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Rhynchophorus ferrugineus

Palm weevil farming contributing to food security in sub-Saharan Africa

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Abstract

African palm weevils (*Rhynchophorus* spp., Dryophthoridae) are amongst the most widely consumed species of insects in sub-Saharan Africa, especially in their larval form. Studies have shown that these insects are very rich in essential food nutrients, with protein, carbohydrates, fat, and energy values comparable to that of beef and fish. Moreover, they are rich in micronutrients, and their exploitation is an important source of income for many forest dependent communities in sub-Saharan Africa. However, grubs are usually collected from raffia stems in the wild and their exploitation is strenuous, seasonal and sometimes unsustainable. In an attempt to promote the use of these resources as an alternative source of protein, this paper describes a farming design that could be used by small-scale farmers to produce these edible larvae in plastic boxes at home within a period of 30 days per cycle. Though fractions of raffia stem tissue are used as substrate in this farming system, it is by far less destructive to the raffia ecosystem and more productive than collection in the wild. If disseminated, grub farming could provide an opportunity for a continuous year round production of these nutrient rich insects, while securing their place as an important alternative to protein and income source in Africa.

Keywords: insects, farming, food security, rural communities

6.1 Introduction

Food insecurity on the African continent has worsened in recent years, and the proportion of the malnourished population in sub-Saharan Africa has surpassed 35%, with the greatest problem being accessibility to edible protein sources (Rosegrant *et al.*, 2005). Most frequently, diets in this sub-region are comprised of cereal or root staple crops, with limited sources of proteins and micronutrients. Because of bushmeat depletion and excessively costly substitution by industrial livestock production (Alkemade *et al.*, 2013), proteins are either too expensive, or locally less available and their access is becoming increasingly critical. They are unequally distributed within households or generally not considered as household priority when incomes are insufficient to meet the needs of a high quality diet (Chastre *et al.*, 2007). Protein deficiency and reduced dietary diversity have serious effects on the nutrition and health of both rural and urban populations and account for a number of illness and death in many countries in Africa (Elemo *et al.*, 2011).

Indigenous food resources constitute the bedrock of the diversity in traditional and indigenous food systems of developing country (FAO, 2014). Though a wide range of indigenous foods are neglected, underutilized, and less promoted by agricultural policies in most parts of Africa, they could be fundamental in resolving some of the many problems induced by malnutrition and food insecurity in most rural areas. Moreover, traditional and indigenous foods are less deleterious to the environment and are vital in the preservation of the cultural heritage of local communities (FAO, 2014). In sub-Saharan Africa where more than half of the population is classified as 'poor' (Beegle *et al.*, 2016), the exploitation of indigenous food resources is irrefutable to secure food security. The need to develop non-timber forest products (NTFPs) in particular as an alternative to improve indigenous livelihoods while cutting down human pressure on biodiversity has largely been acknowledged (Arnold and Ruiz Pérez, 2001; Belcher *et al.*, 2005; Ndoye *et al.*, 1997).

Amongst NTFPs, edible insects are quite abundant, and the gathering of insects for food has for long been part of the culture of many human societies in the developing world (Muafor *et al.*, 2012, 2014). Nowadays, palm weevil grubs, caterpillars, termites, grasshoppers and locusts are the most popular in Africa in general and Central Africa in particular (FAO, 1995; Muafor *et al.*, 2015; Stack *et al.*, 2003). The place of the African palm weevil larvae *Rhynchophorus* spp. is one of the most salient as it is consumed in nearly all countries of sub-Saharan Africa. The African palm weevil larvae are extremely rich in essential food nutrients. According to Womeni *et al.* (2012), the consumption of 100 g of these larvae can effectively satisfy the body daily requirements in energy, proteins, fats, glucose, vitamins (thiamine/B1, riboflavin/B2 and pyridoxine/B6), and minerals (K, Ca, Mg, Zn, P and Fe).

