FL values indicate a wide range of uses with the disagreement of a particular use of some specific species (Jamil and Tanweer, 2016; Dapar et al., 2020). A score of 100% FL for a specific mushroom species indicates that all of the use-reports mention the same mushroom for specific use in the study area (Khastini et al., 2018). In Namtumbo district *Agaricus* spp., *C. isabelinus, A. masasiensis*, *L. denigricans*, *L. pumulis*, *Suillus*, and *Clavulina* species had 100% FL for edibility. This FL value information reveals that the three communities in the Namtumbo district rely on specific mushroom species for food (Kim and Song, 2014).

The ICF for the species was determined to know the agreement among the informants living in the Selous-Niassa Corridor in Namtumbo district for indigenous knowledge on wild mushrooms edibility, inedibility, and medicinal uses. The ICF reflected homogeneity, reliability, and the extent of informants' knowledge in the use of wild mushroom species for food, medicinal purposes, and those that are considered inedible in the communities (Uddin and Hassan, 2014). The high ICF value for edible wild mushrooms indicates that wild mushrooms are a valuable traditionally used macrofungi for three ethics in the Namtunbo district as previously suggested in other studies. The low ICF value for inedible wild mushroom species as recorded in the study could be due to a lack of indigenous knowledge on the identification and toxicity determination (Uddin and Hassan, 2014; Tibuhwa, 2018). This is supported by the fact that some of the wild mushrooms that are not eaten in the Namtumbo district are not all poisonous and they are taken as food in other regions in Tanzania (Tibuhwa, 2012, 2013, 2018). Wild mushroom species with high informant consensus factor and fidelity level are interesting for research and as suggested by other previous researchers they should be given priority to carry out bioassay and toxicity studies (Khastini et al., 2018).

Research highlights

(1) The present study exposes the rich ethnomycological practices of wild mushroom species use and indigenous knowledge of Ndendeule, Yao, and Ngoni ethnic groups of the Namtumbo district.
(2) Exchange of information among the local communities in Namtumbo district was observed among three tribes; however, the younger generation has a potential decline of interest due to modern lifestyles and modern medicines.
(3) Novel medicinal use, nutritional use of edible and inedible wild mushroom species were reported in this study.
(4) The consolidated data of this qualitative and quantitative ethnomycology study contributes knowledge on the indigenous use of wild mushrooms that should be taken up by scientists, physicians, and experts such as phytochemists, botanists, pharmacists, taxonomists, and environmentalists for value addition and products development.

CONCLUSION AND FUTURE ASPECTS

Indigenous communities in the Namtumbo district are rich custodians of traditional knowledge and practice in the utilization of wild mushroom species for food and medicine. They have the ability to identify edible wild mushrooms from inedible and poisonous mushrooms. Further work in scientific identification of edible and medicinal mushroom species, nutritional proximate analyses, and bioactivity assays are needed to support the economic exploitation of this resource.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Basumatary M, Gogoi M (2016). Uses of wild edible macro fungi by Bodo community of Kokrajhar district, Assam, India. Tropical Plant Research 3(1):176-181.

Bloesch U, Mbago F (2006). Vegetation study of the Selous-Niassa Wildlife Corridor. Biodiversity, conservation values and management strategies. Ministry of Natural Resources and Tourism Wildlife Division, Mushroom Study in Co-operation with ADAP, Technical report, The united republic of Tanzania. Dar es Salaam.Available At: https://www.adap.ch/wp-content/uploads/2017/12/SNWC_Vegetation_Study_2006.pdf.

Bloesch U, Mbago F (2008). The potential of wild edible mushrooms in the miombo woodlands of the Selous- Niassa wildlife corridor for the livelihood improvement of the local population. Ministry of Natural Resources and Tourism. Wildlife Division, Mushroom Study in Co-operation with ADAP, Technical Report. The united republic of Tanzania, Dar es Salaam. Available At: http://www.adansonia-consulting.ch/document/SNWC_ADAP_Mushroom_Study.pdf.

