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RESEARCH

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Local knowledge, perception and practices regarding edible insects among different ethnic groups in Northern Uganda

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Abstract

Background Insects are widely recognized as a valuable source of protein and solution to food security, particularly in developing countries like Uganda. This study documents the local knowledge and practices of edible insects consumed and perception and attitudes towards edible insects by different ethnic groups in northern Uganda.

Methods This cross-sectional study was conducted from October 2023 to January 2024 in the districts of Adjumani, Nwoya, Oyam and Zombo in northern Uganda, where 600 questionnaires which comprised of both closed and open-ended questions were administered to randomly selected respondents (60% female, 40% male) in 24 villages spread across four ethnic groups (Acholi, Langi, Alur and Madi). We aimed to find out, whether differences exist in the types of edible insects consumed and which ones were preferred based on ethnicity, age, gender and education level.

Results Our study revealed that eleven edible insect's species belonging to two orders (Orthoptera and Isoptera) and four families—Tettigoniidae, Termitidae, Gryllotalpidae and Acrididae were consumed as food among the Acholi, Alur, Madi and Langi. These species include: *Ruspolia differens, Locusta migratoria, Kraussaria angulifera, Macrotermes subhyalinus, Macrotermes bellicosus, Macrotermes michaelseni, Pseudacanthotermes militaris, Syntermes* spp. soldiers, *Lanista varelai* and *Gryllotalpa africana*. *L. varelai*, locally known as 'Ocene-labolo' in Acholi, is reported as edible insect for the first time. Additionally, one unidentified edible insect, locally known as 'Mumu' in Alur or 'Lakwinyekimo' in Acholi, was reported to be used as food. Preference for edible insects varied among the ethnic groups, with *R. differens* being the most preferred among Alur (85%) and Acholi (41%). Conversely, *M. subhyalinus* (33%) and *M. bellicosus* (64%) were the most popular among the Langi and Madi, respectively. The respondents had positive perception on edible insect's consumption as an alternative protein source (98%) to conventional protein source, particularly for insects that were already known to be eaten in the study areas.

Conclusions The high diversity of utilized edible insects identified in our study area and the responses indicate that entomophagy is a common practice in the region. Therefore, along with being an important delicacy and traditional foods, edible insects can improve household nutrition status by providing an alternative protein source to alleviate food insecurity and malnutrition among rural communities.

Keywords Consumption pattern, Entomophagy, Ethnic group, Local knowledge

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Background

Edible insects are perceived as a promising option for alleviating global food and nutritional challenges [1–3]. Although their nutritional qualities vary from one species to another, edible insects are a rich source of protein (7–65 g/100 g dry weight), amino acids (46-49 g/100 g dry weight), fats (7–77 g/100 g dry weight), vitamins and minerals (3–8 g/100 g dry weight) and high amount of zinc (0.36–78 mg/100 g dry weight), iron (1.75–99.7 mg/100 g dry weight) and copper (0.20–77.8 mg/100 g dry weight) [3–7].

The consumption of insects by humans (entomophagy) is practised in 130 countries throughout the world by more than 3000 ethnic groups [8]. Edible insect consumption is high in America with over 679 recorded edible insect species, the corresponding values being 524 in Africa, 349 in Asia, 152 in Australia and 41 in Europe [9]. In Africa, entomophagy is still a popular practice in many cultures with different edible insect species reportedly consumed [9–12]. For instance, a multi-country study conducted in the Lake Victoria basin between 2012 and 2013 among different ethnic groups revealed that up to 20 edible insect species were consumed in Uganda, 13 in Burundi and six in Rwanda [13]. In Zambia, Cameroon, Congo, Tanzania, Uganda, Kenya and Central African Republic, edible insects species such as *Ruspolia differens, Oryctes boas, Anaphe panda, Apis mellifera* and *Carebara vidua* are the most commonly consumed insects [14]. The majority of consumed insect species are from the orders Coleoptera, Lepidoptera, Hymenoptera, Orthoptera, Hemiptera, Isoptera, Odonata, and Diptera [9].

Throughout Africa, a number of studies have reported variation among ethnic groups in the practice of entomophagy [15, 16]. The availability of edible insects depends on their geographical distributions, availability of their host plants and seasonality [17]. Traditional communities are well-enriched with local knowledge regarding the occurrence, source, methods of collection, processing and consumption of edible insects [16]. Several studies emphasize the importance of documenting traditional knowledge of edible insects to restore, promote and preserve entomophagy practice [16] and to disseminate information to new consumers [18]. Documenting traditional knowledge can also facilitate the formulation of regulatory frameworks in the edible insect sector, as well as the integration of edible insects into dietary and feed industries [3].

In Uganda, the consumption of insects is a long-standing traditional practice. Indigenous knowledge about entomophagy, i.e. information about when to collect, where to collect, how to find and how to prepare different insect species, is learned through experience and passed down orally from one generation to the next [19]. However, this information is being lost over time due to lack of documentation. According to Okia et al. [13] and Akullo et al. [20], the edible insects widely consumed in Uganda belong to the order Orthoptera, Isoptera, Coleoptera and Lepidoptera. Nonetheless, the available data on the distribution of traditional knowledge of edible insect consumption among the different ethnic groups in the Acholi, Lango and west Nile regions of northern Uganda are very limited, and some commonly eaten species have not been reported before in scientific literature. These locations have distinct ecological, cultural and dietary differences, necessitating the need for this study. The aim of this study therefore is to document the local knowledge and practices of edible insect species consumed, preferences and preference factors, perceptions and attitudes towards edible insect consumption, harvesting, processing and preservation of edible insects among different ethnic groups in northern Uganda.

Materials and methods

Study area

The study was conducted from October 2023 to January 2024 in the districts of Adjumani, Nwoya, Oyam and Zombo in northern Uganda (Fig. 1). These districts were purposively selected for this study due to the longstanding practice of entomophagy among the local communities [21], but with commonly consumed species which have not been reported in scientific literature. Moreover, these areas exhibit distinct agroecological conditions and diverse ethnic groups, along with varying demographic, cultural and socioeconomic characteristics that affect the availability and consumption of edible insects.

Agroecological conditions of the study area

Adjumani district is located in the northwestern Uganda, roughly between latitude 32° 24′ and 32° 4′, longitude 2° 53′ and 3° 37′ N and altitude of 900–1500 m above sea level (m.a.s.l) (Fig. 1). It shares a northeastern border with South Sudan and south east border with Amuru. It occupies an area of 3128 km^2 and has a population of 237,100, with Madi being the predominant ethnic group [22]. Madi is the most widely spoken language in the district; Muslim is the predominant religion. The district experiences a bimodal rainfall, with annual rainfall amounts ranging between 1200 and 1600 mm, with peaks in April–May and August–October. The annual mean temperature ranges from 19 to 36 °C.

