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How to turn collectors of edible insects into mini-livestock farmers: Multidimensional sustainability challenges to a thriving industry

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ABSTRACT

Edible insects reared under suitable climatic conditions are an efficient and ecological food source. However, most of the insects come from wild collection and not from farms (FAO, 2013). To establish insects as part of a sustainable food environment, collectors, farmers or small entrepreneurs need to be transformed into mini-livestock farmers, but people who eat or collect insects do not necessarily want to rear them. This paper presents four case studies from Kenya, Madagascar, Myanmar and Thailand, which are in different stages of sector development to show pathways for establishing insect rearing, and the associated economic, resource/ecological and social challenges and opportunities that emerged. The aim is to inform the global debate towards establishment of a sustainable mini-livestock sector.

1. Introduction

Edible insects are currently celebrated as a sustainable solution to food insecurity and environmental pollution when compared to the meat industry across the globe (FAO, 2013; van Huis, Tomberlin, 2017; Gahukar, 2016). Going beyond their food security potential, Dangles/Casas (2019) identified how (edible) insects can contribute to the 17 different sustainable development goals of which a very important one is zero hunger. Insects can also contribute to gender equality and land conservation. The current regulatory reforms in the European Union are also paving the way for integrating insect-based foods into European diets (EU Regulation on novel foods, 2015). Even though research is still in its infancy, there is a large potential that certain edible insect species reared under suitable climatic conditions can be a very efficient protein and food source with low needs of land, water and feed and producing low CO_2 and ammonia emissions (Halloran et al., 2018). However, at present the majority of the edible insects in the global south come from wild collection (FAO, 2013) and only five to ten species out of around 2100 are commonly used for farming (Jonema, 2017). Especially if promoted further, wild harvesting is likely to result in overcollection, decrease in insect populations, and environmental degradation (van Huis, Oonincx, 2017).

Therefore, to push the sector towards producing a sustainable food source and to make it part of sustainable food systems, collectors, farmers or small entrepreneurs need to be transformed into mini-livestock farmers. Doing so is more challenging than it seems at first sight. Cultural and social perceptions are as much in the way as economic constraints and resoure/ecological limitations.

This paper presents four case studies from Kenya, Madagascar, Myanmar and Thailand where the insect sector is in different stages of development. The studies are based on experiences from different insect projects and supported by expert interviews from the edible insect sector in Africa, Asia, Europe and US and secondary literature. They also include interviews with farmers who have gone through the process of becoming mini-livestock farmers or are just about to start a new business.

The aim of this paper is to inform the global debate on the role of insects in food security by highlighting a route towards a sustainable mini-livestock farming system that adequately addresses the resource/ecological, economic and social dimensions across different levels.

The main research questions presented in this paper are:

1. Which local preconditions exist in the specific countries and how do they determine the insect sectors?

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2. How did the insect sectors evolve in the specific cases and which kind of support is given to farmers by whom?
3. Which ecological, economic and social obstacles to establish sustainable insect rearing systems can be identified?

