Inventory Reveals Wide Edible Insects' Biodiversity in Selected Territories of South-Kivu Province, Democratic Republic of Congo

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Research Article

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Posted Date: July 29th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-744787/v1>

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**Inventory reveals wide edible insects' biodiversity in selected Territories of South-Kivu
Province, Democratic Republic of Congo**

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Abstract

In response to growing food demand, edible insects are seen as a potential source to alleviate food insecurity. With its wide edible insects' biodiversity, the Democratic Republic of Congo is one of the most important biodiversity hotspots in Africa. This study aimed at giving a first insight on inventory showing diversity, perception, consumption, availability, host plants, harvesting techniques and processing techniques of edible insects in South-Kivu, DRC. It recorded twenty-three edible insects belonging to nine families and five orders, some of which are consumed in the larval, adult, egg and pupa stages. *Rhyncophorus phoenicis*, *Alphitobius diaperinus*, *Macrotermes subhyllanus* and *Acheta domesticus* were the most preferred edible insects in Fizi Territory, *Ruspolia differens* and *Apis mellifera* larvae in Kabare Territory, *Imbrasia oyemensis*, *Imbrasia epimethea*, *Rhynchophorus ferrugineus* and *Rhynchophorus phoenicis* in Mwenga Territory, *Ruspolia differens*, *Macrotermes subhyllanus*, *Gryllotalpa africana*, *Nsike*, *Nomadacris septemfasciata* and *Apis mellifera* larvae in Walungu Territory. *R. differens*, *I. oyemensis*, *A. mellifera* larvae, *G. africana* and *Nsike* were preferred for their taste. *A. domesticus*, *A. diaperinus* and *A. mellifera* larvae were abundant throughout the year, while others were only available for 9 months or less per year. Numerous plants have been recorded as their hosts, including plants used for food and income. Harvesting strategies and period, processing methods and preservation techniques depend on insect species, local knowledge and practices. These findings suggest similar and thoroughly studies on entomophagy across the country, while encouraging the rearing of edible insects to address the high existing demand and environmental need.

Keywords: Edible insects; Entomophagy; Seasonal availability; Host plants; Harvesting techniques; Processing methods

1. Introduction

The world's population is expected to reach 9.8 billion by 2050 and 11.2 billion by 2100 (UN, 2019), meaning that demand for food and feed production will increase (Godfray, *et al.*, 2010). In this regard, edible insects have been highlighted as potential in tackling this issue, in addition to their environmental and economic benefits (Premalatha *et al.*, 2011; Halloran *et al.*, 2015; Kinyuru *et al.*, 2015). With their protein content and other nutrients similar to and in some cases higher than that of fish and soy (Sánchez-Muros *et al.*, 2014), edible insects production have been advocated as an alternative to conventional meat production (Van Huis, 2013; Payne *et al.*, 2015; Kinyuru *et al.*, 2018).

Edible insects are traditionally consumed in many parts of the world (Rumpold & Schlüter, 2013), as at least 2 billion people eat them on a regular basis (Van Huis & Oonincx, 2017), not only because of their nutritional value but for their taste as well (Kou & Adámková, 2016; Mishyna & Chen, 2020). Moreover, food and nutrient insecurity remains one of the most fundamental challenges in the Democratic Republic of Congo (DRC), especially in places with less favorable climatic conditions (Doocy *et al.*, 2018). Thus, disadvantaged communities desperately depend on forest products, including edible insects, as they are among the most abundant forest resources (Kim *et al.*, 2017; Vliet *et al.*, 2019). Hence, they play an incredible role throughout the year, especially during the rainy season, depending on the geographical location of different cultures (Bomolo *et al.*, 2017).

Among more than 2000 species of edible insects reported worldwide (Jongema, 2017), the most consumed are beetles (Coleoptera, 31%), caterpillars (Lepidoptera, 18%), and bees, wasps, and ants (Hymenoptera, 14%). This is followed by grasshoppers, locusts and crickets (Orthoptera, 13%), cicadas, leafhoppers, plant hoppers, scale insects and true bugs (Hemiptera, 10%), termites (Isoptera, 3%), dragonflies (Odonata, 3%), flies (Diptera, 2%) and 5 % other orders (Van Huis, 2013). Additionally, the availability of some edible insects depends on the geographical distribution of their host plants and seasonality (Chakravorty *et al.*, 2013), and correlate with their harvesting period (Takeda & Sato, 1993). In turn, successful harvesting of edible insects depends on insect habits and ecological factors (Kelemu *et al.*, 2015), as they are harvested at different growth stages, including the larval (bees, beetles, butterflies, and ants) and adult (beetles, ants, grasshoppers) stages. For some species, harvesting is easy at night or early in the morning when they are inactive and, therefore, could not fly (Kinyuru *et al.*, 2010). Harvesting techniques of edible insects are a mixture of observations, hand-picking, tracings, sign interpretations, and trapping strategies (Hanboonsong *et al.*, 2013), and vary from one insect to another. Among them, the most commonly used are hand-picking commonly used for

crickets, Rhinocerus beetle, African palm weevil, and caterpillars, while light trapping is the most used to harvest termites, green grasshoppers, house cricket, and mole cricket (Meutchieye *et al.*, 2016; Ebenebe *et al.*, 2017).

Studies on edible insects have been conducted in Africa, America, Asia, Europe and Australia to assess key variables in entomophagy perception and practices (Van Huis, 2013; Hartmann *et al.*, 2015; Kelemu *et al.*, 2015; Kinyuru *et al.*, 2015; Cicatiello *et al.*, 2016; Laureati *et al.*, 2016; Raheem *et al.*, 2018; Schlup & Brunner, 2018; Wilkinson *et al.*, 2018; Woolf *et al.*, 2019). Despite the wide diversity of edible insects in the DRC, there are few studies on edible insects' inventory except the study conducted on ecological diversity of edible insects and their potential contribution to household food security in Haut-Katanga Province (Bomolo *et al.*, 2017) and on entomophagy in the area surrounding LuiKotale, Salonga National Park (Payne *et al.*, 2016). However, to the best of our knowledge, in South Kivu, there is little-to-no research on the biodiversity, perception, consumption, availability, host plants, harvesting techniques and processing techniques of edible insects. Due to differences in ecology, culture and dietary habits from other studied regions, the results of other research cannot be extrapolated to South-Kivu consumers. Therefore, there is need for more detailed study in this regard.

