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Contents

List of figures, tables and photos

Figures

Tables

Photos

Abbreviations

CIFOR	Center for International Forestry Research
EAA	essential amino acids
FAO	Food and Agricultural Organization of the United Nations
LIFT	Living Forest Trust
MINFOF	Ministry of Forestry and Wildlife
NTFPs	non-timber forest products
WHO	World Health Organization
XAF	Central African CAF Franc

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Summary

The larvae (grubs) of the African palm weevil (*Rhynchophorus phoenicis* Fabricius, 1801) are consumed by the majority of the inhabitants of the Congo Basin. Studies of their biochemistry indicate that they are extremely rich in essential food nutrients; they contain proteins, carbohydrates, fats and energy values comparable to that of beef and fish. They are particularly rich in essential amino acids such as lysine, valine, leucine, isoleucine, phenylalanine, threonine and methionine. They are also an excellent source of minerals such as sodium, magnesium, manganese, calcium, potassium and iron. The exploitation and trade of weevil grubs is an important source of income for most forest dependent communities in Cameroon and the Congo Basin. Palm beetle grubs are currently harvested only from raffia and palm stems in the wild and their availability is linked to seasonal variations. The supply of grubs from the wild is irregular and can't satisfy the increasing demand for this product while indigenous harvesting methods are unsustainable.

As raffia ecosystems are under threat and weevil grubs can provide an alternative food and income source through community-based forest management in Cameroon, a project was jointly implemented by the Living Forest Trust (LIFT), the Center for International Forestry Research (CIFOR) and *Institut de Recherche pour le Développement* (IRD) to study the sustainability of indigenous harvesting methods and trade in grubs, and to find ways to farm these insect resources. The study was conducted using a participatory research approach and by establishing an experimental grub farming scheme in which different food formulas were tested. Seven villages situated in the Center and East regions of Cameroon were selected and surveyed for a period of one year. The study was carried out in two phases: August 2013 to February 2014 and July 2014 to November 2014.

The results of this study show that two indigenous methods (traditional grub gathering and grub semi-farming) were used to exploit grubs in Cameroon. Of the two regions studied, traditional collection was practiced in both the Center and East regions, while the semi-farming method was common in the Center region (especially around the Obout area). Globally, grub exploitation and trade represented 21% of all economic activities (agriculture, fishing, hunting, etc.) in the villages studied. The average monthly income generated by professional grub collectors varied between XAF 90,000 (USD 180) and XAF 300,000 (USD 600), representing 30 to 75% of their household income. However, indigenous harvesting methods proved to be less productive, irregular, unsustainable and involved the destruction of raffia ecosystems.

To address this situation, a grub farming system was established during the course of this study. This system involves collecting, coupling and introducing adult palm weevils in boxes containing fresh raffia tissues. It was estimated that the production of grubs in this farming system would take 30 days. For 3 females introduced, up to 73 grubs were harvested from boxes containing the preferred food formula (an average of 69 ± 5.6). This productivity is higher than the quantity of larvae harvested from a single stem of raffia (35 ± 13.2 and 50 ± 10.1) using traditional grub gathering and semi-farming systems, respectively. The farming system guarantees the sustainability of the raffia ecosystem as it requires the use of small quantities of raffia tissue (less than a quarter of the quantity of raffia used in the semi-farming system). This farming system can be used in the production of grubs at any time of the year, thereby providing an opportunity for a continous year-round production of these nutrient-rich insects, while securing their place as an important protein and income source in Cameroon.

1 Introduction

1.1 Background

Food security remains one of the most fundamental challenges for human welfare and economic growth in most African countries, since sufficient food to meet the needs of all citizens is not available at the national level (Benson 2004). Despite the fact that the Central African subregion is classified as an important agricultural basin, many people in this area are unable to acquire and effectively utilize the food they need for a healthy life. Even in Cameroon, where agriculture and animal husbandry are mostly practiced in the subregion, many cases of food insufficiency have been recorded in recent years, especially in the northern part of the country where climatic conditions are less favorable. This lack of food and high poverty rates have led to both rural and unprivileged urban communities becoming increasingly dependent on the forest for their livelihoods. Unfortunately, the increased dependence on forest landscapes and resources is an important driver of deforestation, biodiversity erosion and climate change. The quest to satisfy household protein needs in rural areas is a major cause of biodiversity erosion and ecosystem conversion. More than half of the population in Cameroon and the Congo Basin live in rural areas and depend on bushmeat to satisfy their daily protein needs. Annual bushmeat consumption in this area is estimated to be between 1 to 3.4 million tonnes (t) per year (Wilkie and Carpenter 1999), with 60% of species harvested at unsustainable rates, constituting a grave threat to biodiversity conservation (Fa et al. 2002).

Many measures have been envisaged to reduce the problems of food insufficiency and biodiversity erosion in Cameroon and the Congo Basin, such as agricultural intensification, improved food processing and the production of alternative food resources. The need to promote the use of non-timber forest products (NTFPs) in particular as an alternative for improving livelihoods, while reducing human pressure on biodiversity has largely been acknowledged. Accordingly, many NTFPs have been identified as beneficial, amongst which are those of plant origin (Ndoye et al. 1997; Arnold and Ruiz Pérez 2001; Belcher et al. 2005), bushmeat (Asibey and Child 1991; Wilkie and Carpenter 1999) and forest insects (FAO 1995; De Foliart 1997; Stack et al. 2003; Vantomme et al. 2004; Muafor et al. 2012, 2014). Of the different NTFPs, edible insects are amongst the most abundant and easily renewable forest resources. Some edible insects are very rich in proteins, fat and energy values, while others are rich sources of important vitamins and minerals (Dreyer and Wehmeyer 1982). Compared to beef and fish, insects have almost the same proportion of proteins, fat and energy value (Malaisse 1997). They are also rich in vitamins such as vitamin B1, vitamin B12 and vitamin B6 as well as mineral salts, especially iron and calcium (De Foliart 1992). Research has shown that 100 g of cooked insects provides more than 100% of the daily requirements of the vitamins and minerals they contain (De Foliart 1992).

Regarding their advantages, edible insects can effectively serve as a substitute to meat and fish in periods of availability. Concerns are rising over the need to optimize the potential of insect resources as an alternative in the development of food and feed, as well as to develop insect mini-livestock farming systems. Currently, the establishment of small insect-based food and feed enterprises is more developed in Asia than in Africa where entomophagy is equally high. However, in developing countries like those of the Congo Basin where it is relatively easy to bring insects to the market, and where demand for edible insects is high, the establishment of insect-based enterprises and the processing of insects into street foods and animal feed could easily be achieved if people were trained in insect production and processing methods (Van Huis et al. 2013).

The main groups of insects that can easily be targeted for industrial production in the Congo Basin are those that have been popular for human nutrition. Such species include: caterpillars, palm beetle grubs, termites, crickets, grasshoppers and locusts (FAO 1995; De Foliart 1997; Stack et al. 2003; Vantomme et al. 2004). The larvae of the African palm weevil *Rhynchophorus phoenicis* (Fabricius, 1801) is particularly significant, as they are extremely rich in essential food nutrients and are consumed and traded across the entire Congo Basin region. The larvae are harvested by systematically extracting them from the trunks of raffia or palms. However, the exploitation of these resources from the wild is unsustainable, irregular and doesn't satisfy increasing market demand. There have been a number of studies on the contribution of grubs to rural livelihoods in the Congo Basin (FAO 1995; De Foliart 1997; Dounias 1999; Stack et al. 2003; Vantomme et al. 2004). Although some of these studies recommend the need to domesticate grubs as a solution to the problem of seasonal irregularity, insufficiency and sustainability, no attempt to farm the insects has ever been made. The lack of interest in the domestication of this species is principally due to a lack of appropriate farming methods.

In order to find ways to produce large quantities of grubs while sustaining the raffia ecosystem, a project was jointly implemented by the Living Forest Trust (LIFT), the Center for International Forestry Research (CIFOR) and *Institut de Recherche pour le Développement* (IRD) to study the sustainaibility of indigenous harvesting methods and trade of weevil grubs, as well as develop a farming method that could be used for the production of grubs in an outdoor situation. In a practical manner, this study provided answers to the following questions:

- What are the indigenous methods of grub exploitation and their effects on raffia ecosystems?
- What is the contribution of palm weevil grubs to food and household income?
- What quantities of grubs are harvested per trunk and per harvesting period?
- What farming method can be used for the production of palm grubs?
- Is there any difference in the physiology and palatability of farm bred weevil grubs and those obtained from the wild?

1.2 Objectives of the study

The overall objective of this study is to contribute to livelihood improvement and the enhancement of community-based conservation through the sustainable and continuous production of African palm weevil grubs (*Rynchophorus phoenicis*). Specifically, the study aims to:

- study indigenous methods of grub exploitation in the Centre and East regions of Cameroon;
- evaluate the contribution of palm weevil grub to livelihoods in the targeted regions;
- determine the impacts of indigenous grubs harvesting methods on raffia ecosystems;
- analyze the grub marketing chain;
- establish a method for the domestication of palm beetle grubs;
- compare the productivity, physiological characteristics and palatability of grubs from indigenous harvesting and farming methods.