In almost all countries where these larvae are eaten, harvesting is done by systematically extracting them from the trunks of raffia in the wild and/or from aging oil palms felled to produce palm wine. Traditionally, collectors used to explore the palms that were naturally infested by the grubs and such exploration required a true ecological expertise. Felling of the weevil infested palms by this indigenous exploitation methods contributed to the sustenance of healthy raffia stands (Dounias, 2003). However, harvesting was seasonal and satisfied only a domestic consumption and, at best, a small-size market trade. In some countries like Cameroon for example, the exploitation of this resource is no longer sustainable as it encourages collectors to clear-cut vast areas of raffia swamps in order to induce weevil infestation in the decaying cut stems. By contrast to past practices, such speculative form of exploitation has become highly destructive (Muafor *et al.*, 2015). In response to these problems and in line with increasing concerns on how to develop mini-enterprises for the production of insect based food and feed in Africa, a team of researchers from the Living Forest Trust (LIFT), the Center for International Forestry Research and the French National Research Institute for Sustainable Development have implemented a farming technique for the production of edible larvae by rural small scale producers in Cameroon. This farming technique, successfully tested in Obout village, is presently fine-tuned and disseminated among smallholders with similar and alternative substrates in selected villages of Cameroon.

6.2 Marketing and socioeconomic potential of grubs in Cameroon

Palm weevil grubs are particularly important economic resources and they provide complementary income to many rural people who depend on their exploitation as main or part-time activity (Dounias, 2004). From the dense humid semi-deciduous forest zone in the East to the highland savannah in the West region, this insect is traded, either cooked or raw, by small-scale roadside vendors. From a recent study (Muafor *et al.*, 2015), in addition to small-scale sales in villages located near harvesting sites, grubs are increasingly traded in larger urban markets. In some markets like Mvog-Mbi and Nkondongo in Yaoundé, or in Bertoua, Abong-Mbang and Ayos a specialised section is dedicated to grub sales (Figure 6.1).

The marketing chain consists of retailers who live in big cities, intermediate suppliers in smaller cities and producers in villages. Each of the producers may sell directly to the retailers or the intermediate suppliers. The intermediate suppliers buy from producers to resell in markets either in local towns or to retailers in the big cities. For instance, market price in a local town like Abong-Mbang is 500 FCFA (USD 1) for a glass containing 25 to 30 individuals of palm weevil grubs. Retailers in bigger cities like Yaoundé and Douala resell the same amount at 1,500 FCFA (USD 3) during seasons of abundance and 2,500 FCFA (USD 5) in periods of scarcity. Brochettes of prepared grubs are equally sold at 100 FCFA (USD 0.2) per

Figure 6.1. Small-scale traders of palm weevil grubs in Abong-Mbang market, Cameroon.

stick of 3 to 4 individuals. Trans-border trade is also important, with sales to neighbouring countries – Gabon, Equatorial Guinea, Nigeria – and even as far as France and Belgium.

In terms of income generated, Dounias (2004) reported that in 2004 the average monthly income for larvae harvesters in rural areas was about 35,500 FCFA (USD 71), for live larvae sold to retailers supplying city markets and 25,000 FCFA (USD 50) for roasted larvae sold in bars and along roadsides. In 2015 figures are much higher with an average income generated by professional grub collectors in Obout village ranging from 90,000 FCFA (USD 180) to 300,000 FCFA (USD 600), representing 30 to 75% of the collectors household income (Muafor *et al.*, 2015). Out of the eight farmers who experimented the proposed farming technique, most were able to complement their income with a regular monthly revenue of 50,000 FCFA (USD 100) to 70,000 FCFA (USD 140) by selling grubs harvested on farm.