On the other hand, Nwoya district lies approximately between 02° 38′ N and 32° 00′ E. The district is bordered to the north by Amuru district; Gulu to the north east; Oyam to the east; Kiryandongo district to the southeast; Masindi district to the south; Buliisa to the south west

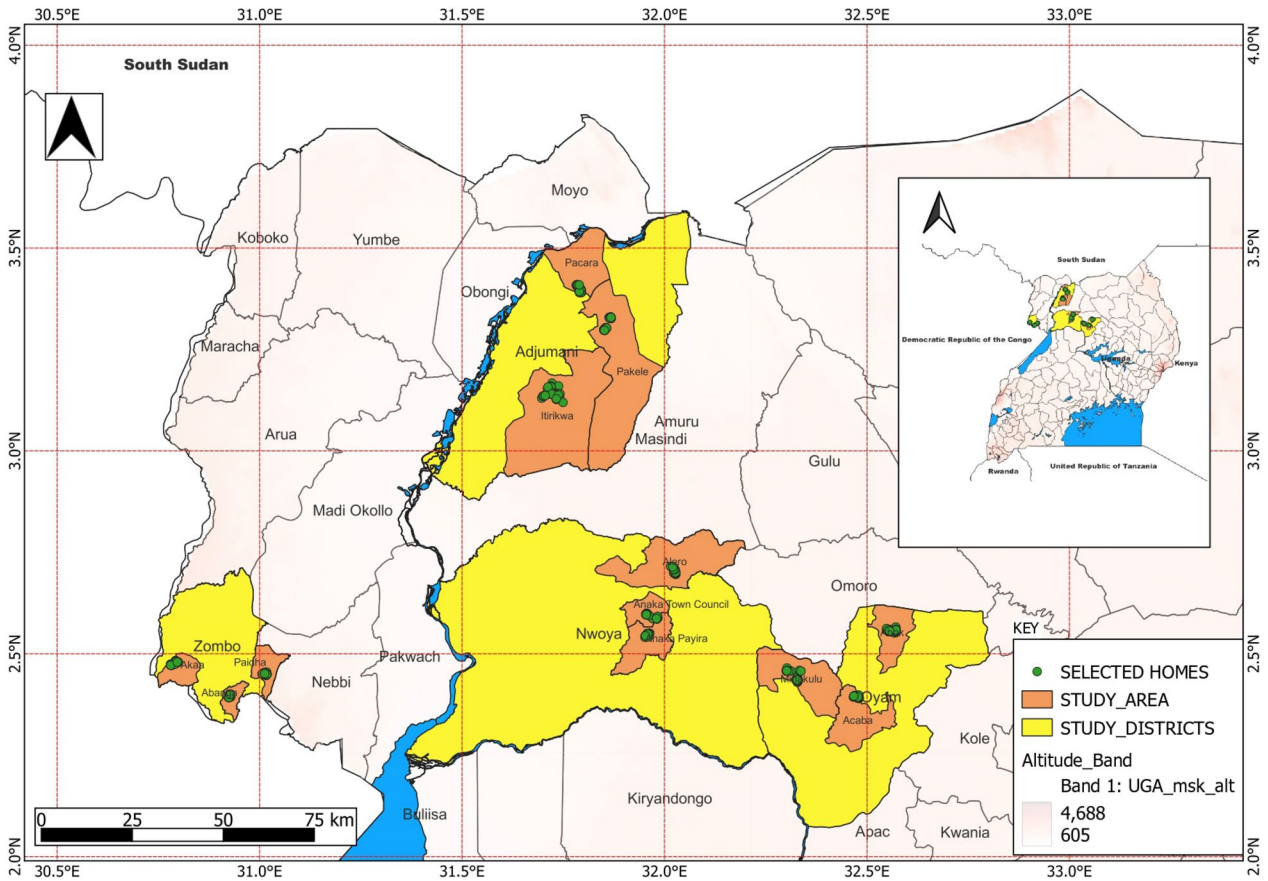

Fig. 1 Location of sub-counties where the study was conducted in Zombo, Nwoya, Oyam and Adjumani districts in northern Uganda. Map was created by the authors using ArcGIS version 10.3.1

and part of the southern district is bordered by Murchison falls national park. It covers an area of 4170 km^2 and has an estimated population of 41,010. The dominant language spoken by the Acholi ethnic group is Luo, and Christianity is the dominant religion in the district [22]. The area is located at an altitude of 3220 m.a.s.l and receives bimodal rainfall pattern with the peak between March to May and July to November, with an annual rainfall ranging between 1000 and 2000 mm and the mean annual temperature range from 17 to 30 °C [23].

Oyam district lies between latitude 2°, 2° 7′ N, longitude 32° 2′ E and altitude 1150 m.a.s.l. The district covers an area of 2207 km^2 and has a population of 453,100, with Langi being the most populous ethnic group. The dominant religion is Christianity, and the dominant language spoken is Lango. The district experiences bimodal rainfall, with an annual rainfall ranging from 1200 to 1600 mm, with the peak occurring between April–May and August–October. The annual temperature ranges from 17 to 36 °C.

Zombo district is located in North Western Uganda, approximately between latitudes 2° 30′, 2° 48′ N, longitudes 30° 45′, 31° 10′ E and altitude 1800 m.a.s.l. The district is bordered to the North by Aura district, to the east by river Nile and Lake Albert, and to the west by the Democratic Republic of Congo (Fig. 1). It has bimodal rainfall pattern which runs from March to October, with a peak in August, an annual rainfall of 1400–1600 mm and an annual temperature range of 17–26 °C. The district covers an area of 2363 km^2 with an estimated population of 283,100. Alur is the major ethnic group in the district, Christianity is the dominant religion, and Alur is the dominant language spoken [22]. In terms of vegetation, all the districts in the study area consist of a mosaic of savanna, dry forests and patches of gallery forests, interspersed with several rivers and streams, as observed from the field. Small-scale agriculture is the main economic activity in all the districts.

Study design, target population and sampling

This was a randomized cross-sectional study conducted among four ethnic groups in selected districts of northern Uganda to assess indigenous knowledge and practices regarding edible insects in their communities. A

total of 600 respondents, 150 from each ethnic group/district were interviewed, preferably those familiar with entomophagy (i.e. people who had eaten edible insects at least once in their life). The sample size was determined using Yamane's formula [24]. The respondents (target population) included the elderly, youth, women and men, with an average age of 41 years, ranging from 18 to 83 years, regardless of their education and occupation, who came from households belonging to the ethnic groups in the study area.

Multi-stage sampling technique was used to identify the survey sites and households for the study. In the first stage, four districts each representing a distinct ethnic group (Acholi, Alur, Langi and Madi) were purposively selected. In the second stage, a stratified random sampling technique was utilized, wherein three sub-counties were randomly selected from each district, followed by the random selection of one parish from each sub-county. The stratification of sub-counties was based on geographical location. Among the sampled households, either the head of the household, spouse or an adult representative, aged 18 years or older was interviewed. If the target respondent was unavailable or unwilling to participate, the next randomly selected household was approached instead.

Data collection

Household surveys were conducted between October 2023 and January 2024 in the following parishes; Amuda, Cana, Pakadha, Mirindi, Boroli, Zoka, Kal, Ogam ward, Pabali, Opuk, Bar and Abanya, with two villages randomly selected from each parish. Information on edible insects was gathered in each of the selected districts of northern Uganda using a pretested semi-structured questionnaire. Pretesting was conducted with 20 participants, comprising 10 males and 10 females. Data were collected at the household level in each village by trained enumerators. A total of 600 respondents participated in the study, 40% of whom were males and 60% females, with an average age of 41 years. Overall, 66% of the respondents had attained primary education, while only 19% and 5% had attained secondary and tertiary education, respectively, and 11% were illiterate. The respondents' further sociodemographic characteristics are shown in Table 1.