2. Material and methods

2.1. Ethics statement

All experimental protocols as well as methods were approved and carried out in accordance with relevant guidelines and regulations from the Interdisciplinary Centre for Ethical Research (CIRE) established by the Evangelical University in Africa, Bukavu, D.R. Congo, with reference (UEA/SGAC/KM 132/2016). Informed consent form describing the aim of the study was signed by all subjects after translation into local languages.

2.2. Study area

The survey and direct observation were carried out in four selected Territories (Fizi, Kabare, Mwenga and Walungu) of South-Kivu Province, D.R. Congo where data on diversity, host plants, seasonal availability, harvesting techniques and traditional processing, consumption, preference of edible insects were collected. These Territories (Figure 1) were purposively selected for their familiarity with entomophagy as it is traditionally practiced by local communities. These selected Territories are in different agroecological conditions with different cultures influencing edible insects' availability and consumption as well.

Figure 1. Map showing South-Kivu Province and the study Territories

2.3. Agro-ecological conditions of the study area

Table 1. Agro-ecological conditions of the study area (CAID, 2021)

Characteristics	Territory			
	Fizi	Walungu	Kabare	Mwenga
Latitude (South)	3°30 to 4° 51'32	2°38'	2°30'	3° to 4°
Longitude (East)	27° 45 to 29° 14'10	28°40'	28°30'	28°25'29''
Area (km ²)	15,789	1,800	1,960	11,172
Altitude (m)	750 to 1,700	1,000 to 2000	1,420 to 3,200	670 to 1,800
Climate type	Humid wet and dry tropical	Humid wet tropical	Humid wet tropical	Equatorial
Dominant soil unity	Acrisols and Cambisols	Ferralsols, Cambisols and Nitisols	Ferralsols and Nitisols	Acrisols and Cambisols
Mean T °C	23.54 °C	17-20 °C	22.6 °C	21-37 °C
Mean Annual P(mm)	1,704	900 to 1,500	1,572	1,650
Estimated Population (2019)	1,093,926	1,509,175	868,616	843,636
Density of population (hab.km ⁻²)	69.3	838.4	443.6	75.5
AEZ*	Low and high altitude	Medium to high altitude	Medium to high altitude	Low and high altitude

P (mm): *Precipitation (rainfall)*; AEZ: *Agro-Ecological Zone (High, Medium, Low)*

Agro-ecological conditions of the study area are presented in the Table 1. The Territory of Fizi is located between 3°30 and 4°51 32 latitude (South), and 27°45 and 29°14 10 longitude (East). Its elevation is subdivided into four zones including the coastline (~750 m), the inland low valley (~1,000 m), a highland (~1,300 m), and the very highland (locally called haut plateau with 1,700 m). The climate in Fizi is highly affected by the elevation. The rainfalls are unevenly distributed according to the month and the climatic subdivision. The north dominated with coastline and inland low valley is characterized with humid tropical climate (of Aw3 type according to Köppen-Geiger classification), the greatest rainfall amounts are recorded in March and November, while the smallest amounts in February and September. The south part has dry humid tropical climate. Available climate data mentioned an average annual rainfall of ~1,704 mm, the mean temperature ~23.54 °C (with the highest observed in April with ~25.6 °C and the lowest ~21.3 °C in September). The territory is dominated by forest, comprising two forest

reserves and a nature reserve. Acrisols and Cambisols are the dominant soil unities according to the WRB classification.

The Kabare Territory is located between 2°30' of South latitude and 28°30' of East longitude. Its altitude varies from ~1,420 to 3,200 m and the Territory occupies an area of ~1690 km² with an estimated population of ~868,616 which makes it among the most populated in the South-Kivu province. The Territory is located in the medium to high altitude AEZ. Available meteorological data mentioned an annual rainfall average of ~1,572mm, and temperature of ~22.6 °C. Most of Kabare is savanna with natural vegetation consisting of wild grasses.

The Territory of Mwenga is located in the middle of the province and is the only Territory surrounded with the other without any country or province borders. It is located between 28°25'29" East longitude and 30°02'16"05" South latitude. Its altitude varies between 1,500 and 1,800 m in the northeast. In the center and the South, it is more or less 670m. In the East, it is more or less 200m and in the West more or less 670m. It has a humid tropical climate with two seasons: the dry season from June to September and the rainy season from September to May. The temperature varies between 21 and 37°C in most of the Territory and is low in the Itombwe area because of the high altitude which goes up to over 2000m. Rainfall reaches 2,000 mm to 3,000mm per year. The vegetation is mainly dense forest and savanna. The forest is home to the Itombwe Nature Reserve (RNI). Relief is dominated with the Itombwe mount uplands and the alluvial valley of the Elila watershed. Soils dominated with clayey (Humic Cambisols) and sandy soil (Acrisols) types.

The Territory of Walungu is located between 2°38' of South latitude and 28°40' of East longitude. Its altitude varies between 1,000m and 2,000m with a cold tropical climate of low altitude. There are two seasons, the dry season (June to August) and the rainy season from September to March. Available station data presented an annual average of ~17-20 °C, and 900 and 1500mm for temperature and rainfall respectively. The vegetation is mainly consisted of grassland, a few forest reserves of Mugaba and Mushwere and woodlands scattered throughout the Territory.

2.4. Sampling and selection of respondents

A total of 520 respondents, about 130 respondents in each Territory, were interviewed, with priority given to people familiar with entomophagy based on the main objectives set. The respondents therefore included adults, women and men over 18 years old and from all social

classes. A structured oral interview was used on an individual basis to ensure better information and to minimize external influences on the respondent's side.

2.5. Sources of data collected

Primary data were obtained from the field survey using three techniques namely questionnaire administration, direct observations and insect collection.

2.5.1. Questionnaire administration

Structured questionnaires were used to obtain information on edible insects in all selected Territories of South-Kivu. The questionnaire was divided into seven sections. In the first section, information about the respondents was collected. Section two contained open-ended questions related to commonly consumed edible insects, focusing on local name and stage of consumption. The third section contained questions about consumer preferences and preference factors. The fourth section included questions related to seasonal availability. In the fifth section, questions about host plants and signs of presence were asked, followed by personal observations. The sixth section dealt with harvesting techniques and timing. The last section dealt with processing methods and preservation techniques. The enumerators translated the questions into the local dialect to enhance understanding of respondents. Pictures and real samples of various edible insects identified from literature were also used to help respondents identify the insects being mentioned. To enhance the depth of information solicited, enumerators probed further for clarification on some responses.