6.3 Reproductive material for palm weevil grubs farming

Adult individuals of the African palm weevils are the reproductive animal material, which is used in the grubs farming system. Members of this species belong to the genus *Rhynchophorus* in Dryophthoridae. Adult individuals are characterized by a snout-like projection of their mandibles called a rostrum, while the larvae (or grubs) have relatively large mandibles and are legless. The modified mouthparts in the adults are used for feeding and to make holes in the host plant material where eggs are laid (Tambe *et al.*, 2013). Palm weevils are distributed throughout tropical Africa where they mainly live in oil palm, date palm, raffia palm and coconut palm (Bong *et al.*, 2008; Gries *et al.*, 1994). However, concrete knowledge on the diversity of this genus in Africa is lacking. In Cameroon, two species – notably *Rhynchophorus phoenicis* (Fabricius, 1801) and *Rhynchophorus quadrangulus* Quedenfeldt, 1888 – are frequently cited as edible. *R. quadrangulus* is adapted to highland areas, while *R. phoenicis* is mostly found in humid lowland areas. The life cycle of these two species is similar to that of other *Rhynchophorus* species and is known to undergo complete metamorphosis. In the wild, adult weevils are generally attracted by wounded and sap producing raffia and/or palm species on which they feed, mate and establish for pupation. During this process, fecundated females deposit eggs on the decaying parts of the trunks, which later hatch into young larvae within a period of one week. These young larvae develop within a few weeks into mature larvae that can be harvested.

6.4 Palm weevil grubs farming technique on experimentation in Cameroon

The experimental method implemented by LIFT NGO to promote palm weevil grubs farming in Cameroon consists of rearing adult palm weevils in plastic boxes of 60 cm long, 40 cm wide and 40 cm high. In this system, the plastic boxes are suspended with the help of woody poles at a height of 80 to 100 cm above the ground in a shaded but air circulating environment. Once the farming dispositive is established, the rearing process begins with the selection and coupling of healthy adult palm weevils in small plastic cups for copulation (Figure 6.2). The fecundated beetles are then introduced into larger plastic boxes for eggs production, incubation, hatching and development into edible grubs. Slices of young woody stem tissues of raffia or other palms are introduced as food substrate and/or laying ground (Figure 6.2).

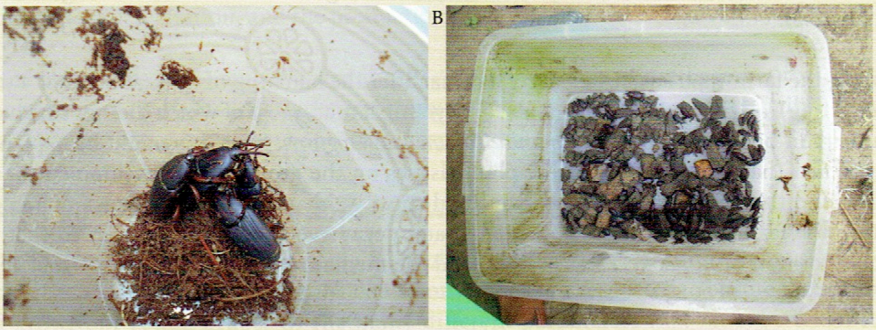

Figure 6.2. (A) Coupling of adults for fecundation and (B) fecundated adults transferred to a larger box for laying and hatching.

Once the eggs are hatched, young grubs are fed by adding pieces of young woody stem tissues from raffia into the boxes containing the young larvae. A handful of fresh stem tissues of raffia is added once a week within the first two weeks, after which the substrate is replaced by hard stem tissues for two additional weeks. With this technique, well fed grubs in suitable farming conditions grow to maturity within a period of 25 to 30 days, when they can be harvested.

6.5 Suitable substrate for rearing the African palm weevil

One of the most challenging aspects in African palm weevils farming is to find the right substrate for adult fecundation, incubation, and development of the young larvae. Various plant materials have been tested as substrate to farm palm weevils in Africa. In Nigeria, Ebenebe and Okpoko (2016) report that it is possible to rear African palm weevils with sugarcane tops and spoilt watermelon. Nonetheless, the authors indicate that growth of the larvae and yields are relatively lower in sugarcane tops than in spoilt watermelon, but are unable to pupate in spoilt watermelon. Monzenga Lokela (2015) similarly studied the possibility of using sugarcane stalks and palm stem tissues in the farming process. In Cameroon, stem tissues from raffia and other palm species as food substrate gave the best results.