The questionnaire comprised of seven parts; in the first part, information about the respondent's sociodemographic characteristics, e.g. their age, education level (illiterate, primary, secondary, tertiary and university), marital status (married, single, widowed and divorced), ethnicity (Acholi, Alur, Langi and Madi), and gender is collected. The second part comprised open-ended questions related to knowledge on commonly consumed

Table 1 Respondent's sociodemographic characteristics ($N=600$) by surveyed districts. The values are means and standard deviation

Respondents' characteristics	Mean (SD)				
	Whole sample ($n=600$)	Adjumani $n=150$)	Nwoya ($n=150$)	Oyam ($n=150$)	Zombo ($n=150$)
Average age of household head	40.85 ± 16.0	38.17 ± 14.8	41.30 ± 15.9	41.89 ± 15.7	42.06 ± 17.3
Household size	6 ± 4	7 ± 4	7 ± 3	5 ± 2	6 ± 4
Gender	*Frequency (%)*				
Male	40	31	35	44	50
Female	60	69	65	56	50
Education level					
No formal education	11	7	16	4	15
Primary education	66	65	61	62	74
Secondary education	19	25	18	24	11
Tertiary education	5	3	5	10	00
Marital status					
Married	96	97	98	100	88
Single	1	1	1	00	3
Window	2	1	1	00	5
Divorced	1	1	00	00	04
Farming activities engaged in (% yes)					
Crop production	19	14	29	10	21
Animal production	8	0	2	1	27
Both animal and crop production	74	86	69	89	51

M, mean; SD, standard deviations and *n* is the number of respondents in each category

edible insects, focusing on their local names, sources, stages of consumption and other uses of edible insects. In the third part, questions were asked about the most preferred edible insects and the reasons for the preference (preference factors) as well as perception and attitudes towards edible insects. The fourth part examined seasonal availability, and the fifth part addressed questions regarding host plants and signs of presence, followed by personal observations. The sixth part covered harvesting techniques and timing of harvesting. The last section dealt with processing methods and preservation techniques.

The questionnaires were administered through face-to-face interviews. Trained enumerators, proficient in the local language of each study area, translated the questions into the local dialect to enhance the respondents' understanding. During the interviews, respondents were presented with pictures or real specimens of insects to assist them in identifying the mentioned insects and specify their local names. The respondents were probed further by enumerators to clarify some of the responses so as to better understand the information being requested. Before administering the questionnaire, each participant was asked for consent, and to ensure the confidentiality of the information, the surveys were conducted anonymously. Samples of edible insects collected were preserved in 70% alcohol and taken to the Multifunctional Research Laboratory at Gulu University for identification. Taxonomical identification of the edible long-horned grasshopper, *Ruspolia differens* followed the identification keys described in Matojo and Njau [25] and Matojo [26]. *Lanista varelai* was identified by Bruno Massa from the department of Agricultural and Forest Sciences, University of Palermo, Italy, a qualified taxonomist who has done extensive research on grasshoppers around the world. The rest of the specimens were identified by competent taxonomists at Makerere University using the identification keys described in Alain Simeu-Noutchom et al. [27], Anantharaju et al. [28], Hasnaoui et al. [29] and Leonard et al. [30].

Data analysis

Binary logit regressions were used to find out whether there was statistically significant relationship between the district, age category, education level, and gender of respondent (the predictors) in the consumption practice of edible insects (response variable; consumes vs. does not consume). The models were fitted separately to each edible insect's species, exceptions being those species which were consumed by almost all respondents, or which were consumed only by very few respondents (< 3%), in which case fitting the model was not possible. The analyses were performed using SPSS version 26 (IBM Corp, Armonk, NY, USA). Finally, to determine which ethnic group had a richer ethnobiological knowledge regarding edible insect collection and consumption, we computed the Ethnobiological Index using the recently developed Botanical Ethnoknowledge quantitative index, abbreviated as BEI [31].

For example, BEI for any particular group = [(ms/sg) + (mc/N)]*sg/st,

where

ms is the mean number of species reported per participant in a particular group,

sg is the total number of species reported by all participants in the particular group,

mc is the mean number of citations per species in a particular group,

N is the number of participants in the particular group and

St is the total number of species reported by all compared ethnic groups in the study.

According to Sulaiman [31], the index values range between 0 (but never equals) and 2 (equals or smaller). Higher values of BEI represent a higher level of ethnobotanical knowledge of a particular group.

Results

Local knowledge of edible insects among ethnic groups in northern Uganda

A total of eleven edible insects belonging to orders Isoptera and Orthoptera were reported as consumed. Among Orthoptera, four different families: Tettigoniidae, Termitidae, Gryllotalpidae and Acrididae (Table 2) were cited. Acholi, Alur, Madi and other ethnic groups consumed eleven taxa, except for the Langi, who consumed only ten (i.e. all except *Locusta migratoria*). The insects consumed included *Macrotermes subhyalinus*, *Ruspolia differens*, *Macrotermes bellicosus*, *Macrotermes michaelseni, Pseudacanthotermes militaris*, *Gryllotalpa africana, Syntermes* spp. soldiers, *Kraussaria angulifera*, *Lanista varelai*, locally known as 'Ocene-labolo' in Acholi, *Locusta migratoria* and another edible insect locally known as 'Mumu' in Alur, whose scientific name is yet to be determined (Table 2). *M. subhyalinus* was cited as the most consumed (100%) edible insects, followed closely by *R. differens* and *M. bellicosus* (both at 99%). Other commonly cited edible insects included *M. michaelseni* (88%), *G. africana* (76%), and *Syntermes* spp. soldiers (54%). The less frequently cited were 'Mumu' (35%), *P. militaris* (34%), *K. angulifera* (26%), *L. varelai* (23%) and *L. migratoria* (3%). Among the recorded species, *L. varelai*, to our knowledge, has never been mentioned as edible insect in Uganda or elsewhere globally. Based on the computed BEI, the ethnic group with the richest

Table 2 Inventory of edible insects consumed in the studied districts of northern Uganda

Common name	Vernacular name (ethnic group)	Species (order, family)	Stage of consumption	Form of consumption	Seasonal availability	Time of harvest	Signs of presence	Host plants	Examples of publication reporting species in Uganda
Long horned edible grasshopper	Ocene (Acholi, Langi), Usene (Alur), Ise (Madi)	*Ruspolia differens* (Orthoptera: Tettigoniidae)	Adult	Raw, fried, roasted, cooked as food	May–June, November–December	06:00–11:00& 19:00–22:00	Chipping sound, flying around light source	*Eleusine coracana, Zea mays, Sorghum bicolor, Megathyrsus maximum, Sporobolus natalensis, Cynodon dactylon, Digitaria abyssinica, Eleusine indica, Hyparrhenia rufa, Heteropogon contortus, Pennisetum purpureum, Sorghum arundinaceum, Urochloa eminii, Chloris gayana, Ageratum conyzoides, Digitaria gayana*	[13, 20, 30, 32–35]
Winged termites	Ngwene Agoro (Acholi,Lang), Ng'wen (Alur), Onya (Madi)	*Macrotermes subhyalinus* (Isoptera: Termitidae)	Winged Adult	Raw, fried, roasted, cooked as sauce, homemade cake, paste	March–August depending on onset of rainfall	19:00–21:00 & 00:00–02:00	Flying around light source	Not known	[13, 20]
Winged termites	Ngwene Aribu (Acholi, Lango), Ng'wen (Alur), Onya (Madi)	*M. bellicosus* (Isoptera: Termitidae)	Winged Adult	Raw, fried, roasted, cooked as sauce, homemade cake, paste	March–May depending on onset of rainfall	03:00–06:00	Flying around light source	Not known	[20, 32, 33]
Winged termites	Ngwene Aliri (Acholi, Lango), Ng'wen (Alur), Onya (madi)	Macrotermes michaelseni (Isoptera: Termitidae)	Winged Adult	Raw, fried, roasted, cooked as sauce, homemade cake, paste	March–August depending on onset of rainfall	14:00–23:00	Flying around light source	Not known	[13]
Winged termites	Ngwene naka (Acholi, Alur, Lango), Onya (Madi)	*Pseudacanthotermes militaris* (Isoptera: Termitidae)	Winged Adult	Raw, fried, roasted, cooked as sauce, homemade cake, paste	March–April	Afternoon when it has rained	Not known	Not known	[20, 32]
Solider termites (of 'Ngwene Agor)	Okok (Acholi, Lango), Ukok (Alur), Eju (Madi)	*Syntermes soldiers* (Isoptera: Termitidae)	Adult	Fried, paste, homemade cake	All year round	Anytime of the day	Presence of tunnels and mud sheet on mound	Not known	[13, 33, 35]
Mole cricket	Odii (Acholi, Lngo), undir (Alur), Diri (Madi)	*Gryllotalpa africana,* (Orthoptera: Gryllotalpidae)	Adult	Fried, roasted	May–August	19:00–21:00	whistling sound, presence of loose soil at the top of the tunnels	Not known	[20]