2.5.2. Direct observations

In the field, direct observations of relevant information related to insects and their habitats in the different territories were recorded. Pictures were taken to verify and support the results of the responses obtained from the interviewees. In addition, the researcher had the opportunity to observe how some edible insects were prepared and consumed.

2.5.3. Collection and taxonomic identification of insect samples

Samples of edible insects were collected as part of the survey and the collected insects were preserved in 70% alcohol and taken to the laboratory at Lwiro Research Center for identification. A mixture of primary data and taxonomic characters was used to identify and classify the various species of edible insects in the different territories. The taxonomic characters were derived mainly from archival sources and published literature.

2.6. Data analysis

Data were analysed using R 4.0.0. and Microsoft Excel 16.16.27. The completed questionnaires were cleaned and information verified. Based on the nature of the research questions descriptive and exploratory approaches were used to delineate and describe the existence and

use of edible insects in various Territories. Descriptive statistics and Pearson's chi-square correlation tests (5%) were applied to analyze the collected data where applicable.

3. Results and discussion

3.5. Commonly consumed edible insects in selected Territories of South-Kivu

A total of twenty-three edible insects including *Macrotermes subhylanus*, *Acheta domesticus*, *Rhyncophorus phoenicis*, *Alphitobius diaperinus*, *Ruspolia differens*, *Gryllotalpa africana*, *Apis mellifera* larvae, *Nomadacris septemfasciata*, *Locusta migratoria*, *Rhynchophorus ferrugineus*, *Imbrasia oyemensis*, *Imbrasia epimethea*, *Oryctes monoceros*, *Cirina forda*, *Nsike*, *Kigelegele*, *Kansenda*, *Bangwangwa*, *Maguina*, *Mingungu*, *Ngohangoha*, *Bikolongo* and *Bachache* were inventoried as source of food in the Territories of Fizi, Kabare, Mwenga and Walungu Territories (Table 2, Figure 2). They all belong to nine families including Termitidae, Gryllidae, Curculionidae, Tenebrionidae, Acrididae, Gryllotalpidae, Apidae, Saturniidae and Scarabaeidae and five orders including Isoptera, Orthoptera, Coleoptera, Hymenoptera and Lepidoptera.

From all the inventoried edible insects, four (*M. subhylanus*, *A. domesticus*, *R. phoenicis* and *A. diaperinus*) were found in Fizi, eleven (*M. subhylanus*, *A. domesticus*, *R. differens*, *G. africana*, *A. mellifera* larvae, *N. septemfasciata*, *L. migratoria*, *R. ferrugineus*, *I. oyemensis*, *I. epimethea* and *Nsike*) in Kabare, seventeen (*M. subhylanus*, *A. domesticus*, *R. phoenicis*, *A. diaperinus*, *R. ferrugineus*, *I. oyemensis*, *I. epimethea*, *O. monoceros*, *C. forda*, *Kigelegele*, *Kansenda*, *Bangwangwa*, *Maguina*, *Mingungu*, *Ngohangoha*, *Bikolongo* and *Bachache*) in Mwenga, and eight (*M. subhylanus*, *A. domesticus*, *R. differens*, *G. africana*, *A. mellifera* larvae, *N. septemfasciata*, *L. migratoria*, and *Nsike*) in Walungu.

The *M. subhylanus* and *A. domesticus* were found to be used as source of food in whole study area, namely Fizi, Kabare, Mwenga and Walungu Territories, while *R. phoenicis* and *A. diaperinus* are consumed only in Fizi and Mwenga. In Kabare and Walungu Territories *R. differens*, *G. africana*, *A. mellifera* larvae, *N. septemfasciata*, *L. migratoria* and *Nsike* are used as source of food. Moreover, *R. ferrugineus*, *I. oyemensis* and *I. epimethea* are used as source of food in both Kabare and Mwenga. However, *O. monoceros*, *C. forda*, *Kigelegele*, *Kansenda*, *Bangwangwa*, *Maguina*, *Mingungu*, *Ngohangoha*, *Bikolongo* and *Bachache* are only used as source of food only in Mwenga Territory.

As for the stage of consumption, some edible insect species were consumed at the larval stage including *R. phoenicis*, *A. diaperinus*, *A. mellifera* larvae, *R. ferrugineus*, *I. oyemensis*, *I. epimethea*, *O. monoceros*, *C. forda*, *Maguina*, *Mingungu*, *Ngohangoha*, *Bikolongo* and *Bachache*, and others at the adult stage (*M. subhylanus*, *A. domesticus*, *R. differens*, *G.*

273 *africana*, *Nsike*, *Kigelegele*, *Kansenda*, and *Bangwangwa*). Unlike the others edible insects,
274 the *A. melifera* is even consumed as egg and pupa.

Table 2. Commonly consumed edible insects in selected Territories of South-Kivu

Common name	Scientific name	Family	Order	Territory				Local name	Stage of consumption
				Fizi	Kabare	Mwenga	Walungu		
Termite	<i>Macrotermes subhyllanus</i>	Termitidae	Isoptera	+	+	+	+	Lolongue/Bushungwe	Winged adult
House cricket	<i>Acheta domesticus</i>	Gryllidae	Orthoptera	+	+	+	+	Makelele/Njanjala/hungwe/Ntoro	Adult
Palm weevil	<i>Rhyncophorus phoenicis</i>	Curculionidae	Coleoptera	+	-	+	-	Ebungu/Sololo/Mpose	Larvae
Beetle	<i>Oryctes rhinoceros</i>	Scarabaeidae	Coleoptera	+	-	+	-	Sungunya/Njukisha	Larvae and adult
Grasshopper	<i>Ruspolia differens</i>	Acrididae	Orthoptera	-	+	-	+	Minunu	Adult
Mole cricket	<i>Gryllotalpa Africana</i>	Gryllotalpidae	Orthoptera	-	+	-	+	Nkwananzi	Adult
Honey bee	<i>Apis mellifera</i>	Apidae	Hymenoptera	-	+	-	+	Magusha/Manyagu	Egg, larva and pupa
Red locust	<i>Nomadacris septemfasciata</i>	Acrididae	Orthoptera	-	+	-	+	Mundurha	Adult
Migratory locust	<i>Locusta migratoria</i>	Acrididae	Orthoptera	-	+	-	+	Tondé	Adult
Red palm weevil	<i>Rhynchophorus ferrugineus</i>	Curculionidae	Coleoptera	-	+	+	-	Bivumbe	Larvae
Caterpillar	<i>Imbrasia oyemensis</i>	Saturniidae	Lepidoptera	-	+	+	-	Milanga	Larvae
Caterpillar	<i>Imbrasia epimethea</i>	Saturniidae	Lepidoptera	-	+	+	-	Taku/Tukumombo	Larvae
Rhinoceros beetle	<i>Oryctes monoceros</i>	Scarabaeidae	Coleoptera	-	-	+	-	Batumbu	Larvae
Misigi	<i>Cirina forda</i>	Saturniidae	Lepidoptera	-	-	+	-	Misigi	Larvae
Nsike	NI	NI	NI	-	+	-	+	Nsike	Adult
Kigelegele	NI	NI	NI	-	-	+	-	Kigelegele	Adult
Kansenda	NI	NI	NI	-	-	+	-	Kansenda	Adult
Bangwangwa	NI	NI	NI	-	-	+	-	Bangwangwa	Adult