Trials conducted by LIFT to test the efficiency of substrate from selected palm species concluded that slices of young woody tissues from *Raphia hookeri* G. Mann & H. Wendl., 1864, *Raphia monbuttorum* Drude 1895 and *Elaeis guineensis* Jacq., 1763 are suitable food substrates for fecundated adults. Moreover, these three materials are equally convenient for egg laying and hatching into young larvae. However, only stem tissues from *R. hookeri* were proven to be suitable food substrate for the development of young grubs after hatching. In all the trials, the quantity of matured grubs harvested in boxes containing *R. monbuttorum* and *E. guineensis* was much lower than the quantity obtained in boxes containing *R. hookeri.* For two or three fecundated female adult weevils that were introduced in each of the boxes containing the different food substrate, the average grubs productivity of boxes containing

R. hookeri was more than twice that of boxes containing *R. monbuttorum* and *E. guineensis* (Figure 6.3).

During the farming trials, it was observed that after the hatching of eggs (about 3 or 4 days after laying), all the boxes were colonised by young larvae, most of which did not survive to maturity in boxes containing *R. monbuttorum* and *E. guineensis*. This might be explained by the fact that the efficiency of the plant tissues on the growth and development of the larvae and the productivity of the farming dispositive depend on the changes that occur within the farming conditions as the substrates decay over time. It was observed that the decomposition of *R. hookeri* was gradual and the medium remained relatively fresh, while

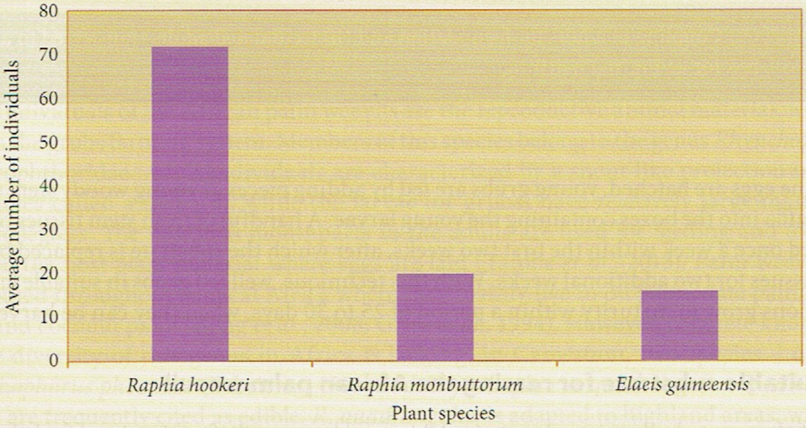

Figure 6.3. Average productivity of grubs in boxes containing different plant tissues as food substrate.

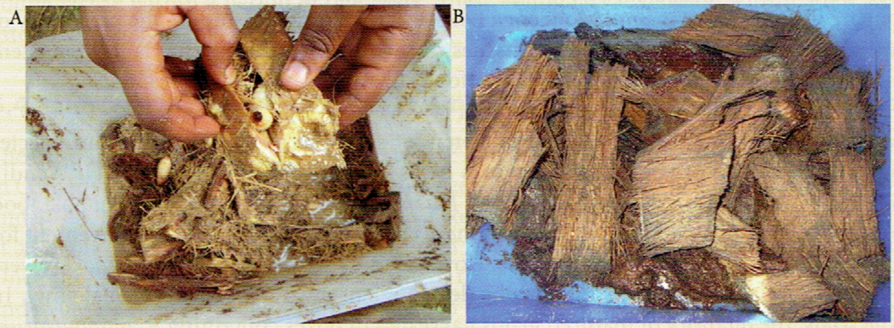

Figure 6.4. Difference in the decomposition and efficiency of substrates from (A) *Raphia hookeri* and (B) *Elaeis guineensis*.

that of *R. monbuttorum* and *E. guineensis* rapidly decomposed, with signs of high level of fermentation, dehydration, and the production of a pungent odour (Figure 6.4).

When composed of *R. monbuttorum* and *E. guineensis*, the medium becomes toxic to the young grubs, most of which die before reaching maturity. This situation is especially frequent when farming procedures are not properly respected.