1.3 Benefits of the project

In addition to information on the socioeconomic importance of indigenous harvesting practices, this study provides first-hand information on a method for the farming of palm weevil grubs. Results obtained could be used for the promotion of sustainable and continuous production of palm weevil grubs. This will ensure increased productivity and year-round availability of these resources, thereby providing increased opportunity for alternative protein sources in the study area. By providing the opportunity for villagers to increase their protein and income sources, this study is expected to contribute to efforts to find solutions to the major problems of poverty, food insecurity and biodiversity erosion in the area. In addition, the adoption of the grub farming method in local communities will considerably reduce the number of raffia palms that are felled for the production of grubs. The results are also a base for future studies that can lead to the development of appropriate methods for the processing, packaging and large scale commercialization of this nutritious 'free' resource.

2 Forest insects as a source of food in Cameroon

2.1 Edible insects

Foods hunted and gathered from forests contribute to food security by providing people with calories, animal and plant proteins, essential minerals and micronutrients (Pimentel et al. 1997). It is largely accepted that food forest products can complement household agricultural production in periods of crisis. Moreover, forest food products are essential for livelihoods, especially in the Congo Basin where over 90% of people depend on natural resources for food, medicine and income generation (COMIFAC 2008). The gathering of insects for food in particular is a very old practice in the Congo Basin region. From the literature, 45 insect species in 16 families have always been popular as human food in Cameroon (Table 1).

However, today the Acrididae, Pyrgomorphidae, Mantidae, Thespidae, Cetoniidae, Buprestidae, Rutelinae, Formicidae, Saturniidae are only consumed in the northern part of Cameroon. In this region, grasshoppers (Orthoptera) and termites (Isoptera) are important delicacies (Seignobos et al. 1996).

Conversely, in the humid forest and savannah zones of Cameroon (south of Adamawa), most of the edible insect species cited in the literature are no longer part of the human diet. This decline can be explained by: the high levels of rural dependence on bushmeat; the proliferation of churches (that forbid the consumption of insects); and the adoption of Western feeding habits. However, due to increasing levels of food-related diseases (e.g. cancer, obesity, diabetes and hypertension), poverty, food shortages and the quest for environmental sustainability, many southern Cameroonians are reintegrating insects into their daily diets. But in southern Cameroon, this is limited to only eight families of insects (Table 2).

Palm weevil grubs, caterpillars, termites and locusts are the most commonly consumed insects. Apart from palm weevil grubs that are available year-round in variable quantities, all the other species occur at different times of year. However, the identification of Cameroon's edible insects is still problematic and little is known about the taxonomy of the different species.

Table 1. Families of edible insects cited in literature for Cameroon.

Family	Number of species	Stage of consumption	Source
Curculionidae	1	Larval and adult	Bodenheimer (1951)
Dynastidae	1	Larval and adult	Tessmann (1913)
Scarabaeidae	1	Adult	De Lisle (1944)
Cetoniidae	1	Adult	Seignobos et al. (1996)
Buprestidae	1	Adult	Seignobos et al. (1996)
Rutelinae	1	Adult	Bodenheimer (1951)
Formicidae	2	Larval and adult	Van Huis (2003)
Saturniidae	2	Larval	Malaisse (1997)
Notodontidae	1	Larval	Merle (1958)
Acrididae	28	Adult	Barreteau (1999)
Pyrgomorphidae	2	Adult	Barreteau (1999)
Gryllidae	1	Adult	Grimaldi and Bikia (1985)
Mantidae	1	Adult	Barreteau (1999)
Thespidae	1	Adult	Barreteau (1999)
Macrotermitidae	2	Adult	Bodenheimer (1951)
Hemiptera	1	Adult	Seignobos et al. (1996)

Table 2. Insects currently eaten in the humid forest zones of Cameroon.

Order	Family	Common name	Stage of consumption
Coleoptera	Curculionidae	Palm weevil grub	Larval
	Dynastidae	Scarab beetle	Larval and adult
Lepidoptea	Saturniidae	Caterpillar	Larval
	Notodontidae	Caterpillar	Larval
Orthoptera	Acrididae	Locust	Adult
	Pyrgomorphidae	Grasshopper	Adult
	Gryllidae	Cricket	Adult
Isoptera	Macrotermitidae	Termite	Adult

2.2 Species of African palm weevil

The African palm weevil is a species of the genus *Rhynchophorus*, which belongs to the family Curculionidae, commonly called snout beetles and known to be one of the most diversified groups of insects in the world. Adult members of this family have a snout-like projection of their mandibles called a rostrum (Photo 1). These modified mouthparts are used for feeding and to make holes in host plant material where eggs are laid. The larvae (or grubs) have relatively large mandibles and are legless (Photo 2).

Photo 1. Adult African palm weevils (*Rhynchophorus phoenicis*).

Photo 2. Larvae (grubs) of the African palm weevil.

In Cameroon, there is little knowledge about the diversity of this genus. However, there is speculation that Cameroon harbors many species of *Rhynchophorus*, with the most popular being *Rhynchophorus phoenicis* (Fabricius 1801) and *Rhynchophorus quadrangulus* (Quedenfeldt 1888). *Rhynchophorus quadrangulus* is adapted to highland areas and occurs within the humid mountain ranges of the Cameroon volcanic belt (Southwest, West and Northwest regions of Cameroon), while *Rhynchophorus phoenicis* is more common in the humid lowland forest and savannah areas of the country.

2.3 Areas where palm beetle grubs are exploited

This genus has been recorded across tropical Africa (Tambe et al. 2013), where it feeds mainly on oil palm (*Elæaeis guineensis* Jacq.), date palm (*Phoenix dactylifera* L.), raffia palm (*Raphia* spp.) and coconut palm (*Cocos nucifera* L.) (Gries et al. 1993). The larvae are important pests of these plant species, due to their boring action into plant stems, which causes yellowing of the leaves (Mariau et al. 1981). In Cameroon, these insects are exploited for consumption and trade in seven of the ten regions of Cameroon (notably the East, South, Centre, Littoral, Southwest, West and Northwest regions). These regions cover the entire humid part of the country south of Adamaoua (Figure 1).

The larvae have different names in different areas of the country. They are commonly called *fos* by the Beti communities of the Centre and South regions, *mbé* in the Yemba dialect (Dschang) in the West, *poseh* by the Baka and the Bagando communities in the East and *tumbu* or *tumbu for palm tree* in Pidgin English that is commonly used by the English speaking communities of the Southwest and Northwest regions of the country. These larvae are highly sought after for food in most parts of Cameroon today; they are even offered as a special dish in important ceremonies and top restaurants in some urban cities in the South and Centre regions of the country. Together with caterpillars, grubs are largely accepted for consumption in the forest regions of Cameroon. Balinga (2003) studied the contribution of these two insects to food security in Cameroon, and reported that palm weevil grubs are more commonly consumed and traded than caterpillars by many tribes in southern Cameroon (Table 3).

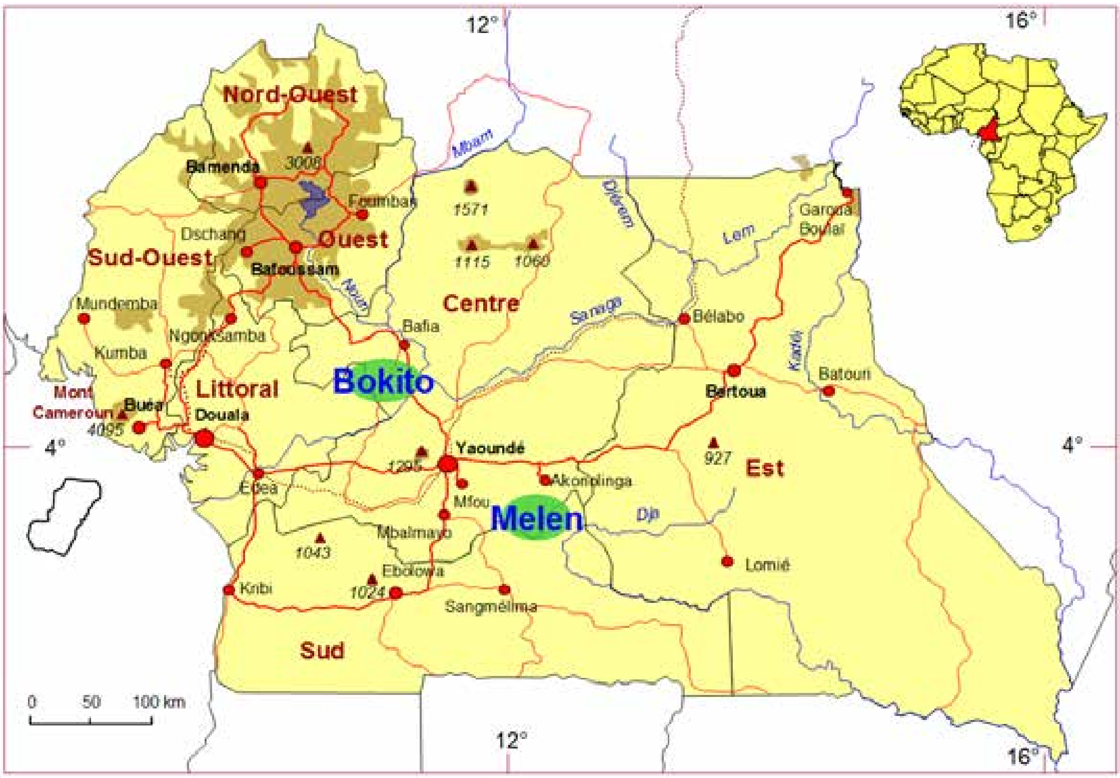

Figure 1. Area of Cameroon where palm weevil larvae are consumed (south of Adamaoua).