Table 2 (continued)

Common name	Vernacular name (ethnic group)	Species (order, family)	Stage of consumption	Form of consumption	Seasonal availability	Time of harvest	Signs of presence	Host plants	Examples of publication reporting species in Uganda
African migratory locust	Bonyo (Acholi, Lango), Bonyu (Alur), Yet to be deteremined (Madi)	*Locusta migratoria* (Orthoptera: Acridid)	Adult	Fried, roasted	November–February	06:00–10:00	Not known	Any plant	[20]
Grasshopper	Lababari (Acholi, Lango), Ajutjut (Alur), Yet to be determined (Madi)	*Kraussaria angulifera* (Orthoptera: Acridida)	Adult	Fried, roasted	December–February	Anytime of the day	Flying around	Any plant	[20]
Edible grasshopper	Ocene labolo (Acholi) Ocene abolo (Langi), Usene Rabolu (Alur), Ise (Madi)	*Lanista varelai* (Orthoptera: Tettigoniidae)	Adult	Fried, roasted	All year round	Anytime of the day	Not known	Banana plant	Not reported by any author
Yet to be determined	Langunyekimo (Acholi, lango), Mumu (Alur), Yet to be determined (Madi)	Yet to be determined	Adult	Fried, roasted	March–April	Afternoon when it has rained	Not known	Not known	Not reported by any author

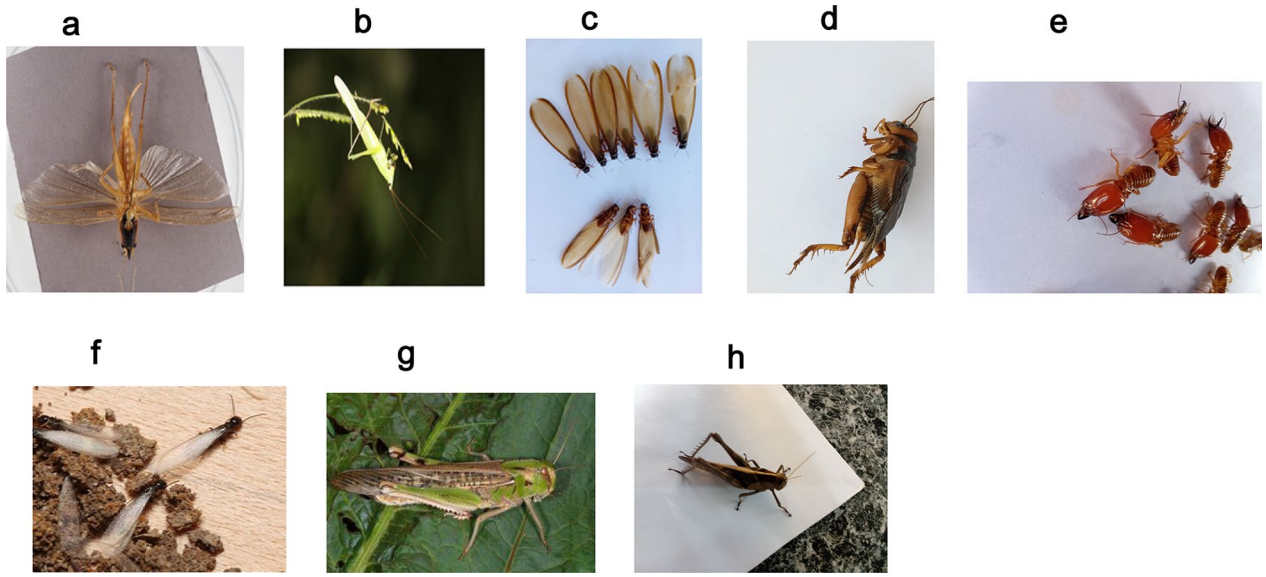

Fig. 2 Pictures of some of the most commonly collected edible insects in northern Uganda: **a** *Lanista varelai*, locally known as 'Ocene-labolo, **b** *Ruspolia differens*, **c** *Macrotermes subhyalinus*, **d** *Gryllotalpa africana*, **e** *Syntermes soldiers*, **f** *Pseudacanthotermes militaris* and **g** *Locusta Migratoria* and **h** *Kraussaria angulifera.*Photo credits:Jiri Vihavainen, (a), Anu Valtonen (b), Martha F. Alaroker (c,d,e,h) and g picture from Insect guide (https://theinsectguide.net/author/melanne-garner/)

ethnobiological knowledge regarding edible insect collection and consumption was the Acholi (BEI = 0.677), followed by the Madi (0.661), Alur (0.572) with Langi being the least (0.564).

Pictures of some of the most commonly collected edible insects in northern Uganda is shown in Fig. 2

Comparison of the number of edible insects cited in the current study to those recorded in other countries with similar vegetation condition in Africa

Table 3 compares the number of edible insects recorded in other regions with similar vegetation condition to the current study. The edible insect species reported in the current study were also found in other African countries

Table 3 Comparison of edible insects cited in the current study to those in other countries with similar vegetation condition in Africa

	Location	Number of edible insects reported	References
This study	Adjumani	11	
	Nwoya	11	
	Oyam	10	
	Zombo	11	
Previous studies in other geological location with similar Vegetation conditions	Democratic Republic of Congo	28	[36]
	Ghana	9	[37]
	Cameroon	31	[38]
	Nigeria	22	[39]
	Central African Republic	96	[40]
	Rwanda	6	[13]
	Burundi	13	[13]
	Uganda	20	[13]
	South-Kiva Province	9	[41]
	Haut-Katanga province	23	[42]

particularly in Democratic Republic of Congo, Rwanda, Burundi, Ghana, Cameroon, Central African Republic, Uganda, South-Kiva Province and Haut-Katanga province (Table 3).

Patterns in consumption

Nearly, all respondents consumed *M. subhyalinus* (100%), *R. differens* (99%) and *M. bellicosus* (99%). On the other hand, only 3% of the respondents consumed *L. migratoria*. Since these species were either consumed by almost all respondents, or by very few individuals, statistical models were not fitted to their data.

Syntermes spp. soldiers were consumed by 54% of the respondents. The binary logit regression result showed differences in the consumption by district ($\chi^2 = 111.8$, d$f = 3$, $p < 0.001$) and level of education ($\chi^2 = 8.7$, d$f = 3$, $p < 0.001$). However, age ($\chi^2 = 5.4$, d$f = 2$, $p = 0.067$) and gender ($\chi^2 = 0.4$, d$f = 1$, $p = 0.502$) did not explain differences in the consumption of *Syntermes* spp. soldiers. The consumption was high in Oyam district (73%), followed by Adjumani and Nwoya at 63% each, while Zombo recorded only 13%. With respect to the level of education, the consumption was 61% among respondents with tertiary level of education, 54% among those with no formal education, or those who had attained primary level of education, and 50% among individuals with secondary level of education.