6.6 Required farming conditions and work schedule

Nevertheless even in farms adopting *R. hookeri*, tissues from matured stems should be harvested as substrate. Some farming conditions need to be respected to ensure the survival and growth of young grubs. Of the many different parameters that must be taken into account for a successful palm weevil farming, humidity of the substrate and temperature in the farming boxes are the most acute. These two parameters are controlled by perforating the farming boxes with six holes of about 1 cm in diameter on the sides and on the base to guarantee a suitable temperature and humidity. In addition to temperature and humidity regulation, the perforations on the sides also ensure the renewal of oxygen in the boxes. The holes at the base are essential for evacuating part of the detritus exudates resulting from the decomposition of the substrate. Periodical cleaning is needed in order to keep the holes clear from any obstacle. The various farming conditions must be controlled during each intervention programmed on a work schedule predetermined in the farming calendar. A typical work schedule for securing good farming conditions is synthetized in Table 6.1.

6.7 Dissemination attempts and performance of small-scale grub farms in Cameroon

The grub farming technique is currently being promoted among small-scale farmers in selected villages in southern Cameroon. Beneficiary villages are selected based on the proximity of a swamp raffia forest and existing exploitation of the forest to harvest palm weevil grubs. In each of the villages, the grub farming is carried out using a Farmer Participatory Research (FPR) approach in which farmers are directly involved in a farming research-based project. Farmers are selected by experts from LIFT, trained on palm weevil farming process and assisted in the establishment and follow-up of individual small-scale pilot grubs farms (Figure 6.5).

Since the last quarter of 2015, a total of 25 small-scale farmers and a cooperative have been trained and assisted in the establishment of grub farms. In the different farms, experts from LIFT collaborate with the farmers to test different farming parameters. Apart from humidity and temperature, two other parameters are being tested through the FPR approach: the first one is the number of fecundated females that should be introduced in a box to assure an optimum yield; the second one is the suitable food substrate for the development of young larvae, by comparing the efficiency of stem tissues from the two raffia species (*R. hookeri* and *R. monbuttorum*) and oil palm (*E. guineensis*).

The PFR approach allows for data collection while continuously adjusting the technique based on remarks and propositions formulated in return by the farmers. It efficiently combines farmer training with on-going improvement of the farming technique inspired from their

Table 6.1. Work schedule and farming conditions for a successful palm weevil grubs farm.

Status	Farming material	Substrate	Conditions	Farming day	Activities
Week 1					
fecundation	small plastic containers with lids	young woody stem tissue of *Raphia hookeri*	two adult couples per container	1	• perforate small plastic containers on the lid • put adult couples in small plastic containers
			fecundation best at 20-25 °C	2	• observe if females have started laying eggs
incubation	large plastic storage containers	young woody stem tissue of *R. hookeri*	incubation is best at 24-25 °C	3	• perforate large plastic storage containers on the sides and at the base • introduce 1 kg of substrate into the container • transfer eggs and fecundated females into the containers (3 females per container)
Week 2 to 4					
growth and development of larvae	large plastic storage containers	hard woody stem tissue of *R. hookeri*	humidity of raffia tissues should be conserved	3 to 6	• control perforations at the base of the containers and reopen if closed
				7	• add 0.5 kg of fresh substrate
				8 to 13	• control perforations at the base of the containers and reopen if closed
			growth is best at 25-30 °C	14	• add 0.5 kg of fresh substrate
				15 to 21	• control perforations at the base of the containers and reopen if closed
			humidity of raffia tissues should be conserved	22	• add 0.5 kg of fresh substrate
				23 to 29	• control perforations at the base of the containers and reopen if closed
				30	• harvesting of grubs

own initial knowledge and 'learning by doing' experience (Freeman, 2001). Selected farmers will be trained to become expert farmers on the grub farming technique. These expert farmers will serve as models to disseminate the grub farming technique to the neighbouring farmers. Production data collected during two experimental farming cycles in 10 small-scale pilot farms and an average of 3 boxes per farm show that a total of 3,956 grubs were produced from 33 boxes that necessitated 12 raffia stems as substrate (Table 6.2).

Figure 6.5. Individual small-scale pilot grub farms promoted by the Living Forest Trust in the Nyong Basin area.

Table 6.2. Grubs produced by small-scale farmers in Obout village in Cameroon.