Source: Aboubacar et al. (2012)

Table 3. Consumption and sale of caterpillars and weevil grubs in southern Cameroon.

Regions	Caterpillars	Weevil grubs	Sale status
West	Not consumed	Consumed by all tribes	No trade of caterpillars and larvae
Northwest	Consumed by the Meta and Bali tribes	Consumed by all tribes	No trade of caterpillars and larvae
Southwest	Consumed by the Bakundu tribe	Consumed by all tribes	No trade of caterpillars and trade of larvae
Centre	Consumed by certain Beti tribes and many non-natives	Consumed by all tribes	Trade of caterpillars (seasonal) and larvae
Littoral	Consumed by certain Mbo tribes and non-natives	Consumed by all tribes	Trade of caterpillars or larvae
South	Consumed by certain Beti tribes	Consumed by all tribes	No trade of caterpillars and trade of larvae
East	Consumed by all tribes	Consumed by all tribes	Trade of caterpillars and larvae

Source: Balinga (2003)

The productivity of these grubs in the western highland region (West, Southwest and Northwest) of Cameroon is very low. Conversely, the Centre, South and East regions are favorable areas for their production, due to the presence of vast raffia ecosystems. The Nyong Basin is particularly productive and constitutes the main production site for weevil grubs sold in cities such as Yaoundé, Douala and Ebolowa.

2.4 Development of palm beetle grubs on host plant species

The larvae are harvested by systematically extracting them from the trunks of oil palms (*Elæaeis guineensis* Jacq.) when the palms have been cut down for palm wine production or from the trunks of dead or wounded raffia palms (*Raphia* spp.) growing densely in swamps. Wounded raffia trunks produce sap, which attracts adult weevils. Once on the plant, female weevils mate with males. The females deposit eggs on the decaying parts of the trunks, and they develop into young larvae within a week. These larvae develop over four weeks into mature larvae that can be harvested. The quantities harvested from oil palm are generally less than from raffia palm. In the case of raffia, harvesters risk insect and snake bites to spend hours or days in dark, muddy waters in order to obtain large quantities. Dead raffia stems are split open with machetes or axes and grubs are picked off by hand.

2.5 The palm weevil grub businesses in Cameroon

Palm weevil grubs are particularly important economic resources in Cameroon. They provide complementary income for many rural people who depend on the palm weevil trade as their main or part-time activity. From the dense, humid, semi-deciduous forest zone in the east to the highland savannah in the west, this insect is traded (cooked or uncooked) by small-scale roadside vendors. Some markets in urban cities are renowned for the sale of palm weevil grubs, such as Mvog-mbi, Mvog-ada and Nkondongo markets in Yaoundé, Bertoua main market, Abong-Mbang market, Ayous market and Mbalmayo market (Photo 3).

In these markets, palm beetle grubs are traded at all times of the year, though they are more abundant during the dry season. Between 25 and 30 individual insects are sold as one item in markets. A single glass-full of this insect costs XAF 500 (USD 1) in rural markets in smaller towns such as Abong-Mbang. This same glass-full is sold in big cities such as Yaoundé and Douala for XAF 1500 (USD 3) in times of abundance and XAF 2500 (USD 5) in periods of scarcity. Brochettes of prepared grubs are sold for XAF 100 (USD 0.2) per brochette and contain 3 or 4 palm weevil grubs. Transborder trade is equally visible, as some grubs are exported to neighboring countries such as Equatorial Guinea, Gabon and Nigeria and even to European countries such as Belgium and France.

Photo 3. Small-scale traders of palm weevil grubs in Cameroon markets.

The palm weevil business involves a network of collectors, intermediate traders (*bayam-sellam*) and retailers. Each of these categories of traders derives important income from the sale of palm beetle grubs. Dounias in López and Shanley (2004) reported that the average monthly income for larvae harvesters in rural areas is about XAF 35,500 (USD 71), for live larvae sold to retailers supplying city markets and CTA 25,000 (USD 50) for roasted larvae sold in snack bars and along roadsides. He compared such income with other rural income sources and concluded that they were significantly higher than the monthly income obtained by unskilled workers in town, or by the rural producers of coffee (XAF 25,000 or USD 50) in good years. Compared with other NTFPs, he noted that the African palm weevil grub generates better monthly income than either bushmeat (XAF 29,000 or USD 58), Gnetum leaves (XAF 15,500 or USD 31) or rattan (XAF 13,000 or USD 26).

3 Nutrient value of palm weevil grubs

Many studies on the biochemistry of palm weevil grubs have indicated that this insect is extremely rich in essential food nutrients. From studies conducted by Womeni et al. (2012), the nutrient content of these grubs is quite interesting (Table 4).

The moisture content of larvae is quite high, comparable to that of fish, meat and eggs. Such high moisture content implies that most of the essential nutrients in the larva will be in solution and in forms that are easily available to the body when the larva is consumed as food (Ekpo and Onigbinde 2005). According to Elemo et al. (2011), the lipid value ranges between 25.30% and 66.61%. This oil extract is different to other animal oils/fat, as it is liquid at room temperature, probably due to the presence of unsaturated fatty acids such as oleic acid (C18:1) and linoleic acid (C18:2). An iodine value of 192.3 Wijs was observed, while the saponification value was observed to be 427.7 mg KOH/g of oil. These values are relatively high when compared to those of lard and other plant oils (Pearson 1976).

In terms of protein, these grubs contain at least 18 known amino acids with almost all the essential amino acids (EAA). Most of the EAA including lysine, valine, leucine, isoleucine, phenylalanine, threonine and methionine, are contained in the larvae. EAA such as lysine and threonine which are normally deficient in grains and cereals have high concentrations in these grubs. Tyrosine and methionine are present in low concentrations in the larvae. Womeni et al. (2012) in Table 5 compared the amino acid profile of these grubs with a conventional food (chicken egg).

Essential amino acids from grubs are superior to those from conventional foods (e.g. eggs). Ogbuagu et al. (2011) compared the essential amino acids of weevil grubs with reference values given by FAO/WHO (1973) and concluded that the content of some essential amino acids in the grubs were higher than the reference values (Table 6).

Palm weevil grubs are also rich in mineral composition. They have high values of sodium, magnesium, manganese, calcium, potassium and iron see (Table 7).

Table 4. Approximate nutrient content of palm weevil grubs.

Component	% Fresh weight	g/100 g dry weight
Moisture	61.85 ± 0.2	–
Lipids	25.30 ± 0.22	66.61 ± 0.35
Proteins	8.21 ± 0.35	21.06 ± 0.22
Carbohydrates	2.97 ± 0.01	7.63 ± 0.12
Energy (Kcal)	684.81	714.25

Source: Womeni et al. (2012).

Table 5. Comparison of the amino acid profile of palm weevil grubs and egg (mg/g protein).

Amino acid	Palm weevil grubs	Egg
Aspartic acid	104.41	82.20
Glutamic acid	155.05	121.30
Serine	41.23	67.20
Glycine	39.68	30.20
Histidine	24.00	20.90
Arginine	34.44	57.00
Threonine	23.91	44.70
Alanine	54.96	50.30
Proline	64.00	33.80
Tyrosine	25.15	38.10
Valine	27.64	54.20
Methionine	22.97	28.10
Tryptophane and Cysteine	not evaluated	17.2 & 19.00
Isoleucine	67.33	48.80
Leucine	96.02	81.10
Phenylalanine	31.59	48.20
Lysine	54.84	65.90

Source: Womeni et al. (2012)

Table 6. Comparison of essential amino acids in palm weevil grubs to reference values.

Amino acid	Composition	FAO/WHO (1991) Ref value
Lysine	8.32	5.8
Methionine + Cysteine	2.30	2.5
Threonine	3.47	3.4
Tryptophan	ND	1.0
Valine	4.50	3.5
Leucine	8.04	6.6
Isoleucine	3.73	2.8
Phenylalanine + Tyrosine	8.62	6.3
Arginine	6.47	–
Histidine	3.51	–

Source: Ogbuagu et al. (2011)

Table 7. Mineral composition of palm weevil grubs (mg/100 g).

Mineral	Recorded value
Fe	65.23 ± 0.15
Zn	10.57 ± 0.89
Mn	1.16 ± 0.09
Pb	0.21 ± 0.08
Cd	0.039 ± 0.022
Mg	127.16 ± 5.13
Ca	60.81 ± 0.32
Cu	1.26 ± 0.04
Na	773.49 ± 1.02
K	26.65 ± 0.24

NB: Values represent the mean ± SEM of three estimations

Source: Ekpo and Onigbinde (2005).

4 Methodology

4.1 Study area

The study was conducted in the Mbalmayo and Abong-Mbang divisions, in the Centre and East regions of Cameroon respectively. The first study site extends across the Obout and Ebomssi II villages in the Mbalmayo division, while the second site covered Ntoung I, Ntoung II, Ndjibe, Djodjok and Nyimbe villages in the Upper Nyong division (Figure 2).

These two sites fall within the River Nyong Basin, which is known to be one of the most fragmented landscapes in the Congo Basin forest. The area is highly fragmented by pressure arising from diverse human activities, such as uncontrolled timber exploitation, small-scale subsistence farming and urbanization. As a result of this increasing anthropic pressure, land, water, forest and other related resources in the basin are endangered (Jiofack 2010).