Gryllotalpa africana was consumed by 76% of the respondents. The binary logit regression result showed differences in the consumption by district ($\chi^2 = 76.6$, d$f = 3$, $p < 0.001$) and age ($\chi^2 = 11.8$, d$f = 1$, $p < 0.001$), whereas no significant differences were seen among respondents based on gender ($\chi^2 = 0.1$, d$f = 1$, $p = 0.74$) or level of education ($\chi^2 = 2.9$, d$f = 3$, $p = 0.394$). In Oyam district, the consumption of *G. africana* was 91%, 89% in Adjumani, 73% in Nwoya and 50% in Zombo. With respect to respondents' age, the percentage of consumption was 83% for respondents that were between 46 years and above, 74% for those 31–45 years and 71% for those18-30 years.

Pseudacanthotermes militaris was consumed by 34% of the respondents. The binary logit regression result showed differences in the consumption by district ($\chi^2 = 22.0$, d$f = 3$, $p < 0.001$) and gender ($\chi^2 = 4.3$, d$f = 1$, $p < 0.037$), while age ($\chi^2 = 2.9$, d$f = 2$, $p = 0.232$) or level of education ($\chi^2 = 1.8$, d$f = 3$, $p = 0.605$) did not explain variation in consumption. In Zombo district, the consumption rate was 45%, in Nwoya 43%, in Adjumani 25% and in Oyam 23%. Among the male respondents, 40% of the respondents consumed *P. militaris*, while among female, the percentage was 31%.

'Mumu' was consumed by 35% of the respondents. The result of binary regression showed differences in the consumption by district ($\chi^2 = 32.7$, d$f = 3$, $p < 0.001$), while gender ($\chi^2 = 1.3$, d$f = 1$, $p = 0.246$), level of education ($\chi^2 = 2.45$, d$f = 3$, $p = 0.485$) and age ($\chi^2 = 0.63$, d$f = 2$, $p = 0.730$) were not significantly different. In Nwoya district, the consumption was 47%, in Zombo 45%, in Oyam 46% and in Adjumani 1%.

Kraussaria angulifera was consumed by 26% of the respondents, the binary regression showed variation in consumption by district ($\chi^2 = 73.4$, d$f = 3$, $p < 0.001$), while there was no difference in consumption by gender ($\chi^2 = 2.4$, d$f = 1$, $p = 0.121$), level of education ($\chi^2 = 4.6$, d$f = 3$, $p = 0.202$) and age ($\chi^2 = 2.9$, d$f = 2$, $p = 0.221$). In Zombo district, the consumption was 56%, in Nwoya 23%, in Oyam 20% and in Adjumani 5%.

Lanista varelai was consumed by 23% of the respondents. The binary logit regression showed significant differences in the consumption by district ($\chi^2 = 76.5$, d$f = 3$, $p < 0.001$), while gender ($\chi^2 = 2.8$, d$f = 3$, $p = 0.093$), level of education ($\chi^2 = 3.4$, d$f = 3$, $p = 0.348$) and age ($\chi^2 = 0.7$, d$f = 2$, $p = 0.390$) did not explain variation. In Nwoya district, the consumption was 44%, in Oyam 43%, in Zombo 5% and in Adjumani 1%.

Macrotermes michaelseni was consumed by 88% of the respondents. Based on the binary logit regression, there was significant difference in consumption by district ($\chi^2 = 7.9$, d$f = 3$, $p = 0.049$) while age ($\chi^2 = 1.9$, d$f = 2$, $p = 0.388$), gender ($\chi^2 = 0.2$, d$f = 1$, $p = 0.629$) or education level ($\chi^2 = 3.2$, d$f = 3$, $p = 0.363$).

Edible insects' source, stage of consumption and forms of consumption

The study revealed that the respondents had good knowledge regarding the source, consumption stages and forms of edible insects. The main source was collection from the wild (99%), followed by purchase from the market (97.3%), with a small percentage received as gifts from relatives or friends (0.5%) and the percentages were notably consistent among the different ethnic groups. All the eleven edible insects cited were consumed as adults (Table 2), and in various forms including raw, roasted, fried, cooked as stew, paste and homemade cake (Table 4).

Months of harvest, time of harvest, signs of presence and host plants

According to the respondents, the edible insects are harvested at different times of the day;

furthermore, also, some of the insects are harvested throughout the year, while others are harvested exclusively in certain months of the year (Table 2). For those whose signs of presence and host plants were known,

Table 4 Forms of consumption of edible insects in the study area

Insect group	Forms of consumption (% of respondents)						
	N	Raw	Roasted	Fried	Paste	Cooked	Homemade cake
R. differens	594	94	98	98	0	97	0
M. bellicosus	591	94	98	98	94	97	98
M. subhyalinus	598	94	98	98	94	97	98
M. michaelseni	528	95	98	98	94	97	98
S. spp. Soldiers	322	99	100	100	99	100	100
P. militaris	205	96	97	97	95	97	96
G. africana	455	0	94	94	0	0	0
'Mumu'	209	97	98	98	0	0	0
L. varelai	139	0	100	100	0	0	0

particularly *R. differens* and *G. africana,* harvesting was mainly done from their host plants after detection.

Other uses of edible insects

In addition to being valued as a food source, edible insects are also used in cultural rites (3%), sale (70%), animal feeds (44%) and baits (23%). Particularly, in this study, five edible insects (*R. differens*, *M. bellicosus*, *M. subhyalinus*, *M. michaelseni* and *P. militaris*) were reported to be traded both within and outside the local markets. Additionally, the wings of *R. differens* were used as chicken feeds, while *P. militaris* served as baits for fishing and bird trapping; meanwhile, *L. varelai* was used to help children with speech difficulties by inserting it under their tongue in the hopes that it would promote speech development. However, aside from being consumed as food, *G. africana*, *L. migratoria* and 'Mumu' had no other uses.

Preference of edible insects

The edible insects were preferred differently in all the study areas. In Nwoya district, among the Acholi ethnic group, *R. differens* was the most preferred (41%), followed by *M. bellicosus* (30%), *M. subhyalinus* (19%), *M. michaelseni* (7%), *S.* spp soldiers (1%) and *P. militaris* (1%). Conversely, in Zombo district, Alur ethnic group exhibited preference for *R. differens* (85%), *M. bellicosus* (15%), and *G. Africana* (1%) was least preferred. Among the Langi ethnic group in Oyam district, *M. subhyalinus* (33%), *M. bellicosus* (27%), and *R. differens* (22%) were most preferred, while *M. michaelseni* (17%) and *P. militaris* (1%) were the least preferred and in Adjumani district, Madi ethnic group, preferred *M. bellicosus* (64%), *R. differens* (32%), *M. subhyalinus* (2%) and *M. michaelseni* (2%) were least preferred. The major reasons for preference of edible insects cited in Zombo, Adjumani, Nwoya and Oyam districts were nutritional value (82%,90%, 89% and 83%), taste (73%,78%,74% and 66%), their colour (78%,34%, 42%, 29%), availability (17%,19%, 28% and 22%), and being eaten in many different forms/the different forms of consumption (33%, 53%, 57% and 78%), respectively.

Perception and attitudes towards edible insects

In general, perceptions and attitudes towards edible insects showed that majority 99% of the respondents consider edible insects as traditional food in their tribe. Meanwhile, 98% of the respondents confirmed that edible insects were prepared as food during ceremonies, could be used as an alternative protein source 98%, they could be produced in an environmentally friendly manner 99% and that they were suitable for human consumption 96%. Nonetheless, a higher percentage, 98% were uncertain about the potential therapeutic benefits of eating edible insects.