Chelela BL, Chacha M, Matemu A (2014). The wild edible mushroom value chain for improved livelihoods in Southern Highlands of Tanzania. American Journal of Research Communication 2(8):1-14.

Dapar MLG, Alejandro GID, Meve U, Liede-Schumann S (2020). Quantitative ethnopharmacological documentation and molecular confirmation of medicinal plants used by the Manobo tribe of Agusan del Sur, Philippines. BMC Journal of Ethnobiology and Ethnomedicine 16(14):1-60.

De leon AM, Kalaw SP, Dulay RM, Undan JR, Alfonzo DO, Undan JQ, Reyes RG (2016). Ethnomycological survey of the Kalanguya indigenous community in Caranglan, Nueva Ecija, Philippines. Current Research. Environmental and Applied Mycology 6(2):61-66.

Debnath S, Debnath B, Das P, Saha AK (2019). Review on an ethnomedicinal practices of wild mushrooms by the local tribes of India. Journal of Applied Pharmaceutical Science 9(08):144-156.

Dutta AK, Acharya K (2014). Traditional and ethnomedical knowledge of mushrooms in west Bengal, India. Asian Journal of Pharmaceutical and Clinical Research 7(4):36-41.

Fui FS, Saikim FH, Kulie J, Seelan JSS (2018). Distribution and ethnomycological knowledge of wild mushrooms in Sabah (Northern Borneo), Malaysia. Journal of Tropical Biology and Conservation15:203-222.

Garibay-Orijel R, Ramirez-Terrazo A, Ordaz-Velazquez M (2012). Women care about local knowledge, experiences from ethnomycology. BMC, Journal of Ethnobiology and Ethnomedicine 8(28):1-13.

Härkönen M, Niemela T, Mwansumbi (2003). Tanzanian mushrooms: Edible, harmful and other fungi. Botanical Museum, Museum of Natural History. Helsinki, Finland.

Hawksworth DL (2012). Global species numbers of fungi are tropical studies and molecular approaches contributing to a more robust estimate? Biodiverse Conservation 21(9):2425-2433.

Hussein JM, Tibuhwa DD (2020). Edible mushrooms in Tanzania: enlightening human health and improved livelihood, International Research Journal of Biological Sciences 9(1):33-39.

Jamil AM, Tanweer A (2016). Indigenous Knowledge of the use of medicinal plants in Bheri, Muzaffarabad, Azad Kashmir, Pakistan. European Journal of Integrative Medicine 8(4):560-569.

Kamalebo HM, Kesel AD (2020). Wild edible ectomycorrhizal fungi an underutilized food resource from the rainforests of Tshoop province of Democratic Republic of Congo. BMC, Journal of Ethnobiology and Ethnomedicine 16(8):1-13.

Khastini RO, Wahyuni I, Saraswati I (2018). Ethnomycology of Bracket Fungi in Baduy Tribe Indonesia. Biosaintifika. Journal of Biology and Biology Education 10(2):423-431.

Kim H, Song M (2014). Analysis of traditional knowledge for wild edible mushrooms consumed by residents living in Jirisan National Park (Korea). Journal of Ethnopharmacology 153(1):90-97.

Kinge TR, Apalah NA, Nji TM, Acha AN, Mih AM (2017). Species Richness and Traditional Knowledge of Macrofungi (Mushrooms) in the Awing Forest Reserve and Communities Northwest Region, Cameroon. Hindawi. Journal of Mycology Available At: https://www.hindawi.com/journals/jmy/2017/2809239/.

Kinge TR, Goldman G, Jacobs A, Ndiritu GG, Gryzenhout M (2020). A first checklist of macrofungi for South Africa. MycoKeys 63:1-48.

Kumar M, Harsh NSK, Prasad R, Pandey VV (2017). An ethnomycological survey of Jansar, Chakrata and Dehradum, India. Journal of Threatened Taxa 9(9):10717-10725.