The climate of these areas is a wet equatorial type (Guinea climate type), with high temperatures (24°C on average). Humidity and cloud cover are relatively high, and precipitation averages 1500–2000 mm per year, spread over four seasons: a long, dry season from December to May, a light, wet season from May to June, a short, dry season from July to October, and a heavy, wet season from October to November. A greater part of the area is covered by swampy ecosystems, most of which are dominated

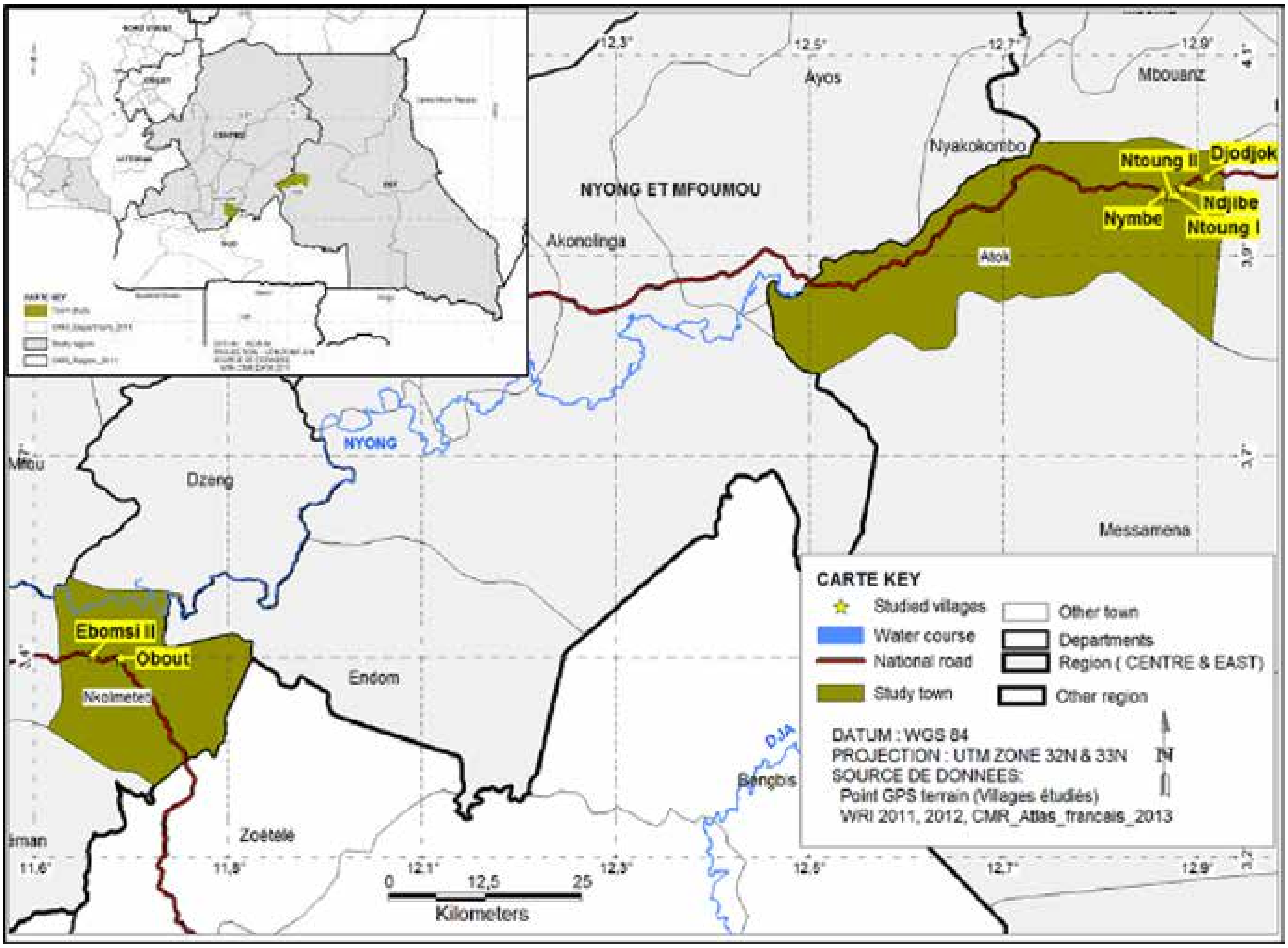

Figure 2. Locations of the study areas.

by raffia species, *Sterculia subviolacea* and *Macaranga asas*. Due to human influence, the forest cover is less intact and alternates with a mosaic of fields, fallow land secondary forest and logged-over forest. Sometimes, dense secondary forest, marshy forest, ripicole forest and savannah riparian forest were recorded at various sites. However, dense forest is dominated by hardwood species, some of which grow to heights exceeding 70 m, such as *ayous* (*Triplochyton scleroxylon*), *sapelli* (*Entandrophagma cylindricum*), *fraké* (*Terminalia superba*), *tali* (*Erytrophleum ivorense*), *kotibé* (*Nesogordia papaverifera*), *kossipo* (*Entandrophragma candolei*), *dibetou* (*Lovoa trichilioides*), *padouk rouge* (*Pterocarpus soyauxii*), *eyong* (*Eribloma oblogum*) and *diana* (*Celtis zenkeri*) grow to heights in excess of 70 m.

4.2 Field methods

Data was collected throughout the course of this study using a variety of social science methods, harvesting practices and an experimental breeding trial system. In each of the villages studied, local assistants were recruited to assist in field data collection (Photo 4).

4.2.1 Methods used

In order to obtain information on the indigenous exploitation of grubs, surveys were conducted using semi-structured questionnaires, focus groups and field observations (Photo 5). Questions focused on the quantities of grubs harvested, harvesting methods, marketing networks, contribution to livelihoods and

Photo 4. Local assistants participating in field data collection.

Photo 5. Interviews using semi-structured questionnaires (left) and a focus group discussion (right).

other aspects of the management of grub resources. Interviews were conducted in 103 households, representing 30.3% of total households in the study area. In each of the households, key informants were mainly men, women and youth above 18 years of age.

The number of informants interviewed was different from one village to the other, based on the population size of the village. The lowest number of households surveyed was in Ebomsi II and the highest was in Nymbe (Table 8).

Focus groups permitted open discussions with villagers on different aspects of indigenous exploitation and trade in palm weevil grubs. At least two focus groups were organized in each of the eight villages.

4.2.2 Participation in harvesting practices

In addition to interviews in the villages, surveys were done in the swampy raffia forest ecosystems to study the different stages of the indigenous harvesting process, as well as to evaluate the productivity and ecological impacts of harvesting (Photo 6).

Table 8. Total number of households sampled per village.

Village	Total number of households	Number of households interviewed	Percentage interviewed (%)
Obout	57	17	29.82
Elende	20	6	30.00
Ebomsi II	24	7	29.16
Ntoung I	77	23	29.87
Ntoung II	34	10	29.41
Ndjibe	34	10	29.41
Djodjok	64	19	29.69
Nymbe	30	11	36.67
Total	**340**	**103**	**30.29**

Photo 6. Survey of indigenous harvesting processes in a swampy raffia ecosystem.

Photo 7. Evaluation of the productivity of raffia stems.

Photo 8. Weighing grubs collected from the wild.

Harvesting was observed and collectors were interviewed at each stage of the process. The ecological impacts of indigenous harvesting practices in the Obout area were evaluated by counting the number of raffia stems destroyed within an area of 2500 m^2. A total of four sample plots of 50 m x 50 m each were created in the swampy forest. All the raffia stems that were cut down in the 2500 m^2 area during the harvest period were counted. Such impacts were not assessed in the Ntoung area because grub exploitation there involves only systematic extraction from naturally infested raffia stems. The productivity of the different harvesting systems was evaluated by counting the number of grubs harvested per stem of raffia exploited (Photo 7).

In order to determine the weight of grubs a collector can harvest per day, harvests were weighed on an electronic scale (Photo 8). The price of 1 kg of grubs was compared with that of other sources of protein such as beef and fish. The physiological characteristics of grubs from the different types of exploitation (wild or farmed) were determined by observing the color and size of grubs.

Data on the palatability and physiological characteristics of farmed grubs were also collected using the above mentioned methods.

4.2.3 Experimental grub farming system

The experimental grub farming system was set up using plastic and wooden boxes 0.6 m long, 0.4 m wide and 0.4 m high. In the first phase of the experiment, wooden boxes were placed in an experimental hut, measuring 4 m long and 3 m wide, constructed in Ntoung village using materials such as wood, metallic grids and aluminum sheets (Photo 9). Villagers helped us to construct this hut. Farming in wooden boxes was less successful (only 10 individuals were obtained in this trial); the second phase of the experimental farming was carried out in plastic boxes, which were suspended in an old hut in Obout village at a height of 1 m above the ground (Photo 10).

The boxes were suspended in the hut to avoid invasion by ants and other crawling invertebrates that could prey on the growing grubs. These boxes were filled with small quantities of four kinds of feed formula including: (i) only fresh tissues of young raffia stems, labeled OFRT; (ii) a mixture of 50%

Photo 9. Experimental hut (left) and trial farming of grubs in wooden boxes (right).

Photo 10. Installation of experimental grub farming apparatus.

Photo 11. Coupling of adult palm weevils before introducing them into experimental boxes.

fresh and 50% old (decayed) raffia tissues, labeled MFDRT1; (iii) a mixture of 75% fresh and 25% old raffia tissues, labeled MFDRT2; and (iv) only decayed or old raffia tissues, labeled ODRT. In total, the apparatus contained 2 boxes of OFRT, 1 box of MFDRT1, 1 box of MFDRT2 and 2 boxes of ODRT.