Harvesting, processing and preservation techniques of edible insects

Harvesting techniques

The methods used to harvest insects varied depending on the insect, local knowledge and practices of the different ethnic groups. For the case of the edible insects identified in this study, harvesting was majorly done by women (99%) and children (99%), while men (90%) were involved in harvesting insects with high commercial value such as *R. differens*, *M. subhyalinus, M. bellicosus* and *M. michaelseni.* The various harvesting techniques for the edible insects identified in the study are as described below:

Harvesting of Ruspolia differens

Majority (99%) of the respondents reported that hand picking was the typical harvesting method for *R. differens*. Harvesting was normally done in the morning between 6 and 11 am, when the insects are still inactive and unable to fly long distances, while night harvesting was done from 19:00 to 22:00 and occasionally until midnight, depending on size of the swarm. A source of light is placed on the compound, and insects are attracted to light from where they are collected.

Harvesting of Macrotermes subhyalinus and Macrotermes michaelseni

For *Macrotermes subhyalinus,* respondents (99%) reported that harvesting was done at night from 19:30 until midnight, depending on the time the alates start to emerge from the mound. After a morning heavy downpour followed by a brief period of sunshine, the mound is prepared by clearing the bush around it and excavating basin-shaped collection holes where the insects are trapped and collected. The dug holes are occasionally smeared to prevent soil from contaminating the insects. The mounds are checked frequently from 19:00 for the presence of alates and when they begin to emerge out of the mound, a source of light is positioned in the collection holes, from where they are collected and put in containers. They stated that during harvesting, complete silence should be observed because noise drives away the insects, resulting in low harvests. For the case of *M. michaelseni*, the vast majority (99%) of respondents stated that the process of harvesting is identical to that of *M. subhyalinus*, but the only variation is in the shape of the mounds from which they are harvested. For *M. subhyalinus,* the mound is round and wide, whereas for *M. michaelseni*, the mound is tall and slender-shaped.

Harvesting of Macrotermes bellicosus

Respondents (99%) stated that when the vents for alates are detected, collection holes are dug and a tent-shaped structure is constructed above the ground using plant materials, mainly from shrubs, flexible tree branches and stems which are fixed into the ground and covered up with grasses or banana leaves. Only a small portion is covered with a transparent material above the collection hole to allow light to attract the alates into the collection hole. The mound is then inspected, and once the alates stops emerging from the mound, the grasses or banana leaves are removed slightly from the side of the collection hole and they are collected by hand and placed in a container with a lid or placed in polythene bags.

Harvesting of Pseudacanthotermes militaris

For *P. militaris,* 99% of the respondents stated that harvesting was similar to *M. bellicosus* described above, except that the tent-like structure constructed is slightly smaller than that for *M. bellicosus.*

Harvesting of Syntermes spp. soldiers

For *Syntermes* spp. soldiers*,* 40% of the surveyed respondents stated that trapping, also known as termite fishing technique, was used, where materials such as flexible sticks, vines, and grasses, particularly spear grass (*Imperata cylindrica*), are inserted into the vents created on the mound by termites. The vents can also be enlarged using knives, spear or sharp sticks. When *Syntermes* spp. soldiers' bite the invading objects, they are removed and collected in a container. *Syntermes* spp. soldiers are also harvested concurrently with *Macrotermes* spp., particularly, *M. subhyalinus* and *M. michaelseni,* during which *Syntermes* spp. soldiers are swept into the collection hole using a broom once alates for *M. subhyalinus* and *M. michaelseni* stops coming out of the mound. Sometimes the mound is partially destroyed to collect *Syntermes* spp. soldiers once the sign of presence such as mud sheet is detected.

Harvesting of Gryllotalpa africana

Gryllotalpa africana is harvested by hand picking (99% of respondents). When its presence is detected, water is poured into its tunnel before it is dug out and handpicked. Occasionally, a long stick is inserted into the tunnel to keep track of it and prevent it from escaping as the soil is gradually removed. The *G. africana* inside the tunnel is handpicked and placed in a container with a lid to keep it from escaping. Generally, tunnels are recognized by the presence of loose soil at the top of the tunnel.

Harvesting of Lanista varelai ('Ocene-labolo'), Locusta migratoria and Kraussaria angulifera

Harvesting of these edible insects were done by hand picking (99%) from their hosts plants. *L. varelai* is collected by hand from the sheaths of banana stems. Nonetheless, in Zombo, they are reported to appear together in swarms of *R. differens* and are often harvested together in light traps.

Processing and preservation of edible insects

Processing and preservation methods used depend on the insect species. Generally, frying (99%) and roasting (99%) were the main processing methods reported in this study. The insect species processed by roasting or frying include *R. differens, M. subhyalinus*, *M. bellicosus,*

Table 5 Nutritional composition of edible insects in the current study

Nutrient (g/100 g)	*R. differens*	*M. subhylanus*	*M. bellicosus*	*P. militaris*	*S. soldiers*	*G. africana*	*L. migratoria*	*K. angulifera*	*L. varelai*	"Mumu"	*M. michaelseni*
Moisture	66.4 ± 0.5	6.50 ± 0.02	2.31 ± 0.54	5.04 ± 0.15	2.55 ± 0.30	5.58 ± 0.32	4.0	NR	NR	NR	NR
Crude protein	43.1 ± 0.5	39.34 ± 0,12	40.72 ± 0.26	33.51 ± 0.85	64.72 ± 0.75	67.88 ± 0.552	50.79 ± 2	64.69 ± 0.08	NR	NR	NR
Crude fat	48.2 ± 0.2	44.82 ± 2.89	44.84 ± 0.35	46.59 ± 2.13	3.05 ± 1.33	8.48 ± 0.133	34.93 ± 3.37	11.71 ± 0.27	NR	NR	NR
Dietary fibre	3.9 ± 0.1	6.37 ± 1.18	5.27 ± 0.51	6.59 ± 0.07	23.03 ± 0.05	7.55 ± 0.14	15.65 ± 1.7	5.60 ± 0.40	NR	NR	NR
Ash	2.8 ± 0.5	7.58 ± 0.05	4.96 ± 0.07	4.58 ± 0.06	4.19 ± 0.12	12.60 ± 0.97	2.42 ± 0.11	NR	NR	NR	NR
Carbohydrates	N/A	1.89 ± 0.76	2.16 ± 0.62	8.73 ± 1.87	2.46 ± 1.40	47.20 ± 0.32	13.46 ± 4.53	1.43 ± 1.04	NR	NR	NR
Minerals (mg/100 g)											
Potassium (K)	370.6 ± 1.0	NR	676.96 ± 60.8	NR	897.15 ± 0.00	52.33 ± 1.32	29.58 ± 4.32	886.15 ± 2.37	NR	NR	NR
Sodium (Na)	358 ± 1.0	NR	110.94 ± 1.03	NR	115.75 ± 3.89	36.65 ± 0.46	NR	59.21 ± 0.40	NR	NR	NR
Calcium (Ca)	27.4 ± 0.1	58.72 ± 1.29	9.34 ± 2.04	48.31 ± 7.09	4.16 ± 0.00	26.39 ± 0.63	NR	137.5 ± 0.28	NR	NR	NR
Phosphorus (P)	140.9 ± 1.1	NR	49.55 ± 0.07	NR	36.75 ± 0.07	NR	NR	146.47 ± 0.10	NR	NR	NR
Iron (Fe)	16.6 ± 0.1	53.33 ± 1.46	42.71 ± 0.60	60.29 ± 1.11	32.50 ± 3.54	53.28 ± 0.61	0.554 ± 0.03	23.05 ± 0.07	NR	NR	NR
Zinc (Zn)	17.3 ± 0.0	8.10 ± 2.80	16.90 ± 1.47	12.86 ± 0.92	17.64 ± 0.00	15.42 ± 0.77	0.0879 ± 0.009	13.09 ± 0.07	NR	NR	NR
References	[43]	[44]	[44]	[44]	[44]	[45, 46]	[47, 48]	[49]			