<i>Maguina</i>	NI	NI	NI	-	-	+	-	Maguina	Larvae
<i>Mingungu</i>	NI	NI	NI	-	-	+	-	Mingungu	Larvae
<i>Ngohangoha</i>	NI	NI	NI	-	-	+	-	Ngohangoha	Larvae
<i>Bikolongo</i>	NI	NI	NI	-	-	+	-	Bikolongo	Larvae
<i>Bachache</i>	NI	NI	NI	-	-	+	-	Bachache	Larvae

Legend: + : Insects present and consumed; - : Insects not present; NI = not identified. All of these edible insects are identified by local names mainly in the dialects Kibembe (Fizi), Kirega (Mwenga) and Mashii (Kabare and Walungu) that are attached to specific physical characteristics or uses.

Figure 2. **a.** *Macrotermes subhyllanus* (Termite); **b.** *Acheta domesticus* (House cricket); **c.** *Rhyncophorus phoenicis* larvae (Palm weevil larvae); **d.** *Alphitobius diaperinus* larvae (Beetle); **e.** *Ruspolia differens* (Grasshopper); **f.** *Apis mellifera* larvae (Honey bee); **g.** *Locusta migratoria* (Migratory locust); **h.** *Rhynchophorus ferrugineus* larvae (Red palm weevil); **i.** *Imbrasia oyemensis* (Caterpillar); **j.** *Oryctes monoceros* larvae (Rhinoceros beetle); **k.** *Imbrasia epimethea* (Caterpillar); **l.** *Gryllotalpa Africana* (Mole cricket); **m.** Nsike ; **n.** *Nomadacris septemfasciata* (Red locust); **o.** *Cirina forda* (Misigi).

The wide biodiversity of edible insect species revealed in South Kivu clearly depicts the importance of entomophagy in the region. Our findings are largely in agreement with that of Bomolo *et al.* (2017) who reported a list of eleven edible insect species belonging to four families in Haut-Katanga Province confirming that the Democratic Republic of Congo has a high diversity of edible insects making it one of the most important biodiversity hotspots in Africa. This biodiversity in terms of edible insects in DRC is also confirmed by Raheem *et al.* (2018) who reported on traditional consumption and rearing of edible insects in Africa, Asia and Europe. Similarly, Kelemu *et al.* (2015) noted that most edible insects consumed in DRC belong to these orders.

This diversity could be associated to the richness of the natural environment conditions (Twine *et al.*, 2003) in each Territory as most of the edible insects are gathered from the wild (Levang *et al.*, 2015). In addition, the geographic distribution of host plants influences the availability of certain edible insects. A low number of caterpillar species has been attributed to marked deforestation, forest degradation and pollution (Ramos-elorduy, 2006; Schabel, 2006). This situation is likely to worsen, with the growing human populations and declining forest base

(Hoare, 2007). Previous studies reported that edible insects consumption and preference are also influenced by their availability and cultures (Hanboonsong *et al.*, 2013; Raubenheimer & Rothman, 2013).

Findings from this study line with Raheem *et al.* (2019) who reported that more than a thousand insect species are worldwide consumed at some stage of their life cycle. In addition, Lepidoptera consumed as caterpillars and Hymenoptera are mostly eaten in their larval or pupal stages like the *A. melifera* mentioned from the survey to be consumed as egg and pupa. Adults as well as larvae of Coleoptera are consumed, while the Orthoptera, Isoptera and Hemiptera orders are mostly consumed as mature adults (Kelemu *et al.*, 2015). Moreover, Kulma *et al.* (2020) who investigated the effect of developmental stage on the nutritional value of edible insects (*Blaberus craniifer* and *Zophobas morio*) reported that there were no significant variation in basic nutrient content, in protein quality expressed as the essential amino acid index. In contrast, they reported a significant difference in protein digestibility, fat content and lipid quality.

3.6. Consumer preference for edible insects

The inventoried edible insects were appreciated differently (Figure 3). In Fizi the most preferred edible insects were the *R. phoenicis* (41%), *A. diaperinus* (26%), *M. subhyllanus* (20%), and *A. domesticus* (13%), while in Kabare the most preferred were *R. differens* (55%) and *A. melifera* larvae (45%). Furthermore, *I. oyemensis* (65%), *I. epimethea* (20%), *R. ferrugineus* (11%) and *R. phoenicis* (4%) were the most preferred in Mwenga, while, *R. differens* (39%), *M. subhyllanus* (22%), *G. africana* (21%), *Nsike* (10%), *N. septemfasciata* (7%) and *A. melifera* larvae (1%) were most preferred in Walungu. Some edible insects were preferred in more than one Territory, such as *M. subhyllanus* (Fizi and Walungu), *R. phoenicis* (Fizi and Mwenga), *R. differens* and *A. melifera* larvae (Kabare and Walungu).

Figure 3. Most preferred edible insects in each Territory (n=130). This is the number of times each edible insect is preferred. The preference is expressed in percentage.

This preference have been reported to be linked to availability (Van Huis, 2013; Obopile & Seeletso, 2013), ethnicity/cultures (Riggi *et al.*, 2016), palatability (Chakravorty *et al.*, 2013) and seasonality (Kinyuru *et al.*, 2013) as some species are more prevalent and familiar in some Territories than others. In addition, indigenous knowledge and processing can also influence the preference of edible insect species (Obopile & Seeletso, 2013). Familiarity appears to be the key driving force, allowing most respondents to react positively to all edible species in terms of their willingness to eat them and thus contribute to addressing food and nutrition insecurity and related issues.