Individual female and male adult palm weevils were collected from the raffia stems by hand and coupled by placing them in closed, perforated small plastic cups for 48 hours before introducing them into the tubs containing the different food formulas (Photo 11). The rostrum of males is hairy and rough, while that of females is smooth and does not contain hairs.

A total of three couples of adult palm weevils were introduced to each box. The substrates (feed) in each of the boxes were enriched with newly harvested raffia tissues every 2 days to ensure good development of the grubs.

4.3 Data analysis

Data were computerized, treated and analyzed using Excel 2010. Quantitative analysis consisted of estimating percentages, mean values and standard deviations of variables. Results were presented in tables and graphs to facilitate interpretation. Statistical tests (ANOVA, T-test and correlation tests) were conducted using the statistical software R® version 3.0.0 to compare any differences.

5 Results and discussion

5.1 Indigenous methods of grub exploitation

Traditional collection and semi-farming method were used to exploit palm weevil grubs.

5.1.1 Traditional collection method

Grubs were harvested by systematically extracting them from the trunks of oil palms when the palms had been cut down for palm wine production or from the trunks of raffia palms which were infested naturally by grubs in the swamps (Photo 12).

The quantity of grubs harvested from oil palm was lower than from raffia. In this system, collectors spent hours, and sometimes days, in raffia ecosystems to identify raffia stems that had been colonized by grubs. These raffia stems were uprooted and split open with machetes or axes to extract the grubs (Photo 13).

However, the identification of naturally infested or dead raffia stems required some expertise. This includes the detection of young raffia stems with slightly yellow juvenile leaves or dead adult raffia stems. In addition, collectors smelled the trunks and listened carefully for the noise produced in the trunks to detect the vibrations produced by nibbling grubs. According to Dounias, this method was practiced by about six villages in southern Cameroon who specialize in the harvesting of larvae for trade. Such specialized collectors have developed specific harvesting tools and methods (Dounias 1999). This is the only method used for harvesting grubs in the Ntoung and Abong-Mbang areas.

5.1.2 Semi-farming method

This method has been developed and practiced in the Obout village area where the extraction and trade of palm weevil grubs is one of the main activities practiced by a large proportion of the populace. In this system, grub farmers begin the harvesting process by identifying the raffia that favors the development of grubs. In the Obout area, villagers have identified two types of raffia: *essa* and *zam* in the Ewondo dialect. *Essa* is exploited for weevil grubs while *zam* is used for wine production. *Essa* is exploited for the production of grubs in the Obout area. Although these two raffia species could not be identified taxonomically, some morphological differences were identified between the two species. Z*am* is characterized by stems grouped into small bunches of dense and tightly closed individuals; *essa* is made of single stems which are less dense. In addition, the leaves of *zam* are larger in size and are characterized by the presence of many thorns compared to those of *essa* (Photo 14).

Photo 12. A stem of a felled oil palm tree (left) and a stem of young raffia colonized by grubs (right).

Photo 13. Collecting grubs from naturally infested raffia stems.

Photo 14. A leaf of *zam* with thorns (left) and *essa* without thorns (right).

Photo 15. Felling of raffia stems for grub production in the semi-farming system.

In the grub semi-farming process, mature stems of *essa* raffia are selected and cut down to facilitate their colonization by grubs (Photo 15).

Once the stem has been felled, an incision of 20 to 25 cm long and 5 cm deep is made on the trunk at about 1 m from the base of the crown. This incision is then covered with fresh raffia leaves to provide heat, and to prevent animals such as rats, squirrels and other predators consuming grubs (Photo 16).

The stems are then allowed to decay for a period of 25 to 30 days, which gives enough time for the grubs to mature before harvest. The grubs develop inside the raffia stem and accelerate the decay of portions of the stem that have been colonized. The collection process begins by removing the leaves that covered the incision (Photo 17).

In order to determine if palm weevil grubs have colonized a raffia stem, the collector places his ear on the incision to listen for grubs nibbling the trunk. Once grubs are confirmed present in the trunk, the collector then proceeds to split the trunk (Photo 18).

The invaded raffia trunk is split open with an axe from the incision to about 60 cm towards the base and 40 cm to the apex of the trunk. This exposes the grubs for collection. However, the length of trunk split depends on the level of infestation. The productivity of trunks is affected significantly by the water level of the raffia ecosystem. Generally, trunks that are partly submerged are less productive. The grubs are hand picked off the stem one by one (Photo 19).

The productivity of raffia trunks varies between the two indigenous systems. A single trunk can produce an average of 35 ± 13.2 grubs by traditional gathering and 50 ± 10.1 grubs per trunk using the semi-farming method. With an average of 50 ± 13.2 individuals, the productivity per stem of raffia is higher for the semi-farming system than for the traditional grub gathering method (Figure 3).

Photo 16. Incision of felled raffia stem (left) and covering the stem with raffia leaves (right).

Photo 17. Removal of raffia leaves from the incision on the stem of felled raffia.


Photo 18. Listening for grubs (left) and splitting open the raffia trunk (right).


Photo 19. Removal of grubs by hand in the semi-farming system.

The difference observed in the productivity of the semi-farming and the traditional gathering methods is significant at a 95% confidence interval (t = 25.9808, df = 6, p-value = 2.144e-07). However, each of these indigenous harvesting methods has its advantages and disadvantages (Table 9).

5.1.3 Average daily production for a single collector in the two harvesting systems

The daily production of grubs varies from one collector to another, depending on whether they use the traditional grub gathering or the semi-farming method, as well as the number of raffia trunks they exploit in a day. In the semi-farming system, a single collector can harvest between 8 and 10 trunks per day, compared to 10 to 15 in the traditional gathering system. On average, daily grub production is higher in the Obout area – where the semi-farming system is practiced – than in the Ntoung area where traditional methods are used (Table 10).

From this table, it is clear that in order to produce 570 individuals (grub mass 5.3 kg, valued at XAF 14,250), a total of 10 raffia stems are felled in the semi-farming system. Each raffia trunk can be exploited twice before it is abandoned. Most collectors exploit an average of 40 to 50 raffia stems per month.

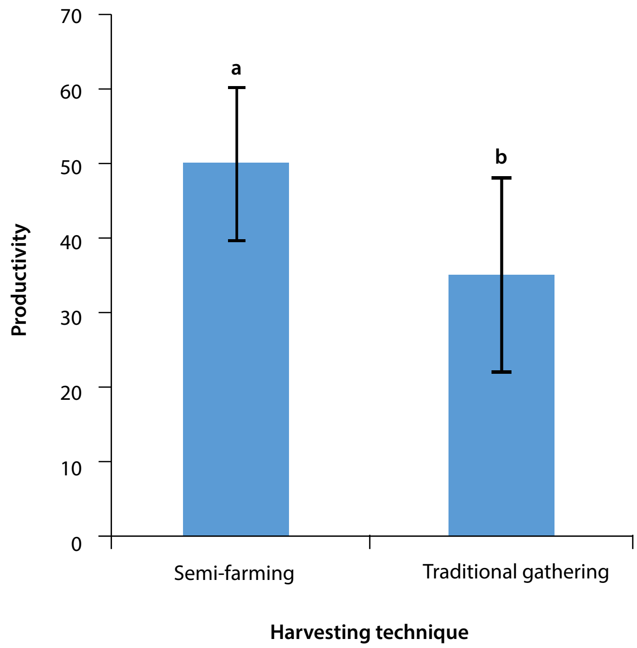

Figure 3. Comparison of the daily productivity of grubs by stem harvesting method.

5.1.4 Period of harvest

In the Obout area, grubs are harvested from November to June, while in the Ntoung area harvesting takes place between October and March (Table 11).

The months of July, August, September and October are not good for the production of grubs in either area because of heavier rains during this period. These months are characterized by high rainfall and higher water levels in the raffia swamp ecosystem. The high water levels have a negative impact on the productivity of felled or dead raffia stems and cause access problems for collectors to the swamp forest; carnivorous or omnivorous fish species also consume the grubs during this time.

Table 9. Advantages and disadvantages of the two indigenous harvesting systems.

	Indigenous systems	
	Semi-farming method	**Traditional gathering**
Advantages	More productive than traditional gathering	More sustainable as only dead or infested raffia stems are exploited
	Collectors do not spend days in the forest during harvest	Demands very little or no investment
	Grubs are sold in a fresher state, since sales are carried out just a few hours after collection	Demands less labor input and grubs are collected as soon as the stem is cut down
Disadvantages	Very destructive and unsustainable as it involves the felling of thousands of raffia stems	It is less productive and collectors must spend days in the forest to collect adequate numbers of grubs
	More labor intensive and requires some investment (e.g. hiring of assistants) to harvest prepared trunks	Some grubs might die after harvesting because collectors stay longer in the forest.

Table 10. Daily production of grubs by harvesting system.

Village	Method of harvest	Average number of stems exploited	Average daily Production (individuals)	Estimation in kg	Sales (XAF)
Obout	Semi-farming	10	570	5.27	14,250
Elende	Semi-farming	8	496	4.58	12,400
Ebomsi II	Semi-farming	9	518	4.79	12,950
Ntoung I	Traditional gathering	15	418	3.86	10,450
Ntoung II	Traditional gathering	10	398	3.68	9,950
Ndjibe	Traditional gathering	12	395	3.75	9,875
Djodjok	Traditional gathering	12	410	3.79	10,250
Nymbe	Traditional gathering	13	389	3.59	9,725

Table 11. Period of grub harvest.