NR, not reported

M. michaelseni, P. militaris, G. africana, L. migratoria and K. angulifera. Apart from frying and roasting, insect species, particularly *M. subhyalinus*, *M. bellicosus, M. michaelseni, S.* spp. soldiers and *P. militaris,* are also cooked as food or home-made cake (98%). During processing, the insects are sorted, cleaned, dewinged and de-legged. Removal of wings and legs was reported to be done on insects that belongs to order Orthoptera such as *R. differens, G. africana, L. migratoria* and *K. angulifera*, while for the order Isoptera (*M. subhyalinus*, *M. bellicosus, M. michaelseni*, *P. militaris*) only the wings are removed during processing. The different ethnic groups reported that processing was majorly done by women (99%), followed by children (98%) and men (90%). On the other hand, *R. differens, M. subhyalinus*, *M. bellicosus, M. michaelseni* and *P. militaris* were the only edible insects preserved since they are harvested in large quantities. The remaining species (*G. africana, L. migratoria and K. angulifera, S.* spp. soldiers, 'Mumu' and *L. varelai*) were not preserved because they were always collected in limited quantities. The main preservation techniques reported in the study included sun drying (100%), boiling (77%) and salting (76%).

Nutritional composition of edible insects identified in the study

The proximate and mineral compositions of edible insects reported in the present study based on secondary data are shown in Table 5. Table 5 shows that *G. africana* (67.88 ± 0.552) had the highest amount of crude protein content, whereas *P. militaris* had the lowest (33.51 ± 0.85). Crude fat content was highest in *R. differens* (48.2% ± 0.2), while *S. soldiers* had the least (3.05 ± 1.33). The dietary fibre content was high in *S. soldiers* (23.03% ± 0.05), while *R. differens* had the lowest (3.9% ± 0.1). Ash and carbohydrate contents were highest in *G. africana* (12.60% ± 0.97) and (47.20% ± 0.32), whereas *R. differens* and *M. subhylanus* had the least ash (2.8% ± 0.5) and carbohydrate (1.89% ± 0.76) contents, respectively. In terms of mineral content, iron content was most abundant in *P. militaris* (60.29 ± 1.11), while *S. soldiers* had high zinc (17.64%) and potassium (897.15 ± 0.00) contents. The highest amount of sodium (358 ± 1.0) was recorded in *R. differens*, while *K. angulifera* had the highest amount of phosphorus (146.47 ± 0.10) and calcium (137.5 ± 0.28).

Discussion

Local knowledge of edible insects among ethnic groups in northern Uganda

Our results indicate that a total of eleven edible insects were identified as food sources among the four ethnic groups (Acholi, Alur, Langi and Madi) in northern Uganda. Among these species, *Lanista varelai* and "Mumu" were cited as the edible insect species consumed in the region but has not been reported in any literature. This diverse array of edible insects identified among the four ethnic groups in northern Uganda demonstrates how rich the region is with edible insects that can be used as an alternative protein source, which is consistent with previous observations [50–52]. The diverse edible insect species identified could also be attributed to the different agroecological conditions that supports the existence of their host plants, which serve not only as food source but also as habitat for these insects.

Different studies have also reported varying number of edible insects across different countries, locations and ethnic groups in Africa. For instance, while the current study identified 11 edible insects species, other studies have reported 9 species in Ghana [37], 31 in Cameroon [38], 22 in Nigeria [39], 96 in Central African Republic [40], 28 in Democratic Republic of Congo [36], 20, 13 and 6 in Uganda, Burundi and Rwanda, respectively [13], 9 and 23 species in the South-Kivu province and Haut-Katanga province in the Democratic Republic of Congo, respectively [41, 42], and seven species were identified among Langi ethnic group in northern Uganda [20]. The variation in the number of edible insect species reported our study with those in other similar geological locations could be attributed to the differences in the geographical distribution of edible insects' host plants [36].

Our results also provide compelling evidence that the household interviewed, at one point, consumed edible insects and has some local knowledge particularly, regarding their sources, stages of consumption, forms of consumption, harvesting seasons, processing and preservation techniques. However, the consumption of certain edible insect species is influenced by cultural taboos; for example, among the Alur ethnic group, newly married women are prohibited from eating *R. differens* until when their first-born child is old enough to harvest it for them. However, they are permitted to prepare it for their husbands, who in turn offer them a traditional garment known as "gomasi" as a token of appreciation.

Edible insects' source, stage of consumption and forms of consumption

The findings in our study align with previous research indicating that edible insects were predominantly sourced from the wild [53, 54]. Other studies conducted by Akullo et al. [20] and Fasoranti and Ajiboye, [55] in northern Uganda and Kwara state, Nigeria, respectively, indicated that edible insects from the order, Homoptera, Hymenoptera, Isoptera and Hemiptera were consumed in their adult stage; meanwhile, Séré et al. [56] and Acosta-Estrada et al. [52] also found that edible insects were consumed in diverse forms across cultures and regions, with

variations attributed to the local culinary practices, availability and preferences [36].

Months of harvest, time of harvest, signs of presence and host plants

Edible insects were harvested at various times throughout the year. Some insects were associated with specific host plants and were collected as soon as signs of their presence were observed. For instance, *Ruspolia differens* was detected by its chipping sound, while mole crickets produce whistling sound. *Lanista varelai* and *Ruspolia differens* were harvested from their host plants. Our findings is in line with previous studies done on edible insect consumed in southern Nigeria [53], sub-Saharan Africa [57] and Kenya [58].

Other uses of edible insects

Diverse use of edible insects in the study area was recorded. Other than their food value, edible insects are utilized for cultural rites, medicinal purposes and feeds for the birds [59, 60]. This result is consistent with that of Tamesse et al. [61] who pointed out that edible insect like honeybees was used for ritual purposes, while termites and cockchafer were used for medicinal purposes. Similar observation was made by Mignon [62] and Van Huis [63]; however, we identified a gap in local knowledge on edible insect use among the younger generation, suggesting a potential erosion of the local knowledge, a trend that may persists if not addressed.

Preference of edible insects and preference factors

The inventoried edible insects were preferred differently among the four ethnic groups in northern Uganda. For instance, *R. differens* and *M. bellicosus* were the most preferred edible insects across the four ethnic groups. A study conducted in the Democratic Republic of Congo found that *R. differens, I. oyemensis, A. mellifera* larvae and *G. africana* were the most preferred edible insects [41, 42]. The difference in preference could be attributed to the familiarity, taste, nutritional value, availability and colour. Similar study conducted by Van Huis [3] and Chakravorty et al. [17] linked consumers preference for edible insects to factors such as availability, familiarity, palatability, local traditions and customs, while Kitsa [64] and Vantomme et al. [65] reported that caterpillars were preferred both for their nutritional value and their taste. These findings align well with the results in this study where edible insects were also preferred because of their nutritional value, taste, colour and availability, among the different ethnic groups. However, this finding was contrary to the result reported by Obopile and Seeletso [10] who found that nutritional value was not the major reason for the consumption of edible insects in Botswana since only 5% of the respondents indicated this reason.