2. Study site and methods

The paper sources from four case studies by experienced insect experts in the specific countries with several years of experience in the insect sector and project experience in setting up rearing systems. They all received the same questionnaire with a set of questions on species, rearing infrastructure, policy environment, etc. The four case studies were backed up by primary data, by 15 semi-structured interviews with key experts from the insect sector in the global north and south, different from the case study authors, including universities (2 Wageningen, Copenhagen, Khon Kaen, Kasetsart, Chiang Mai and Georgia), organizations associated with insects [International Centre of Insect Physiology and Ecology (*icipe*) in Kenya, Asian Food and Feed Association (AFFIA) in Thailand, New Generation Nutrition (NGN) in the Netherlands, International Platform of Insects for Food and Feed (IPIFF) Brussels, Belgium, Bioversity International, Madagascar] and the business sector (two start-ups in Uganda and Thailand, and one insect company in Germany). In addition, 12 focus group discussions (8 Madagascar, 6 Myanmar and 3 Thailand) and 28 in-depth interviews with different participants than in the focus group discussions (FGDs) (4 Madagascar, 6 Myanmar, 4 Thailand and 14 Kenya – in the latter case used from a doctoral research project) were conducted with farmers who were in different stages of insect rearing development. With the exception of Kenya, the FGDs and interviews were all conducted as part of an ex-ante analysis for a project that aims to set-up functioning insect rearing and processing systems in the global South. On Kenya data was used from a doctoral project that investigated potential of insect production and consumption across the country. The FGDs were usually held with 5–10 participants in mixed groups, predominantly women – who did not receive a monetary incentive for participation. The farmers were involved with or had dropped insect production, had recently received an insect rearing training, or expressed interest in setting up an insect farm. Interviewees in Thailand came from the surroundings of Khon Kaen, Bangkok and Chiang Mai, where insect production is prominent. In Myanmar they came from the eastern Shan state, Kayin and Kayah state all which border Thailand and have major insect consumption and first attempts of cricket rearing. In Madagascar, research was conducted around Ambositra, where first insect rearing trainings took place in 2019, and in Antananarivo, where the first cricket farm was set up. In Kenya the research took place in Western Kenya and the coastal region, where insect consumption and some production is most prominent. Market visits played an important role in understanding the economic potential. The farmers' villages were located near larger towns or cities, and all had access to paved roads and local markets. Qualitative interviews were screened using a structuring content analysis with encoding rules following Mayring (2000). Limitations of the study included the language barrier that required translation, which always means a loss of information, the limited time that also limited the number of discussions and interviews that enabled the researchers to only get a snap-shot of the local situation and in the case of Kenya data was used that was gathered for a different research project, so that the researchers did not have the chance to visit the location themselves and get first-hand experience of the sector.

3. Research results

3.1. Case study Kenya

Edible insect rearing in Kenya was initiated by foreign funding. The fact that Kenya hosts the most important international insect science research center, i.e., *icipe*, produces an encouraging environment for the edible insect sector. *icipe* initiated the work on edible insect rearing in 2012 and hosted two big international projects and several small ones in recent years in Kenya and neighboring countries. At the center itself, research is on the rearing of 20 different edible species, including several cricket (especially the newly described species, *Scapsipedus icipe*), grasshopper, locust, African fruit beetle, darkling beetle (mealworm), silkworm, saturniid caterpillar, African palm weevil, black soldier flies and tephritid fruit fly species that are available for promotion and upscaling trials. The colony of the giant cricket species *Brachytrupes membranaceus*, which is widely preferred and consumed by the population of Western and Coastal Kenya collapsed due to high level of cannibalism. Also, production of *B. membranaceus* is not cost-effective because of their extreme long lifespan (+9 months). The first project funded by Denmark (GREEiNSECT) had an academic focus and covered insect production and processing (crickets), and environmental and livelihood assessments (Orinda et al., 2017). It was followed by the Dutch project Flying Food, which had a strong business component and included all stakeholders along the value chain (traders, vendors, processors, microfinance institutions, policy stakeholders) and tried to set up a contract farming business model for insects in Kenya and Uganda with around 1000 farmers who participated (Pambo et al., 2018), EntoNUTRI funded by Federal Ministry for Economic Cooperation and Development (BMZ), InsBiz funded by Bioinnovate Africa Programme and others who followed their role model. Initially marketability of crickets was challenging because the acceptance of crickets was not as high as expected. The coordinator of Flying Food, described the marketability as smooth in their project with an orientation towards export and contract-farming, but there was a major drawback because of the emergence of bacteria (resembling the genus *Rickettsiella* sp.) that led to a collapse of large parts of the newly reared cricket populations. This is now being investigated by G.M. Vergara under the umbrella of *icipe* and Wageningen University. It was estimated that only 20 percent of the farmers continued cricket rearing after the disease outbreak (McNeish, 2018). Another cultural constraint in setting up rearing of insects such as saturniid caterpillars for food (one doctoral research project) was superstition. If individuals were trained in this unknown technology and started insect production without approval from the community they were suspected of witchcraft. It was important to target the community as a whole and engage leaders in setting up insect rearing communities.