Bomolo *et al.* (2017) revealed that caterpillar consumption is a common practice among ethnic populations in D.R. Congo. This is not the case for the population of Walungu, Kabare and Fizi, although it is the most appreciated edible insects in Mwenga. In Katanga the Bemba and Lamba tribes have a long history of caterpillar consumption since the 18th and 19th centuries (Malaisse & Latham, 2014), while the other tribes (Musanga, Tetela, Mongo, Baluba, Rund, Bacongo, Katshokwe, Emba, Songe, Ndembo, Kaminungu, Kalwena, Kete, Basankusu, Kanyoka, Sanga, Mbote, Yombe, etc.) appear to lack a strong history of caterpillar consumption. In addition, some of these tribes are reluctant to engage in entomophagy,

specifically to consume caterpillars due to their religious beliefs (Meyer-rochow, 2009). Studies have shown that education would play a crucial role in increasing the positive attitude towards edible insects among consumers (Looy & Wood, 2006; Van Huis, 2013).

3.7. Preference for edible insects

The plotted data (Figure 4) give an idea of the factors of appreciation for the most preferred inventoried edible insects (*G. africana*, *R. differens*, *A. melifera* larvae, *Nsike*, *N. septemfasciata* and *I. oyemensis*) represented in two Territories (n=260). Respondents rated them according to taste, size, shape, nutritional value and color. Most of these insects were valued for their taste especially *R. differens* (33%), *I. oyemensis* (32%), *A. melifera* larvae (17%), *G. africana* (3%), and *Nsike* (2%) with the exception of *N. septemfasciata* which was valued for its size (3%) and shape (0.4%). As for size, *R. differens* (5%), *G. africana* (4%) and *N. septemfasciata* (3%) were the most valued. Most of these edible insects were not valued for their nutritional value or color except for *A. melifera* larvae (0.4%) and *I. oyemensis* (1%) for nutritional value and *R. differens* (3%) and *Nsike* (1%) for color.

Considering *M. subhyllanus* and *A. domesticus* represented in all Territories (n=520). Irrespective of Territories, their appreciation depended only on their taste, size and

shape (Figure 5). More appreciation was based on the taste with 8% and 3% against 2% and 1% for the size for *M. subhylanus* and *A. domesticus* respectively, only *M. subhylanus* was appreciated for its shape (1%).

Entomophagy habits differ from country to country and culture to culture, as do preference factors. Insect consumption depends not only on sensory characteristics (Van Huis, 2013) and nutritional value (Obopile & Seeletso, 2013; Kinyuru *et al.*, 2018), but also on customs, ethnic preferences, prohibitions (Van Huis & Oonincx, 2017), and medicinal properties (Musundire *et al.*, 2014). Insects were once associated with filth, fear of contamination and disease, as well as psychological and biased thinking about taste, smell, and color (Deroy *et al.*, 2015), with a sense of disgust that entomophagy was motivated by starvation and is merely a survival mechanism (Van Huis, 2013). This is far from the truth, as insects are not inferior to other protein sources, such as fish, chicken, and beef. Although it will take a bit more motivation to reverse this mentality (Pliner & Salvy, 2006). It is possible to explore edible insects for consumption and increase the possibility of replacing animal products with insects, given that there is evidence that they are clean, tasty, and nutritious (Gahukar, 2011).

In addition, insects have too many ecological advantages over other animal protein sources (Rumpold & Schlüter, 2013). Some studies in European countries such as the Netherlands (Lensvelt & Steenbekkers, 2014) on the acceptance of entomophagy have shown that people who have eaten insects in the past show significantly more positive attitudes towards entomophagy than people who have not, and are more likely to eat them again. Therefore, it seems important to encourage people to take the "first step" and familiarize them with insect consumption. Therefore, consumer "education" about entomophagy should be practiced in its broadest sense (Lensvelt & Steenbekkers, 2014).

3.8. Seasonal availability of various inventoried edible insects

Regardless of Territory, three groups of edible insects, mainly *A. domesticus*, *A. diaperinus* and *A. melifera* larvae, are abundant throughout the year (Table 3). *Nomadacris septemfasciata* is also available throughout the year, but abundant only during 5 months and less abundant from February to August. *Gryllotalpa africana* and *R. ferrugineus*, on the other hand, were abundant throughout the rainy season and are less abundant in the dry season. *G. africana* and *R. ferrugineus* are not abundant, respectively in August and June. Both species are all unavailable in July. Elsewhere, *M. subhylanus*, *R. phoenicis* and *R. differens* are available half the year (6 months). However, *M. subhylanus* and *R. differens* were less available for 3 months of the year while *R. phoenicis* are only available for one month of the year. Other groups such as *Oryctes monoceros*, *Cirina forda*, *Ngohangoha*, *I. oyemensis*, *Nsike*, *Mingungu*, *Bikolongo* and *Bachache* were abundant for only 3 to 4 months of the year. In contrast, *I. epimethea*, *Maguina*, *Kigelegele*, *Kansenda* and *Bangwangwa* were the most available and abundant for only one to two months of the year.

Table 3. Seasonal availability of various inventoried edible insects

Insect species	Rain season					Dry season			Rain season				TMA	TLA
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Termite	+	+	+	+	-	0	0	0	-	-	+	+	6	3
House cricket	+	+	+	+	+	+	+	+	+	+	+	+	12	0
Palm weevil	0	0	0	+	+	+	+	-	0	0	+	+	6	1
Beetle	+	+	+	+	+	+	+	+	+	+	+	+	12	0
Grasshopper	+	-	-	+	+	0	0	0	-	+	+	+	6	3
Mole cricket	+	+	+	+	+	0	0	-	+	+	+	+	9	1
Honey bee	+	+	+	+	+	+	+	+	+	+	+	+	12	0
Red locust	+	-	-	-	-	-	-	-	+	+	+	+	5	7
Migratory locust	-	-	0	0	0	0	0	0	0	0	+	+	2	2
Red palm weevil	+	+	+	+	+	-	0	0	+	+	+	+	9	1
<i>Imbrasia oyemensis</i>	0	+	+	+	-	0	0	0	0	0	0	0	3	1
<i>Imbrasia epimethea</i>	0	+	+	-	0	0	0	0	0	0	0	0	2	1
Rhinoceros beetle	+	+	+	-	-	0	0	0	0	0	0	+	4	2
<i>Misigi</i>	+	+	+	-	0	0	0	0	0	0	0	+	4	1
<i>Nsike</i>	0	0	0	+	+	+	-	-	0	0	0	0	3	2
<i>Kigelegele</i>	0	+	-	0	0	0	0	0	0	0	0	0	1	1
<i>Kansenda</i>	0	0	+	-	0	0	0	0	0	0	0	0	1	1
<i>Bangwangwa</i>	-	0	0	0	0	0	0	0	0	0	0	+	1	1
<i>Maguina</i>	0	+	+	-	0	0	0	0	0	0	0	0	2	1
<i>Mingungu</i>	0	0	+	+	+	-	0	0	0	0	0	0	3	1
<i>Ngohangoha</i>	0	0	0	0	0	0	+	+	+	+	-	0	4	1
<i>Bikolongo</i>	0	0	+	+	+	-	0	0	0	0	0	0	3	1
<i>Bachache</i>	0	+	+	+	-	0	0	0	0	0	0	0	3	1