Codes of individual farmers	Number of farming boxes	Number of raffia stems exploited for all the boxes	Number of grubs produced in 1st trial	Number of grubs produced in 2nd trial	Total
Farmer 1	3	1	191	161	352
Farmer 2	3	1	158	168	326
Farmer 3	3	1	253	192	445
Farmer 4	3	1	148	160	308
Farmer 5	3	1	230	135	365
Farmer 6	3	1	201	abandoned	201
Farmer 7	3	1	273	118	391
Farmer 8	6	2	590	512	1,102
Farmer 9	3	1	159	168	327
Farmer 10	3	1	139	abandoned	139
Total	33	12	2,342	1,614	3,956

The advantage of this farming technique is that the productivity of a single stem of raffia that is used as substrate in the farming system is at least four times higher than that in the wild. Generally, raffia stems in the wild hardly produce more than 60 individuals. Moreover, it allows farmers to produce grubs at any period of the year for household consumption and/or trade (Figure 6.6).

Figure 6.6. Grubs harvested from small-scale grub farms in Obout village in Cameroon.

However, the dispositive must be closely supervised in order to ensure good yields. Some farmers who could not provide the required attention to the farming dispositive abandoned the experiment after the first trial, while others only obtained low yields during both trials for reasons that remain unexplained.

6.8 What future for insect based enterprises in sub-Saharan Africa?

Insect farming is quite new in sub-Saharan Africa, in spite of the fact that insects have for long been part of human food in this sub-region. Traditionally, forest dependent people have been gathering insects from the wild for family consumption and trade. However, with increasing concerns over the need to optimize the potential of insect resources as an alternative in the development of food and feed, procurement from the wild is reaching its limits and insect farming is alternatively developing in different corners of the world. Although there is no legislation forbidding the consumption of insects or the use of processed insect products in human and/or animal nutrition in sub-Saharan Africa, no significant effort has been made by authorities in charge of agriculture and even private investors to develop enterprises that promote the processing of insect resources into innovative products. In an area where entomophagy is culturally well established, this growing economic opportunity needs to be elicited to alleviate endemic poverty and malnutrition while promoting highly valued food resources.

According to Van Huis *et al.* (2013), the establishment of insect-based enterprises and the processing of insects into street foods and animal feed could easily be achieved in low-income countries where it is relatively easy to bring insects to the market, and where demand for edible insects is high. However, this can only be achieved if people are trained in insect farming and if the processing of insects into quality products is secured. Some organisations have started investing in the promotion of insect-based enterprises in sub-Saharan Africa and the local farmers are gradually being educated on the economic potential of the edible-insect trade sector. One rare example of a pioneer organisation that promotes insect-based enterprises in Cameroon and Central Africa at large is LIFT that is developing and training farmers on palm weevil grubs farming. Other promising initiatives to develop insect-based industry in sub-Saharan Africa are those of ASPIRE that has similarly introduced palm weevil farming in Ghana and the efforts of FASOPro in the processing and trade of edible insects in Burkina Faso. Apart from grubs farming, other types of insects like mealworms and crickets are being introduced for farming in sub-Saharan Africa. The increasing interest in the development of insect-based enterprises and products is a strong incentive to pursue research exploration on the controlled rearing of other edible insects so far picked out from the wild.

6.9 Conclusions

The development of palm weevil farming is an important gateway for the development of insect-based small-scale enterprises in sub-Saharan Africa. Palm weevil grubs (Figure 6.7) are largely accepted as food in most of the countries in the sub-region. The technique of domestication promoted by LIFT is relatively simple and easy to implement. The enthusiasm of small-scale farmers in the experimental grub farming in Cameroon demonstrates the high potential of edible-insect farming as an economic activity. With an existing market for grubs and other species of insects, this sub-region presents a huge potential for the development of insect-based mini-enterprises and processed food and feed products. However, the region is still fledgling in the domain of growing insect economy and more efforts need to be deployed jointly by authorities, entrepreneurs, and researchers to transform traditional gathering practices into a more profitable and specialised insect-based economic sector. The effective