In addition to the species investigated at the *icipe* laboratories in Kenya, other reared species by farmers are, for example, long-horned grasshoppers (*Ruspolia differens*) and desert locusts (*Schistocerca gregaria*) for food, and black soldier flies (*Hermetia illucens)* for animal feed. Even though the sector in Kenya is quite dynamic, legislation is lagging behind. Most activities in the sector are pushed forward by research institutions such as *icipe*, Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Egerton University and Jomo Kenyatta University of Agriculture and Technology (JKUAT). In 2016, research institutions, the business sector and the government of Kenya initiated an International Conference on Legislation and Policy on the Use of Insect as Food and Feed in East Africa in Kisumu, Kenya, with the aim of enlightening regulatory authorities regarding the importance of insects for food and feed and the need to have policies governing these sectors. The government of Kenya and Uganda have recognized insects as indigenous food and a draft policy document is currently being reviewed. However, policies governing the use of dried insect products compounded in animal feeds such as the black soldier fly has already been legally approved by Kenya Bureau of Standards (2016) (KEBS) and, Uganda National Bureau of Standards (2017) (UNBS). Thus, opening new markets and opportunities for commercialization of insect-based feed products.

3.2. Case study Thailand

With its 500 years of documented insect consumption, today

Fig. 1. Cricket farmer in Thailand.

Thailand has the largest cricket rearing sector in the world and is an important knowledge center of insect rearing and processing for import and export (Yhoung-Aree, Viwatpanich, 2005; Hanboonsong et al., 2013). Even though government support was strong, the interviewed farmers mostly learned cricket rearing through internet sources (youtube) or from other insect farmers (e.g. Fig. 1). It is estimated that around 27,000 farmers rear crickets (Kongsomboon, 2019), mostly the two spotted cricket (*Gryllus bimaculatus*), followed by house cricket (*Acheta domesticus*) and ground cricket (*Gryllus confirmata*). Currently, cricket producers are 80 percent women, and 75 percent rear on a small scale (Phankaew, 2019). Other popular species are the red palm weevil (*Rhynchophorus ferrugineus*), which is produced by 1000 farmers and, as a side product of silk production, the mulberry silkworm (10,000 farmers), which has already been produced and consumed since 1901 (The Queen Sirikit Department of Sericulture, 1994). Recently a very strong interest for the silkworm pupae has emerged in the food industry. The interviewees explained that packed snacks of sesame silkworm pupae are available all over the country in 7-Eleven shops, and other insect snacks or pasta made of insect flour can be found in supermarkets or online. Furthermore, the mealworm and black soldier fly for feed have recently gained ground, and around 100 farmers each produce them. Compared to other species, which have been reared or semi-domesticated for several decades, crickets are a new phenomenon, and have been strongly promoted by Khon Kaen University supported by the Thai Government and FAO since 1997. Further support was by Kasetsart and Chiang Mai University (Sirimungkararat et al., 2010; Hanboonsong et al., 2013; Tonchow, 2017).

Whereas mealworm and black soldier fly production is controlled by the private sector, crickets and red palm weevil are strongly promoted by the government extension sector, which has specific training units for crickets in the north and east of the country (agricultural technology promotion center in Chiang Mai and Khon Kaen) and for the palm weevil in the south (Chumporn province) (Hanboonsong et al., 2013; Whittle, 2016, Tonchow A. 2017). The expert from Khon Kaen university explained that initially, market development was at the center of the establishment of commercial cricket rearing. Not only were funds given to interested farmers by the government bank and trainings on rearing techniques conducted along with exposure visits, consumers were also trained in developing the "right" taste through education and tasting programs. At that time they collected crickets from the wild and favored the giant cricket (*Brachitrupes portentosus*), which is also the most popular edible insect in Myanmar but not suitable for rearing due to a long life cycle of nine months and because it can only survive in a soil environment as trials in Thailand have shown (Hanboonsong, Rattanapan, 2001).

Now the small cricket species dominate the market and demand. The expert from Khon Kaen University describes the strong focus on crickets in number of insect farmers as a "cricket bubble", which is also true for the global edible insect sector. The reason is that farming is easy to learn, and feed demands are not too complicated. Although initial investment is low, marketing can be difficult and sustainability is at stake because most crickets are fed on fishmeal. Farmers around Khon Kaen reported that they currently could produce more than the market could absorb. Thailand has an active and innovative business landscape, and government bodies support the sector. Not only are GAP-certified (Good Agricultural Practices) insect and model farms now available (Preteseille et al., 2018). The National Bureau of Agricultural Commodity and Food Standards and the Department of Livestock Development along with private companies have also submitted dossiers to the European Union (EU), e.g., for the house cricket under the novel food regulation in order to export insects to the UN (National Bureau of Agricultural Commodity and Food Standards, 2019).