Legend: + : month of availability ; - : month of less availability ; 0 : month of none availability; TMA: Total month of availability; TLA: Total month of less availability.

Availability is an important factor in the consumption of edible insects (Chakravorty *et al.*, 2013). Our results corroborate with those of Ebenebe *et al.* (2017) who pointed out that most of the harvesting is done during the rainy season in Nigeria especially for winged termites, cricket, caterpillars, *A. domesticus*, *G. africana*, and greenish beetle. Smith & Paucar (2000) suggest that vibrations caused by rain and the sound of thunder would trigger their emergence. Chakravorty *et al.* (2013) also confirmed that the availability of edible insects is seasonal, stating that peak numbers of edible beetles occur from June to September, before decreasing in winter and early spring. They also reported that Odonata and Orthoptera were most abundant in September and October (late summer). Insects of the order Hemiptera and Hymenoptera are less abundant in the period from November to February (winter), while others such as bugs and ants are available throughout the year. This would be attributed to seasonal changes in various regions of the world. In the Central African Republic, the average consumption of caterpillars increases as a consequence of their greater abundance during the rainy season (Van Huis, 2013), as seasonal availability and consumption of edible insects are correlated (Takeda & Sato, 1993). In contrast to our findings, all developmental stages of *R. differens* can be found throughout the year in non-swarming population but at low densities during dry seasons population and high densities during rainy seasons (Opoke *et al.*, 2019).

3.9. Host plants for various inventoried edible insects

Some edible insects such as *M. subhyllanus*, *A. domesticus*, *G. africana*, *A. melifera* larvae, *Kigelegele*, *Kansenda* and *Bangwangwa* do not necessarily have host plants, but others such as *R. phoenicis*, *A. diaperinus*, *R. differens*, *N. septemfasciata*, *L. migratoria*, *R. ferrugineus*, *I. oyemensis*, *I. epimethea*, *O. monoceros*, *C. forda* and *Nsike* require host plants to serve either for habitat or source of food (Table 4). Edible insects such as *N. septemfasciata* and *L. migratoria* are dangerous as they use maize (*Zea mays*), rice (*Oryza sativa*), soy bean (*Glycine max*), sugar cane (*Saccharum officinarum*), ground nuts (*Arachis hypogaea*) and sweet potato (*Ipomoea batatas*) crops as host plants, while the latter are also sources of staple foods for humans. On the other hand, others species *R. phoenicis*, *A. diaperinus*, *R. ferrugineus* and *O. monoceros* were hosted on *Raffia palm*, *Cocos nucifera*, *Elaeis guineensis*, and *Mangifera spp* trees which are not only source of food for humans and a source of income for many people. Their signs of presence differ from one to another. The presence of *R. phoenicis*, *A. diaperinus*, *R. ferrugineus* and *O. monoceros* is noticed by cracking noises in palm trunks, odor and indication of their activities at the hole of entrance. Furthermore, caterpillar smells and typical

439 bird songs were signs of presence for *I. oyemensis* and *I. epimethea*. Moreover, *G. africana*, *N.*
440 *septemfasciata*, *L. migratoria* and *C. forda* are noticed by whistling and canals in the wet
441 ground.

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Table 4. Host plants of various consumed edible insects

Insect species	Host plants		Signs of presence
	Common name	Scientific name	
Termite	NA	NA	NA
House cricket	NA	NA	NA
Palm weevil	Palm, Coconut and African oil palm	<i>Raffia palm, Cocos nucifera</i> and <i>Elaeis guineensis</i>	Cracking noises in palm trunks and odor
Beetle	Palm, Yellow Flame and Mango	<i>Raffia palm, Peltophorum pterocarpum</i> and <i>Mangifera spp</i>	Indication of its activity at the hole of entrance and cracking noises in palm.
Grasshopper	Grass, Guinea grass and giant rat's tail grass	<i>Digitaria sp, Panicum maximum</i> , and <i>Sporobolus pyramidalis</i>	NA
Mole cricket	NA	NA	Whistling and canals in the wet ground
Honey bee	NA	NA	NA
Red locust	Maize, Rice, Soyabean, Sugarcane, Groundnut and Sweet potato	<i>Zea mays, Oryza sativa, Glycine max, Saccharum officinarum, Arachis hypogaea</i> and <i>Ipomoea batatas</i>	Whistling
Migratory locust	Maize, Rice, Soyabean, Sugarcane, Groundnut and Sweet potato	<i>Zea mays, Oryza sativa, Glycine max, Saccharum officinarum, Arachis hypogaea</i> and <i>Ipomoea batatas</i>	Whistling
Red palm weevil	Coconut, African oil palm and sugarcane	<i>Cocos nucifera, Elaeis guineensis</i> and <i>Saccharum officinarum</i> ,	Indication of its activity at the hole of entrance, odor and cracking noises in palm.
<i>Imbrasia oyemensis</i>	Red mangrove	<i>Rhizophora mangle</i>	Caterpillar smells and typical bird songs
<i>Imbrasia epimethea</i>	Red mangrove and African blackwood	<i>Rhizophora mangle</i> and <i>Erythrophleum africanum</i>	Caterpillar smells and typical bird songs
Rhinoceros beetle	Coconut and African oil palm	<i>Cocos nucifera</i> and <i>Elaeis guineensis</i>	Indication of its activity at the hole of entrance and Cracking noises in palm.
<i>Misigi</i>	Red mangrove and African blackwood	<i>Rhizophora mangle</i> and <i>Erythrophleum africanum</i>	Whistling

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Table 4. *Continued*

Insect species	Host plants		Signs of presence
	Common name	Scientific name	
<i>Nsike</i>	Jaragua grass, Weeping lovegrass and Giant rat's tail grass	<i>Hyparrhenia rufa</i> , <i>Eragostis curvula</i> and <i>Sporobolus pyramidalis</i>	NA
<i>Kigelegele</i>	NA	NA	NA
<i>Kansenda</i>	NA	NA	NA
<i>Bangwangwa</i>	NA	NA	NA
<i>Maguina</i>	NYD	NYD	NYD
<i>Mingungu</i>	NYD	NYD	NYD
<i>Ngohangoha</i>	NYD	NYD	NYD
<i>Bikolongo</i>	NYD	NYD	NYD
<i>Bachache</i>	NYD	NYD	NYD

Legend: NA= Not Applicable; NYD = Not Yet Determined.