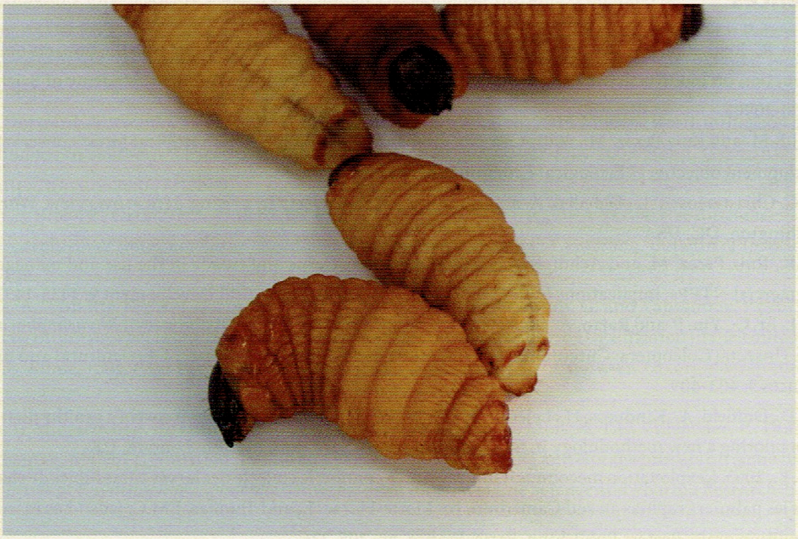

Figure 6.7. *Rhynchophorus phoenicis* larvae.

development of this sector in sub-Saharan Africa might be geared by a number of factors, amongst which:

- enhancement of research on farming procedures and conditions of grubs and other edible insect species;
- putting in place of suitable mechanisms that facilitate access to funds for research and development of insect product-based enterprises;
- active involvement of all development stakeholders (government, NGOs, donors, private investors, local communities) in the development of this new economic sector;
- transfer of technologies and training of small-scale farmers;
- development of a legal framework for securing product quality;
- promotion of entomophagy among non-insect consumers and the use of insect-based products as food and feed.

Acknowledgements

We would like to thank the C2D-PAR program of the Ministry of Scientific Research and Innovation (MINRESI) for providing substantial funds to promote insect farming and insect-based enterprises in Cameroon. Great thanks to the Center for International Forestry Research (CIFOR), the managers of the CGIAR CRP-FTA fund and particularly Dr Peter Cronkleton for supporting our palm weevil grubs farming project. We are equally grateful to the French National Research Institute for Sustainable Development (IRD), as well as the RAPHIA Project of IRD for providing supplementary funds for the training of small-scale farmers. Special thanks to Michel Owona Tseungui for his decisive contribution during the experimental farming phase.

References

Alkemade, R., Reid, R.S., Van den Berg, M., De Leeuw, J. and Jeuken, M., 2013. Assessing the impacts of livestock production on biodiversity in rangeland ecosystems. Proceedings of the National Academy of Sciences 110: 20900-20905.

Arnold, J.E.M. and Ruiz Pérez, M., 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics 39: 437-447.

Beegle, K., Christiaensen, L., Dabalen, A. and Gaddis, I., 2016. Poverty in a rising Africa: overview. World Bank, Washington, DC, USA.

Belcher, B., Ruiz Pérez, M. and Achdiawan, R., 2005. Global patterns and trends in the use and management of commercial NTFPs: implications for livelihoods and conservation. World Development 9: 1435-1452.

Bong, C.J., Er, C., Yiu, P. and Rajan, A., 2008. Growth performance of the red-stripe weevil *Rhynchophorus schach* Oliv. (Insecta: Coleoptera: Curculionidae) on meridic diets. American Journal of Agricultural and Biological Sciences 3: 403-409.

Chastre, D., Duffield, A., Kindness, H., LeJeune, S. and Taylor, A., 2007. The minimum cost of a healthy diet: findings from piloting a new methodology in four study locations. Save the Children, London, UK.

Dounias, E., 2003. L'exploitation méconnue d'une ressource connue: la collecte des larves comestibles de charançons dans les palmiers raphias au sud Cameroun. In: Motte-Florac, E. and Thomas, J.M.C. (eds.) Les insectes dans la tradition orale. Peeters Publishing, Paris, France, pp. 205-226.