Zone	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Obout area	■	■	■	■	■	■					■	■
Ntoung area	■	■	■							■	■	■

5.2 Contribution of palm weevil grubs to livelihoods

The exploitation and trade in palm weevils is an important source of livelihoods in both the Obout and Ntoung village areas. The exploitation of palm weevils is particularly important for securing or supplementing household food, income and medicinal sources (Table 12).

However, a greater proportion of the harvest is destined principally for trade and only individual grubs that fail to meet standard market criteria (injured, small-sized and dead specimens) are used for domestic consumption.

5.2.1 The use of grubs as medicine

The use of grubs as medicine in some of the villages, such as Obout, Elende, Ntoung I and Ntoung II dates back to the ancestral period. Although the level of local dependence on grubs for medicine has decreased in recent years, this resource is still important in the treatment of a number of ailments (Table 13).

5.2.2 Contribution of the grub trade to household income

The exploitation and trading of grubs is an important source of income for many households in all the villages in the study area. Monthly income generated by professional grub collectors from this activity varies between XAF 90,000 (USD 180) and XAF 300,000 (USD 600), while annual earnings reached XAF 2,400,000 (USD 4800) (Table 14).

During the harvest season income generated by professional grub collectors in Obout varies from XAF 1,600,000 (USD 3200) to XAF 2,400,000 (USD 4800). These incomes were higher than those observed from the exploitation of bushmeat (XAF 1,820,000 or USD 3640) in villages around Lobeke National Park (Tieguhong and Zwolinski 2009). Income from grub trading is also significantly higher than the monthly income obtained by unskilled workers in town, or by the rural producers of coffee (XAF 25,000 or USD 50 in good years). Compared with other NTFPs, African palm weevil grubs generate more monthly income than bushmeat

Table 12. Socioeconomic importance of grubs by villages.

Uses	Villages							
	Obout	Elende	Ebomsi II	Ntoung I	Ntoung II	Ndjibe	Djodjok	Nymbe
Food	X	X	X	X	X	X	X	X
Income	X	X	X	X	X	X	X	X
Medicine	X	X		X	X			

Table 13. Medicinal value of grubs in the study area.

Medicinal value	Prophylaxis	Percentage of respondents (%)
Treatment of women's infertility	Eat oil extract with specific plant species (unidentified)	24
Treatment of rashes and wounds in children	Apply a mixture of burned grubs, nest and grub oil extract on the skin	44
Treatment of coughs and colds	Application of oil extract inside the nose	9
Fortification of children bone's	Consumption of pupae	5

Table 14. Importance of grubs for household income.

Villages	Monthly income (XAF)		Annual income (XAF)		Number of professional grub collectors	Percentage of household annual income
	Minimum value	Maximum value	Minimum value	Maximum value		
Obout	200,000	300,000	1,600,000	2,400,000	17	65 to 75
Elende	200,000	300,000	1,600,000	2,400,000	4	60 to 75
Ebomsi II	180,000	300,000	1,440,000	2,400,000	3	50 to 75
Ntoung I	100,000	240,000	600,000	1,440,000	16	40 to 60
Ntoung II	90,000	180,000	540,000	1,080,000	7	40 to 50
Ndjibe	120,000	150,000	720,000	900,000	4	30 to 40
Djodjok	90,000	120,000	540,000	720,000	8	25 to 40
Nyimbe	120,000	160,000	720,000	960,000	6	30 to 40

NB: USD 1 = XAF 500

(XAF 29,000 or USD 58), Gnetum leaves (XAF 15,500 or USD 31) or rattan (XAF 13,000 or USD 26) as reported by Dounias in López and Shanley 2004).

Nonetheless, the contribution of this sector to household income is less than 40% in villages such as Ndjiebe, Djodock and Nyimbe. In each of these villages, inhabitants exploit grubs to a lesser extent and generate earnings of less than XAF 90,000. Generally, income from grub trading is only possible from November to June in the Obout area and from October to March in the Ntoung area. In these periods and even when grubs are no longer available, village inhabitants rely on other activities such as agriculture, fishing, animal husbandry, hunting and gathering of other NTFPs for household income. Overall, agriculture, fishing and grub exploitation are the most common activities practiced across the entire study area (Figure 4).

Grub exploitation represents 21% of activities practiced in all the villages surveyed (Figure 4). This value is higher than the 15% observed for all the other of NTFPs gathered for livelihoods in the areas (e.g. bush mango, njansang and palm wine). It is clear that the exploitation of palm weevil grubs plays an important role not only as an alternative source of protein, but also as a valuable potential income source in the areas. This result confirms the work of Arnold et al. (2011) who stated that insects offer a good opportunity for employment and income in developing countries, particularly for the poor in urban and rural areas.

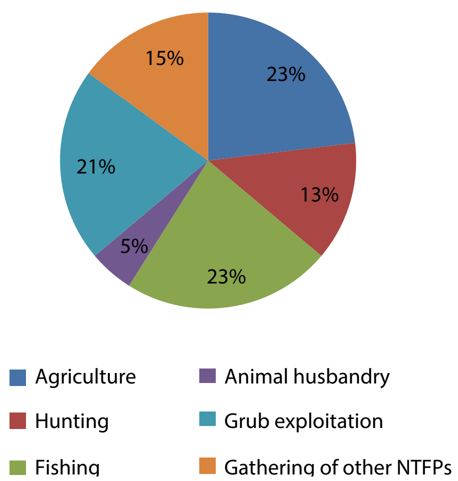

Figure 4. Comparison of grub exploitation with other economic activities in the study areas.

5.2.3 Preference for grubs as an alternative food source

Although grub exploiters mainly consume grub specimens that do not meet market criteria, almost everyone in the villages studied consume beetle grubs. The habit of grub consumption in these areas dates back a very long time and a greater number of respondents derive more satisfaction from consuming palm beetle grubs than bushmeat (Figure 5).

However, it is difficult to satisfy household protein needs with grubs, as most local production is destined for trade.

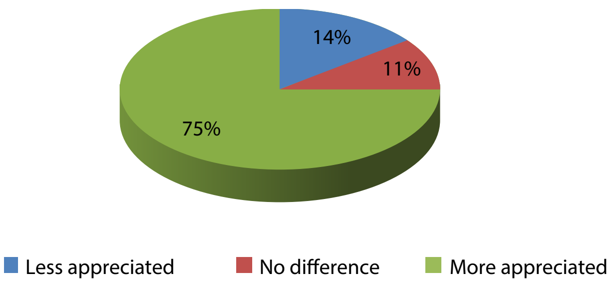

Figure 5. Popularity of grubs compared to bushmeat.

5.2.4 Social perception and gender implication of weevil grub exploitation

The exploitation and trade of palm weevil grubs are important activities in all the villages surveyed. The local perception of these activities is similar to that of many other sectors in village economies. Consequently, they are practiced by people of all social classes: poor, middle income and rich (Figure 6).

In addition, this activity is practiced by people of all age groups, including children, teenagers, middle-aged people and the elderly (Figure 7).

More adolescents and adults are involved in grub exploitation and trading (Figure 7). These age groups are more important in the Obout area where semi-farming is practiced. However, in the Ntoung area, traditional gathering is practiced by older people. Both men and women are involved in grub exploitation and trading in the Ntoung village area, in contrast to the Obout area, where only men are involved in these sectors (Table 15).

Table 15 reveals that all the grub collectors in Obout, Elende and Ebomsi II villages are men. In Ntoung I, Ntoung II and Djodjok, both men and women are involved. The semi-farming system practiced in the Obout area is harder work than the traditional gathering practiced in villages around Ntoung village. Grub exploiters and traders include both married and unmarried men and women. In total, 55 collectors were married (or living together like husband and wife) while 48 were single (Table 16).

Income obtained from grub trading has an important social impact in village communities. In villages such as Obout, Ebomsi II and Elende where grub exploitation is one of the major activities, grub collectors/traders have set up a

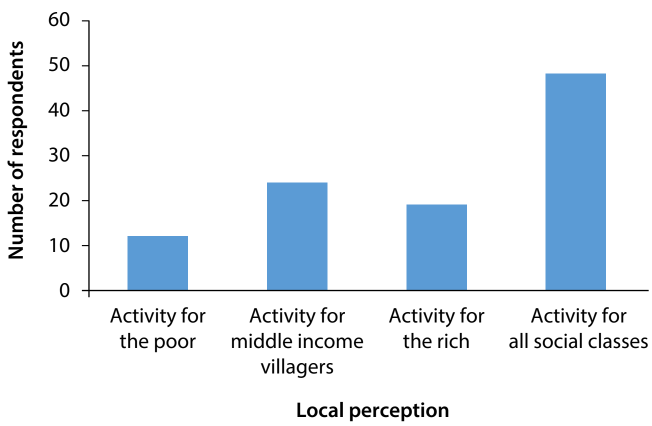

Figure 6. Local perceptions of grub exploitation and trading.