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Ebenebe *et al.* (2017) highlighted that certain edible insects are associated with the following host plants: cricket-yam; yam beetle-yam; African palm weevil-raffia palm; Rhinoceros beetle-raffia palm, oil palm, coconut tree; butterfly-iroko (*Chlorophora excelsa*), locust bean seed (*Parkia biglobosa*), flamboyant tree (*Delonix regia*), croton (*Croton tiglium*) and ngwu tree; grasshopper and honey bee-*Jatropha gossypifolia*, *Citrus sinensis*, *Morinda lucida*, *Psidium guajava* and *Sarcocephala laifolius*. According to Ngute *et al.* (2020), five of the eleven caterpillar species studied in central Cameroon were reported to have only one host plant, while others had more than one. They identified eighteen plants of which eleven are restricted to natural forest habitats, including *Entandrophragma cylindricum* and *Baillonella toxisperma*. Although many of the identified caterpillar host plants are generally in the wild, a few are domesticated and grown in home gardens and agroforestry systems such as *Mangifera indica* and *Dacryodes edulis*, or are in the process of domestication such as *Ricinodendron heudelotii*, *B. toxisperma* and *E. cylindricum* (Ngute *et al.*, 2020). Also, it should be noted that most of the hosts are plants used as a source of food and revenue; for example, the plant *B. toxisperma* is a class A timber species, which produces fruits with a highly valued and edible oil is extracted (Meunier *et al.*, 2015).

It has been reported that out of 21,252 observations, *R. differens* were observed 20,915 (98%) times on grasses and sedges, with a total of 19 grass species (*Poaceae*) and two sedge species (*Cyperaceae*). Among the grasses the dominant species were *P. maximum*, *B. ruziziensis*, *C. gayana*, *H. rufa*, *Cynodon dactylon*, *Sporobolus pyramidalis* and *P. purpureum* (Opoke *et al.*, 2019). When reared in the laboratory *R. differens* accept artificial food, leaves, flowers, and grains of many grasses, including cultivated cereals (Malinga *et al.*, 2018; Valtonen *et al.*, 2018). At this point, our findings line with those of Meutchieye *et al.* (2016), who observed that the cracking noises in the palm trunks three to four weeks after the final collection of palm wine, the yellow of the internal raffia bamboo, caterpillar odors and typical bird songs and whistling are the signs indicating the presence of *R. phoenicis*, caterpillars, *R. differens* and field crickets.

3.10. Harvesting and processing techniques of edible insects

In this study, we found that harvesting time and techniques vary according to local knowledge, practices, and the insect species (Table 5). Three harvesting techniques were identified, including trapping, hand picking and collection. *M. subhyllanus* (during and after the first rains) and *R. differens* (during the swarming season) are trapped with light near a container, once attracted by light, they fall inside before being collected then dewinged. In addition, *R. differens* are also hand-picked on host plants while *A. domesticus* are collected by trapping and hand

picking at any time. Furthermore, *R. phoenicis*, *A. diaperinus*, *G. africana*, *A. melifera* larvae, *N. septemfasciata*, *L. migratoria*, *R. ferrugineus*, *I. oyemensis*, *I. epimethea*, *O. monoceros*, *C. forda*, *Nsike*, *Maguina*, *Mingungu*, *Ngohangoha*, *Bikolongo* and *Bachache* are hand-picked.

As for the harvesting period, some edible insects are collected only in the morning or evening, while others are collected any time, but preferably in the evening or morning. *R. differens* are light trapped soon after the dark. Like *N. septemfasciata*, *L. migratoria* and *Nsike*, *R. differens* are also hand-picked in the morning before the sun rises when they are not yet able to fly. The harvest decreases with the intensity of the sun. On the other hand, *A. melifera* larvae and *G. africana* are respectively collected at night and in the evening preferably. *Rhyncophorus phoenicis*, *A. diaperinus*, *R. ferrugineus*, *I. oyemensis*, *I. epimethea*, *O. monoceros*, *C. forda*, *Maguina*, *Mingungu*, *Ngohangoha*, *Bikolongo* and *Bachache* are collected Any time during the day, but preferably in the morning and evening hours.

Processing methods and preservation techniques vary according to the type of edible insect and the purpose, whether it is for direct consumption or for preservation. Generally, they are all dried or dry-fried for preservation except for the honeybee (Table 5). Most of the edible insects with wings such as *M. subhyllanus*, *A. domesticus*, *R. differens*, *G. africana*, *N. septemfasciata*, *L. migratoria* and *Nsike* are dewinged before being roasted, dry-fried, fried or boiled for *G. africana*. *M. subhyllanus* are also eaten raw. *Rhyncophorus phoenicis*, *A. diaperinus*, *R. ferrugineus*, *I. oyemensis*, *I. epimethea*, *O. monoceros*, *C. forda*, *Maguina*, *Ngohangoha* and *Bachache* are gut removed, washed, boiled, fried or roasted, and sometimes prepared in stews. *A. melifera* larvae are only boiled while *Kigelegele*, *Bangwangwa*, *Mingungu* and *Bikolongo* are boiled and roasted.