Dounias, E., 2004. Edible weevil larvae: a pest for palm trees but a delicacy for city-dwellers. In: López, C. and Shanley, P. (eds.) Riches of the forest: for health, life and spirit in Africa. CIFOR-DFID-EC, Bogor, Indonesia, pp. 9-12.

Ebenebe, C.I. and Okpoko, V.O., 2016. Preliminary studies on alternative substrate for multiplication of African palm weevil under captive management. Journal of Insects as Food and Feed 2: 171-177.

Elemo, B.O., Elemo, G.N., Makinde, M.A. and Erukainure, O.L., 2011. Chemical evaluation of African palm weevil, *Rhychophorus phoenicis*, larvae as a food source. Journal of Insect Science 11: 146.

Food and Agriculture Organisation (FAO), 1995. Non-wood forest products for rural income and sustainable forestry. Non-wood forest products 7. FAO, Rome, Italy.

Food and Agriculture Organisation (FAO), 2014. Promotion of underutilized indigenous food resources for food security and nutrition in Asia and the pacific. FAO Office for Asia and the Pacific, Bangkok, Thailand, 200 pp.

Freeman, D., 2001. Teacher learning and student learning in TESOL. TESOL 35: 608-609.

Gries, G., Gries, R., Perez, A.L., Gonzalez, L.M., Pierce Jr., H.D., Oehlschlager, A.C., Rhainds, M., Zebeyou, M. and Kouame, B., 1994. Ethyl proprionate: synergistic kairomone for African palm weevil, *Rhynchophorus phoenicis* L. (Coleoptera: Curculionidae). Journal of Chemical Ecology 20: 889-897.

Monzenga Lokela, J.C., 2015. Ecologie appliquée de *Rhynchophorus phoenicis* Fabricius (Dryophthoridae: Coleoptera): phénologie et optimisation des conditions d'élevage à Kisangani. PhD thesis, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, 201 pp. Available at: http://hdl.handle.net/2078.1/157580.

Muafor, F.J., Levang, P. and Le Gall. P., 2014. A crispy delicacy: Augosoma beetle as alternative source of protein in East Cameroon. International Journal of Biodiversity: 214071.

Muafor, F.J., Levang, P. and Le Gall, P., 2012. Making a living out of forest insects: beetles as income source in Southwest Cameroon. International Forestry Review 14: 314-325.

Muafor, F.J., Gnetegha, A.A., Le Gall, P. and Levang, P., 2015. Exploitation, trade and farming of palm weevil grubs in Cameroon. CIFOR Working Paper 178, Bogor, Indonesia, 32 pp.

Ndoye, O., Ruiz-Perez, M. and Eyebe, A., 1997. The markets of non-timber forest products in the humid forest zone of Cameroon. ODI Network Paper 22c, Overseas Development Institute, London, UK.

Rosegrant, M.W., Ringler, C., Msangi, S., Cline, S.A. and Sulser, T.B., 2005. International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACTWATER): model description. International Food Policy Research Institute, Washington, DC, USA.

Stack, J., Dorward, A., Gondo, T., Frost, P., Taylor, F. and Kurebgaseka, N., 2003. Mopane worm utilisation and rural livelihoods in southern Africa. CIFOR Livelihood Conference, 19-23 May 2003, Bonn, Germany. Available at: http://tinyurl.com/y73t3by9.

Tambe, T.J., Riolo, P., Okolle, N.J., Isidoro, N., Fanciulli, P.P. and Dallai, R., 2013. Sexual size differences and color polymorphism of *Rhynchophorus phoenicis* in the southwest region of Cameroon. Bulletin of Insectology 66: 153-159.

Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. and Vantomme, P., 2013. Edible insects: future prospects for food and feed security. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, FAO Forestry Paper no. 171, 187 pp. Available at: http://www.fao.org/docrep/018/i3253e/i3253e.pdf.

Womeni, H.M., Tiencheu, B., Linder, M., Nabayo, C.M.E., Tenyang, N., Mbiapo, T.F., Villeneuve, P., Fanni, J. and Parmentier, M., 2012. Nutritional value and effect of cooking, drying and storage process on some functional properties of *Rhynchophorus phoenicis*. International Journal of Life Science and Pharma Research 2: 203-219.

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