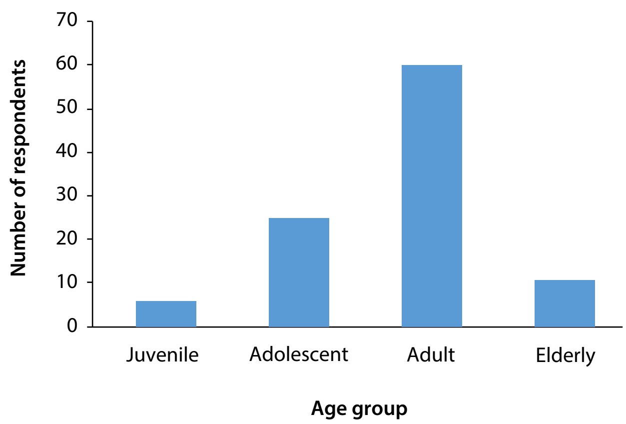

Figure 7. Distribution of grub exploiters by age.

Table 15. Distribution of grub collectors by gender.

Sex	Obout	Elende	Ebomsi II	Ntoung I	Ntoung II	Djibe	Djodjok	Nyimbe
Men	17	6	7	20	9	10	17	11
Women	0	0	0	3	1	0	2	0
Total	**17**	**6**	**7**	**23**	**10**	**10**	**19**	**11**

Table 16. Distribution of respondents by marital status and village.

Villages	Married	Single	Total
Elende	2	4	6
Ebomsi II	4	3	7
Obout	6	11	17
Ntoung I	18	5	23
Ntoung II	5	5	10
Ndjibe	7	3	10
Djodjok	8	11	19
Nymbe	5	6	11
Total	**55**	**48**	**103**

prestigious financial group which bring members together weekly. This group allows members (who are principally grub collectors) to contribute or save at least XAF 10,000 (USD 20) a week. Sometimes, group meetings helps members to harvest grubs from felled raffia stems in the semi-farming system. On such occasions, people who are assisted produce large quantities of grubs that they then take to major cities such as Yaoundé or Douala for sale. Income generated from this kind of community-assisted grub exploitation is generally used for purposes such as weddings, housebuilding, purchase of motorcycles, and paying for hospital bills and children's education. Generally, group members take turns to benefit from this initiative. Members who have already benefited from the group help others and who have large quantities of felled trunks usually employ villagers to harvest the grubs. A sum of XAF 2500–3000 (USD 5–6) is paid as a daily wage to those recruited for the harvesting process.

5.3 Environmental impacts of indigenous harvesting methods

The exploitation of grubs has a negative impact on the environment, both on raffia palms and populations of wildlife that share the same swampy ecosystem. This is because thousands of raffia stems are felled monthly. However, the semi-farming method is more destructive than traditional gathering method practices where exploited trunks are mostly dead or young raffia stems that have been naturally infested by grubs (Photo 20).

Photo 20. Extraction of grubs from infested young raffia palms using the traditional gathering method.

Nonetheless, it is difficult to determine the actual number of trunks that are exploited in the traditional gathering system, as collectors generally cover vast areas in order to identify raffia stems that have been naturally infested by grubs. In the semi-farming system, healthy mature trunks are cut down for grub production (Photo 21).

In the Obout area, this method has led to the massive destruction of raffia ecosystems. The total number of trunks that could be felled in 2500 m^2 plots was estimated during the course of the study (Table 17).

An average of 38 raffia stems, representing 32.2% of the total population, are felled in an estimated area of 2500 m^2 (Table 17). This figure represents the minimum number of raffia stems that can be felled by a single collector during a period of 45 days in the Obout area. However, larger-scale collectors can exploit three to four times this number. Generally, each collector exploits raffia stems every 2 months, and the average total number of raffia trunks felled by a single collector varies between 152 and 601 per year.

Photo 21. Destruction of raffia ecosystems in the semi-farming method.

Table 17. Number of raffia stems felled per plot.

Number of raffia	Plot 1	Plot 2	Plot 3	Plot 4	Average
Number of adult stems per plot	120	147	97	109	118
Number of adult stems felled	40	56	21	34	38
Percentage of adult stems felled (%)	33.33	38.09	21.65	31.19	32.20

5.4 Grub marketing chain

The commercialization of palm weevil grubs in the two study sites involves direct sales to travelers at the roadside or through middlemen, known locally as *bayam-sellam*, who buy grubs to resell in big cities such as Yaoundé and Douala or in towns such as Mbalmayo and Abong-Mbang (Photo 22).

Some traders from big cities who cannot get grubs directly from collectors buy from town markets. Business arrangements are largely facilitated by phone calls, generally a day before collectors go to do the harvesting. The market chain for palm weevil grubs is summarized in Figure 8.

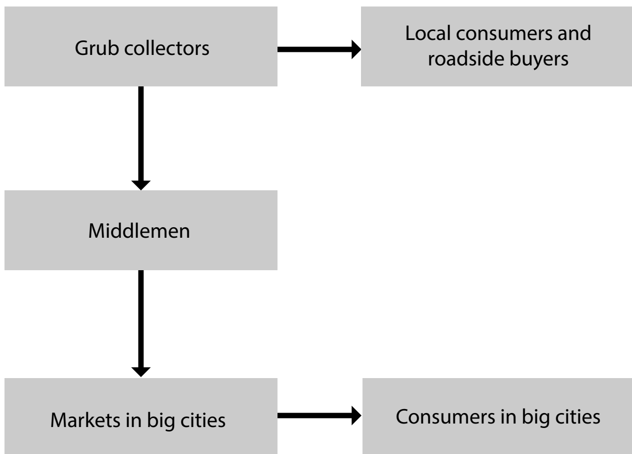

Figure 8. Market chain for palm beetle grubs.

Photo 22. Sales of grubs in an urban market (left) and at roadsides in villages (right).

The rising demand for grubs in recent years has increased market prices at both the local level and in urban cities. In the late 1990s, the price for 12 weevil grubs was XAF 100 (USD 0.20) in most of the villages around the Obout area. Currently the price has increased drastically and the number of grubs sold for XAF 100 has fallen from 12 to 4 individuals. Compared to other sources of protein, a kilogram of weevil grubs is still less expensive than beef without bones, but more expensive than fish and beef with bones (Figure 9).

In cities such as Yaoundé for example, a glass containing an average of 43 grubs is sold at XAF 1500 (USD 3). In some cases, sticks with 3 large-sized roasted grubs or 4 small grubs are sold at XAF 100 (USD 0.20) at bus stops and other public places. In a single business trip, a grub trader from the city can buy an average of 50 kg of grubs around neighboring villages. The estimated value of this quantity of grubs is XAF 133,500 (USD 267), which is shared between the collectors who have contributed to the supply.

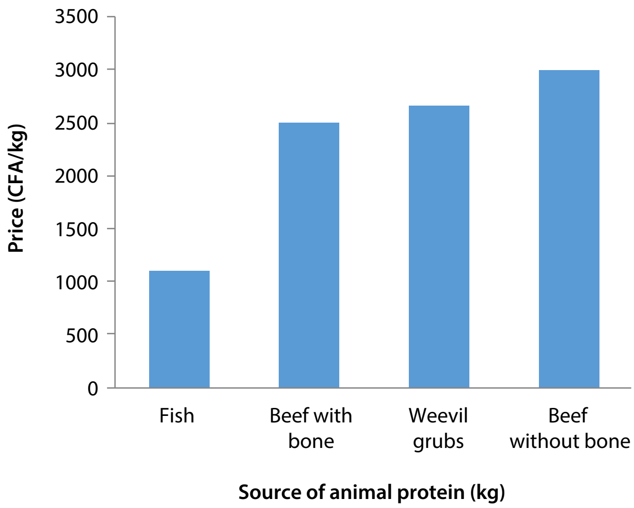

Figure 9. Comparison of the per-kilogram prices of grubs and other sources of protein.

5.5 Grub farming method and productivity of food formulas

The grub farming method consists of mating adult palm weevils and putting them into boxes containing different food formulas. Plastic boxes were more productive than wooden boxes, probably because it was more difficult to maintain wooden boxes at a temperature favorable for the development of grubs. For three pairs of adult weevils introduced in plastic boxes, a total of 173 grubs were harvested from three boxes of the experimental farming apparatus containing suitable food formulas (Photo 23).

However, of the four food formulas tested, boxes containing only fresh raffia tissues (OFRT) were the most productive, recording up to 73 weevil grubs per box, with an average production of 69 ± 5.6. These values are higher than those of the food formula composed of a mixture of 75% fresh and 25% dry raffia (MFDRT1), which recorded an average of 30 grubs, and those with food formula composed of a mixture of 50% fresh and 50% dry raffia tissue (MFDRT2), in which only five individual grubs were harvested. The fourth food formula consisted

Photo 23. Harvesting of grubs from the experimental farming system.

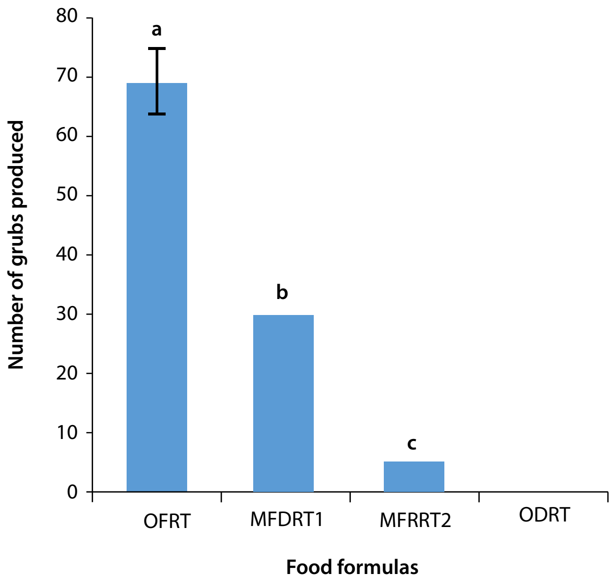

Figure 10. Number of grubs produced per food formula.