Table 5. Harvesting and processing techniques for various consumed edible insects in selected Territories

Insect species	Harvesting techniques	Harvesting period	Processing methods	Preservation techniques
Termite	Trap termites with light near a container, termites attracted by light fall inside before being collected and have their wing removed	During and after the first rains	Dewinged, roasted or dry-fried; also eaten raw	Drying
House cricket	Trapping and hand picking	Any time	Dewinged, roasted or dry-fried	Drying
Palm weevil	Hand picking after signs of their presence are detected.	Any time based on signs	Gut removed, boiled, fried or roasted, sometimes prepared in stews	Drying
Beetle	Hand picking after signs of their presence are detected.	Any time based on signs	Washed, boiled, fried or roasted, sometimes prepared in stews	Drying
Grasshopper	During the swarming season light trapping technique is used to attract grasshopper in addition to hand picking on host plants	Soon after the dark for light trapping and morning before the sun rises when they could not fly for hand picking	Dewinged, roasted or dry-fried	Dry-fried during the swarming season
Mole cricket	Hand picking	In the evening following their small holes	Dewinged, roasted or dry-fried and boiled	Drying
Honey bee	Collecting honeycomb from the hive following with honey extraction	At night preferably	Boiled	None
Red locust	Hand picking on host plants	Morning time	Dewinged, roasted or dry-fried	Drying
Migratory locust	Hand picking on host plants	Morning time	Dewinged, roasted or dry-fried	Drying when it's enough
Red palm weevil	Hand picking after signs of their presence are detected.	Any time based on signs	Washed, boiled, fried or roasted, sometimes prepared in stews	Drying
Caterpillar	Hand picking: caterpillar directly picked after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled, fried or roasted, sometimes prepared in stews	Drying

Continued

Table 5. *Continued*

Insect species	Harvesting techniques	Harvesting period	Processing methods	Preservation techniques
Rhinoceros beetle	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled, fried or roasted, sometimes prepared in stews	Drying
<i>Misigi</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled, fried or roasted, sometimes prepared in stews	Drying
<i>Nsike</i>	Hand picking on host plants	During the sunny period, they are easy to identify and hand picking on the top of the host plants	Dewinged, roasted or dry-fried	Dry-fried during the swarming season
<i>Kigelegele</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled and Fried	Drying
<i>Kansenda</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Fried	Drying
<i>Bangwangwa</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled and roasted	Drying
<i>Maguina</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled, fried or roasted, sometimes prepared in stews	Drying
<i>Mingungu</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled and roasted	Drying
<i>Ngohangoha</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled, fried or roasted, sometimes prepared in stews	Drying
<i>Bikolongo</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled and roasted	Drying
<i>Bachache</i>	Hand picking after signs of their presence are detected.	Any time during the day preferably morning and evening hours	Boiled, fried or roasted, sometimes prepared in stews	Drying

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These results are consistent with those of Meutchieye *et al.* (2016) and Ebenebe *et al.* (2017), who also pointed out that hand picking is one of the major techniques used to harvest crickets, Rhinocerus beetle, stinking grasshopper (in the early hours of the morning), African palm weevil (from rotting palm tree) and caterpillars, while light trapping is used to harvest termites, green grasshoppers, house cricket and mole cricket. In addition, Ebenebe *et al.* (2017) added that crickets were also harvested by digging out from the tunnels during the dry season, and that house cricket were also harvested by digging out from small sound mounds with depression that indicates their entrance. In contrast to the results of this study, Ebenebe *et al.* (2017) stated that mole crickets were harvested by light trapping. Singing a "Wee wee" song at the base of the host tree is another notable technique used to harvest the caterpillar of a particular moth species. The more you sing, the more they fall from the top of the tree and are harvested.

To harvest enough *R. differens* by light trapping during the swarming season, locals lit the lamps/bulbs outside the houses and secure the areas where these lamps/bulbs are located with corrugated iron sheets bent into a cone shape leading to baskets, small drums where the falling *R. differens* are harvested (Mmari *et al.*, 2017). For non-swarming *R. Differens*, harvesting is done early in the morning between 6 and 7 AM, when they are inactive and not able to fly (Kinyuru *et al.*, 2011). Additionally, Dao *et al.* (2020) reported two harvesting techniques including direct collection of termites from their mounds and trapping of termites in containers. Direct collection involves partially destroying termite mounds while trapping implies looking for signs of termite presence such as mud sheets and tracks on the ground. Techniques depend on the termite genus. Small termite mounds of *Trinervitermes* and *Cubitermes* can be dug with a hoe or pickaxe, and the mounds are collected in the morning between 6 and 9 AM. In trapping technique, the traps are placed in the morning 6 and 8 AM or in the evening around 6 PM and covered with foliage or pieces of cloth to protect it from the sun. The same harvesting techniques were recently described in Ghana by Bofo *et al.* (2019).

Ayieko *et al.* (2010) and Chung (2010) reported that edible insects were sun-dried, baked, steamed and processed into crackers, muffins and sausage meat. Our findings confirm those of Ebenebe *et al.* (2017) who also found that salted roasting is one of the techniques used to process termites, crickets, Rhinocerus beetle, grasshopper and locust. They added that grasshopper and locust are consumed dried as well. On the other hand, African palm weevil are consumed raw or fried with pepper sauce. This study found that drying was the most used preservation technique as it's the most widely used technology for increasing the shelf-life of

foods. It ranges from traditional methods such as roasting, frying and solar drying to modern methods such as freeze-drying and microwave assisted drying (Melgar-lalanne *et al.*, 2019).

4. Conclusion and recommendations

The wide biodiversity of edible insects observed clearly depicts the importance of entomophagy in the region. Twenty-three edible insects were recorded belonging to nine families and five orders. These insects are consumed as larvae, adults or as eggs and pupa. About four of them were the most popular edible insects in Fizi and Mwenga, two in Kabare, and six in Walungu Territory. Additionnally, *R. differens*, *I. oyemensis*, *A. melifera* larvae, *G. africana* and *Nsike* were the most preferred for their taste. Besides, some are available throughout the year, while the others are less available. A large number of plants have been recorded as host plants, including even plants used as source of food, feed and income for humans. Like harvesting strategies and time, processing methods and preservation techniques vary according to local knowledge and practices, as well as to the insect species. These results suggest similar studies across the country and further research on the nutritional and safety profiling of processed and non-processed edible insects, while encouraging the rearing of certain edible insects for mass production as the demand is too high.

Acknowledgements

The authors would like to thank Benjamin Kalalizi, Belanila Victoire, Rebecca Kajuru, Sandra Lukausa and Tresor Buhendwa for their contribution to data collection. We also extend our acknowledgements to the Université Evangélique en Afrique (UEA) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for their support (Grant ID: Grant#RU/2020/GTA/DRG/015).

Author contributions

Conceptualization; J. I. and R. A. Methodology; J. I., R. A., J. K., K. K., D. B., S. N. and P. U. Validation; All authors; Data collection; J.I. Data curation; J. I and R. A. Formal analysis & drafting paper; J. I. Review & Editing of the manuscript; All authors

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