Mérida Ponce JP, Hernǎndez Caldern MA, Cǒmandini O, Rinaldi AC, arzǔ RF (2019). Ethnomycological knowledge among Kaqchikel, indigenous Maya people of Guatemalan highland. BMC, Journal of Ethonobiology and Ethnomedicine 15(36):1-24.

Molares S, Toledo CV, Stecher G, Barroetaveña C (2019). Traditional mycological knowledge and processes of change in Mapuche communities from Patagonia, Argentina: A study on wild edible fungi in Nothofagaceae forests. Mycologia 112(1):1-16.

Njouonkou AL, De Crop E, Mbenmoun AB, Kinje, TR, Biye EH, Verbeken A (2016). Diversity of edible and medicinal mushrooms used in the Noun division of West Region of Cameroon. International Journal of Medicinal Mushrooms 18(5):387-396.

Oso BA (1975). Mushrooms and the Yoruba People of Nigeria. Mycologia 67(2):311-319.

Panda MK, Tayung K (2015). Documentation and ethnomedical knowledge on wild edible mushrooms among ethnic tribes of Northern Odisha, India. Asian Journal of Pharmaceutical and Clinical Research 8(4):139 -143.

Prance GT (1984). The use of edible fungi by Amazonian Indians. Advances in Economic Botany 1:127-139.

Ruan-Soto FR (2006). Garibay-Orijel, Cifuentes J. Process and dynamics of traditional selling wild edible mushrooms in tropical Mexico. BMC. Journal of Ethnobiology and Ethnomedicine 2(3):1-13.

Sitotaw R, Luleka E, Abate D (2020). Ethnomycological study of edible and medicinal mushrooms in Menge districts, Assossa zone, Benshangul Gumuz region, Ethiopia. BMC. Journal of Ethnobiology and Ethnomedicine 16(8):1-13.

Soro B, Kone NA, Vanie-Leabo LP, Konate S, Bakayoko A, Kone D (2019). Phytogeographical and Sociolinguistical patterns of diversity, distribution and uses of wild mushrooms in Cote d'Ivoire, West Africa. BMC. Journal of Ethonobiology and Ethnomedicine 15(5):1-12.

Tantengco OAG, Ragragio EM (2018). Ethnomycological survey of macrofungi utilized by Ayta communities in Batan, Philippines. Current Research. Environmental and Applied Mycology 8(1):104 - 108.

Teke NA, Kinge TR, Bechem E, Nji TM, Ndam LM, Mih AM (2018). Ethnomycological study in the Kilum-Ijim mountain forest, North west region, Cameron. BMC, Journal of Ethnobiology and Ethnomedicine 14(25):1-12.

Tibuhwa DD (2012). Folk taxonomy and use of mushrooms in communities around Ngorongoro and Serengeti national park, Tanzania. BMC. Journal of Ethnobiology and Ethnomedicine 8(36):1-9.

Tibuhwa DD (2013). Wild mushroom-an underutilized healthy food resource and income generator: Experience from Tanzania rural areas. BMC. Journal of Ethnobiology and Ethnomedicine 9(49):1-13.

Tibuhwa DD (2018). Edible and medicinal mushrooms sold at traditional markets in Tanzania. Research Journal of Forestry 12(1):1-14.

Uddin MZ, Hassan A (2014). Determination of informant's consensus factors of ethnomedical plants used in Kalenga forest, Bangladesh. Journal of Plant Taxonomy 21(1):83-91.

United Republic of Tanzania (URT) (2013). 2012 population and Housing Census: Distribution by administrative areas. National Bureau of Statistics, Ministry of Finance, Dar es Salaam. The United Republic of Tanzania.

Venkatachalapathi A, Paulsamy S (2016). Exploration of wild medicinal mushroom species in Walayar valley, the Southern Western Ghats of Coimbatore District Tamil Nadu. Mycosphere 7(2):118-130.

Vishwakarma P, Singh P, Tripathi NN (2017). Diversity of macrofungi and its distribution pattern of Gorakhpur District, Uttar Pradesh, India. Studies in Fungi 2(1):92-105.

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