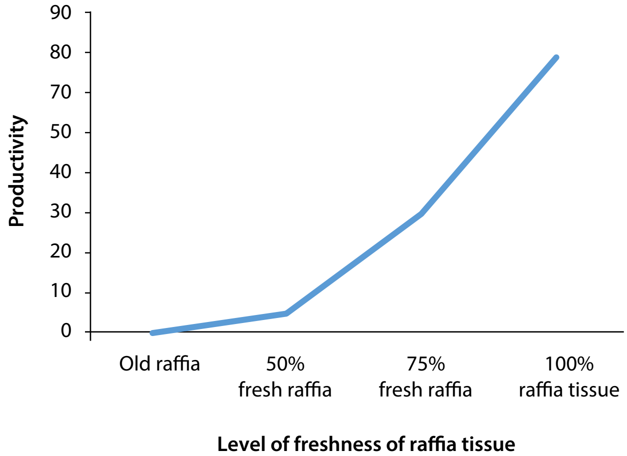

Figure 11. Variation of grub production with the level of freshness of raffia tissue.

of dead raffia tissue (ODRT) and was nonproductive (Figure 10).

A significant difference was observed in the efficiency of the different food formulas (one-way ANOVA: $F_{1,3}$= 4.781e+31; Pr =2e-16). The productivity of OFRT was significantly higher than that of all the other food formulas (Turkey post hoc test: p = 0.000). The time period required for the farming process was exactly 30 days (from the collection and coupling of adults to the harvest of grubs). From these results, we can conclude that the productivity of the different food formulas is directly linked to the level of freshness of the raffia tissues (Figure 11).

A linear correlation of 0.93 was observed between the mean production of grubs and the level of freshness of the raffia tissues in the different food formula (i.e. production of OFRT> MFDRT1>MFDRT2>ODRT). Verifying this observation with T-tests, the correlation was confirmed at 95% confidence interval (t = -5.1082, df = 4, p-value = 0.006943). From this observation, we can conclude that the fresher the raffia tissue, the higher the production of grubs. Although food formulas with old raffia tissues were less productive, they were favorable to the development of a species of grub parasite that could not be identified during the course of this study (Photo 24).

5.6 Comparison of the production, physiological characteristics and palatability of grubs from the indigenous harvesting and farming systems

The number of grubs produced by a single box in the grub farming system was higher than the production

Photo 24. An unidentified species of grub parasite.

per stem of raffia in both the traditional gathering and semi-farming systems. A total of two raffia stems were used as substrate in the three boxes that yielded 173 grubs in the farming system (about ¼ of a raffia stem was used per box). The average productivity per box containing approximately ¼ of raffia stem in the farming system was estimated at 69 ± 5.6. A single stem of felled raffia can be used to establish four boxes in the farming system. With an average of 69 individuals per box, a single stem of raffia used as substrate in the boxes will produce a total of 276 grubs. This value is more than five times the maximum productivity of a single stem of raffia in the semi-farming system (50 ± 10.1) and nearly eight times that of the traditional gathering method (35 ± 13.2). The difference in the estimated productivity per stem of raffia for the three production systems is shown in Figure 12.

Figure 12 shows that the grub productivity of a single stem of raffia is highest in the experimental farming system than in the semi-farming system or through traditional gathering. If the farming system is well managed, grubs would be produced to meet market demands and ensure year-round regularity of supply. The number of raffia stems that would be exploited for grub production would be reduced significantly, thereby assuring the survival and sustainability of the raffia ecosystem.

Although the period from felling raffia stems to when grubs are mature enough for harvest is estimated at 25 to 30 days for both the semi-farming and the farming systems, the number of working days required for the production of the same quantity of grubs is higher for the two indigenous methods than using the farming system. With traditional gathering, collectors go to the forest for many days in order to harvest a reasonable quantity of grubs. In the semi-farming method, collectors spend many days in the forest to cut and prepare raffia stems. From the second week, each of the prepared stems is visited twice a week in order to verify and eventually control the colonization process. The return per working day is therefore higher in the farming system than in the other methods of harvesting. In addition, the quality of grubs exploited and those produced from the farming system had the same physiological characteristics and palatability as those collected from the wild (Table 18).

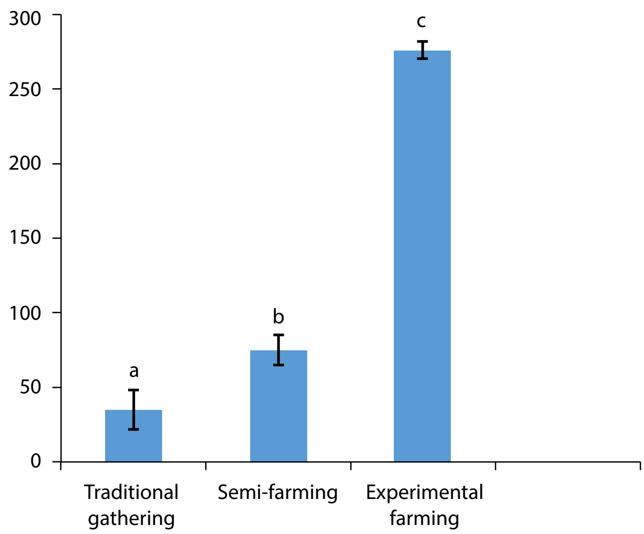

Figure 12. Comparison of grub productivity per stem of raffia exploited in the different production systems.

Table 18. Physiological characteristics and palatability of wild and farmed grubs.

Production system	Quantity of raffia used	Productivity	Grubs' physiological characteristics		Palatability
			Color	Length	
Traditional gathering	1 raffia stem of 2 to 3 m	35 grubs	Whitish yellow	5–6 cm	Sweet fatty taste
Semi-farming	1 raffia stem of 2 to 4 m	50 grubs	Whitish yellow	5–6 cm	Sweet fatty taste
Farming	Less than ¼ stem	69 grubs	Whitish yellow	5–6 cm	Sweet fatty taste

These characteristics were confirmed by local people who assisted in the harvest, preparation and sampling (tasting) of grubs from the boxes in the experimental farming system (Photo 25).

The cooked grubs from the experimental farming system had the same taste as those collected from raffia in the wild. This system of production has a number of advantages over the two indigenous harvesting systems.

- It is more productive than all the indigenous harvesting methods;
- It ensures year-round production of grubs, allowing a regular supply of grubs in both the dry and rainy seasons.
- It prevents massive destruction of raffia ecosystems, as it involves the use of smaller amounts of raffia tissue.
- It is less labor intensive and does not require collectors to spend hours and days in the forest to collect the grubs.
- It is less risky than the indigenous methods (which include accidents and snakebites).

Photo 25. Preparation of farmed grubs for sampling.

6 Conclusion and recommendations

The exploitation and trade of palm weevil grubs is an important source of livelihood in the Obout and Ntoung areas. Many local people depend on this resource for food, income and medicine. The market prices and demand for this resource are increasing, providing new market opportunities. Due to the high economic value of this resource, the exploitation of grubs is commonly practiced and considered to be more important than hunting, fishing and animal husbandry. However, the exploitation of this resource from the wild is characterized by a low productivity, irregular supply and negative environmental impacts. The newly developed grub farming system is particularly sustainable, highly productive and consumes raffia stems than the traditional gathering or semi-farming systems. Promotion of this farming method will guarantee farmers sustainable and continuous production of grubs and enhances the contribution of this resource to local livelihoods and participatory forestry.

From the results obtained in this study, the following recommendations can be made to the different actors of the palm weevil grub sector:

a) Cameroon Government

- Promote palm weevil grubs as an important NTFP for livelihood improvement and to enhance participatory forestry and community-based conservation
- Promote sustainable exploitation and farming of palm weevil grubs as an alternative source of protein in the study area and in Cameroon
- Define a legal framework for the exploitation and trade of palm weevil grubs.

b) Researchers

- Identify the species of parasite observed during the experimental grub farming system
- Develop ways in which grubs can be processed to produce globally accepted human food and feed
- Improve and disseminate the newly developed grub farming method.

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The larvae (grubs) of the African palm weevil are consumed by the majority of inhabitants of the Congo Basin. These larvae are extremely rich in essential food nutrients; they contain proteins, carbohydrates, fats and energy values comparable to those of beef and fish. They are also an excellent source of a range of minerals and vitamins. The exploitation and trade of weevil grubs is an important source of income for forest dependent communities in the Congo Basin. These grubs are currently harvested from raffia and palm stems in the wild. This study evaluates the sustainability of indigenous harvesting techniques, and investigates ways in which these insect resources could be farmed in Obout and Ntoung village areas. Results show that grubs are harvested by collecting them from naturally infested raffia stems (the traditional collection method) or by cutting and preparing healthy raffia stems for grub production (the semi-farming method). Both methods are unsustainable, as thousands of raffia stems are cut down on a monthly basis. To address this situation, a grub farming system has been developed within the course of this study. It has proved to be more productive and sustainable than both the traditional collection and the semi-farming methods. This farming system could be used to produce grubs at any time of the year, thereby providing an opportunity for year-round availability of these nutritious insects, while securing their place as an important alternative to protein and a valuable income source in Cameroon.

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