Perception and attitudes towards edible insects

Despite the tremendous benefits of edible insect's consumption, some people still have reservations in the use of insects as food citing neophobia as the key factor [66, 67]. Our results showed that respondents from the different ethnic groups had a positive perception towards the consumption of edible insects but did not emphasize the medicinal benefits of entomophagy. This explains why they basically consumed edible insects just for food. Our findings are consistent with Anagonou et al. [15] who reported that perception and attitudes towards edible insects consumption varied among ethnic groups. For instance, among the Dendi, Fon, Yoruba and Ottamari ethnic groups, positive perception towards edible insects' consumption was observed, but they were not aware of the health benefits of eating edible insects especially the Yoruba and Ottamari ethnic groups in the Republic of Benin. A similar study conducted by Megido et al. [68] among the Wallonia people in Belgium also reported a positive perception of edible insect's consumption with about 78% of respondents willing to include edible insects in their diet. Previous studies have reported that the perception and attitudes towards edible insects can be improved through a number of strategies, such as creating awareness about edible insects and insects-based products; particularly among the younger generation, presenting edible insects in different product forms that are appealing to consumers, using positive sensory exposures and tasting trials to increase familiarity with edible insects, developing different edible insects based-products with diverse flavours and ingredients to encourage consumption of edible insects across different categories of people in the society, as well as providing information about the health benefits of consuming edible insects and insect-based products. A study conducted by Gorman et al. [69] found that presenting different information influenced consumers' perception of cricket-containing cookies.

Harvesting, processing and preservation techniques of edible insects

Insects are mainly harvested from the wild by women and children, while men participated only in harvesting species with high commercial value such as *Macrotermes subhyalinus*, *Macrotermes bellicosus* and *Ruspolia differens*. Normally harvesting and processing of edible insects is seen as a women-driven task in all the study districts and this explains why they are the main participants in harvesting and processing of insects [69]. In the current

study, hand picking and light trapping were the main harvesting technique used. This correlates with findings reported by Ebenebe et al. [57], Akullo et al. [20] and Ishara et al. [36], who stated that hand picking and light trapping were the most commonly used harvesting techniques for harvesting crickets and grasshopper, while alates termites were harvested by light trapping.

Processing and preservation techniques differ according to insect's species, purpose for which it is processed, i.e. either for consumption or for preservation and the quantity of the harvest. In this study, *R. differens, Locust migratoria, Kraussaria angulifera, Gryllotalpa africana*, 'Mumu' and *Lanista varelai* were fried when harvested in huge quantities and roasted when only a small amount is collected. For *M. subhyalinus, M. bellicosus, Macrotermes michaelseni, Pseudacanthotermes militaris and Syntermes* spp. soldiers were either roasted, fried, cooked as stew or baked into homemade cake locally known as 'ajabo', 'jabu' and 'alakene', among the Acholi, Alur and Langi ethnic groups. The different cooking methods of edible insects are influenced by tradition, culture and the knowledge that has been passed down from the older generations. Cooking of edible insects helps to improve the sensory characteristics such as taste, colour, odour and texture through formation of aromatic compounds and reduce degenerative enzymes which helps to prolong the shelf life [69]. This finding aligns with the study reported by Akullo et al. [20]; Ayieko et al. [70] and Van Huis [51].

Most of the edible insects reported in this study were preserved by boiling, salting and sun drying. From this study only *R. differens, M. subhyalinus, M. bellicosus, Macrotermes michaelseni, Pseudacanthotermes militaris* and *Syntermes soldiers* were preserved since they were harvested in large quantities; meanwhile, *Locusta migratoria, Kraussaria angulifera, Gryllotalpa africana*, 'Mumu' and *Lanista varelai* were collected in small number and consumed, thus not preserved. Preservation of the edible insects was done to prolong their shelf life and to be used at a later time even when it's not its season [69].

The nutritional composition of edible insects

The reported edible insects have a high nutritional composition that varied among species. These variations could be due to differences in ecotypes, dietary habits of the insect or the age of the insect. [71–73]. These results show that edible insects can provide a good source of protein which ranged from 12 to 79% on dry matter. A study by Probst [74] also reported that edible insects are rich in protein source compared to beef (22.3%), chicken (22.25%), pork (22.0%) and lamb (19.8%). The high protein content of edible insects could help to reduce malnutrition in Africa [74]. Therefore, consumption of edible insects should be encouraged particularly among the rural communities where access to protein sources is limited [75, 76]. Most of the reported edible insects have high moisture contents implying that they cannot be preserved for longer duration due to risks of microbial deterioration and spoilage [77]. However, the shelf life of these edible insects could be extended through preheating, putting under refrigeration, roasting and drying on the sun [78].

The reported edible insects have a high fat content ranging from 12.9 to 48.2%. The high fat content is vital in providing essential fatty acids and energy needed by human body [79]. This implies that consuming edible insects provides energy source that helps to reduce malnutrition associated with energy deficiency particularly in developing countries [4, 10, 67]. The carbohydrate content ranged from 1 to 47%. The high carbohydrates content also provides a primary source of energy. This is, however, lower than that reported by Adámková et al. [80] and Cichon et al. [81]. These edible insects are also rich in minerals, for instance; the reported high amounts of zinc and iron is an indication that edible insects could be used to lower deficiencies associated with zinc and iron which is common in sub-Saharan Africa [81].

Conclusions

This paper analyses the local knowledge and practices regarding edible insects among different ethnic groups in Northern Uganda. Eleven edible insects were consumed in their adult stage and in different forms such as raw, fried, roasted, paste, cooked in stew and homemade cake but preferred differently among four ethnic groups in northern Uganda; the major reasons for preference were taste and nutritional value. Among these edible insects, ten were identified using both common and scientific names, while one is yet to be identified.

Harvesting was mainly done by hand picking and light trapping. Different processing and preservation techniques were used; however, there is need to modify the indigenous processing and preservation techniques so that these edible insects are processed into more palatable forms that can be marketed and consumed and to prolong their shelf life.

In general, the observed high consumption of edible insects in the study area is an indication that entomophagy is still dominant in northern Uganda. However, to further promote consumption of these insects particularly among the young generation, there is urgent need to properly document, package and disseminate the available local knowledge and practices of edible insects so as to encourage its consumption particularly

among the young generation. Formulation of policies would also greatly help in promoting integration of edible insects into the food value chain and establishing market and business frameworks to enhance their trade, thus improving food security and rural livelihoods in the region. Additionally, the high nutritional value of edible insects implies that they can contribute to reduction in malnutrition associated with protein and mineral deficiencies which is common in African countries. Nevertheless, one major limitation of this study was the local population's usage of common vernacular names to refer to several species belonging to one insect order/genus which could have resulted in underrepresentation of the total number of edible insects consumed in the region. Nonetheless, our findings contribute to identification of edible insects that has not been reported in the world and this adds to the global list of edible insects.

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Author contributions
GMM, RT, PN and SVM designed and supervised the project. MFA collected the data and wrote the initial draft of the manuscript. MFA, GMM, RT and AV analysed and interpreted the data. BM identified the new edible insect species (*Lanista varelai*) reported in this study. PN, FS and HA commented the initial draft of the manuscript and contributed to final manuscript. All the authors have read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical clearance to undertake the research was obtained from the Gulu University Research Ethics Committee (GUREC) 002/10/2023 and from the Uganda National Council of Science and Technology, office of the Ugandan President. All the respondents consented verbally after describing the aims of the study and translating into local languages before participating in the study. The authors followed the guidelines of the International Society of Ethnobiology.

Consent for publication
All co-authors have read and agreed to submit the manuscript.

Competing interests
The authors declare no competing interests.

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