3.3. Case study Madagascar

In Madagascar, insect consumption is popular in many parts of the country, especially in rural areas. One professor at the University of Antananarivo explained that in urban areas, people over 40 years old mostly consumed insects in their childhood, while the young urbanites are rather disgusted by the idea. The FGDs showed that insect consumption is seasonal, and rearing is an unknown concept among common farmers with the exception of the wild silkworm (*Borocera cajani*) and the domesticated silkworm (*Bombyx mori*), of which the pupae is eaten, and bee keeping. In 2015, a young entrepreneur founded the company called Mad'Insect in Antsirabe, which was the first attempt to rear locusts for the local and French market, and to produce dehydrated locusts whole and as flour for biscuits, bread and the snack "caca pigeons". Other than that there are only few, mostly foreign initiated, projects. The California Academy of Science and the NGO Madagascar Biodiversity Center under the technical backstopping of *icipe*, successfully established a mass cricket rearing facility in 2017 (*Teleogryllus* spp. and the local two-spotted cricket species *Gryllus madagascariensis*) and one private company called Madagascar Century Food recently started rearing black soldier flies. One employee of Valala farms in Antananarivo explained that crickets are produced on their farm, of around 85 kg per week. They are processed into cricket powder that is used in government midday meals. The farm has received a first certification by food safety authorities. In Madagascar, edible insects are included in the National Nutrition Plan (ONN, 2017) by the Office National de Nutrition, but implementation strategies are still to be developed. One informant from the agricultural ministry highlighted the interest of the government in insects as feed because of the countrywide protein deficiency and scarcity of animal feed. The FGDs revealed that farmers in Sandrandahy village collect locusts during the season, dry them and feed them to pigs. They described a surprising

Fig. 2. Cricket-rearing training in Madagascar.

positive growth effect because of the extra protein. So far the insect sector is pushed more by researchers than by government and business, e.g., the interdisciplinary IPSIO network or NGOs such as Concept Mihary, who promote insect collection for livelihoods and use of insect flour, or the NGO Fanamby who trains communities in cricket rearing. The expert interviews and FGDs showed that the main obstacle to insect rearing is the lack of a concept showing that rearing is possible (e.g. through trainings as in Fig. 2), and appropriate skills along with a lack of resources to start such a business. Many farmers live from hand to mouth and have nothing to invest. Consumption of insects from wild collection is highest in the central highlands, unfortunately, there temperatures are less suitable for insect rearing.

3.4. Case study Myanmar

The edible insects industry is still in its infancy in Myanmar. There is a vast difference between the scale of insects collected in the wild and reared insects, with 20–30 species commonly collected in the wild and only about 6 species reared. The latter are black or two-spotted crickets, white crickets, cockroaches and black soldier flies, plus silkworms and bees. However, other species like sago worms are harvested and then cultivated for live export. The researchers could identify between 20 and 30 farmers presently engaged in insect rearing in the whole country. The current public preference is for wild giant crickets, particularly female crickets with eggs, because of their taste and size. The formerly large silk industry declined over a 40-year period because it could not compete technologically with the surrounding countries and might be revitalized in both Kayin and Chin States. Currently, only small amounts (50 kg) of silkworm pupae per month remain in Myanmar and are consumed by silk laborers and farm animals. Sericulture in Myanmar is mostly organized in form of contract farming, so that cocoons produced by individual farmers are exported to China for reeling, processing and consumption. Currently, there is no official government or development business involvement. Apart from pest aspects, beneficial pollination aspects, and silk and honey by-product industries, there is negligible policy in the edible insects area. Recently though, the largest insect farm in Kayin State was visited by the state Minister of Agriculture, who was very enthusiastic about pushing this activity forward. In-depth interviews showed that edible insect rearing in Myanmar has primarily been self-initiated in the last few years by people who have seen the large numbers of cricket-raising farmers in Thailand and have returned to Myanmar with eggs and an interest to do likewise. They realize that insect farming can become a business opportunity with low setup costs that can suit family members working from home. FGDs proved that consumption of insects collected in the wild is widespread. However, it has an ethnic dimension, the Barmar (ethnic group of central Myanmar) hardly eat insects and, if they do, favor only the giant crickets. The majority of insect farmers are male, living in rural and peri-urban villages, men usually having more financial resources than women. Few farmers have learnt about insect farming from development projects, e.g., German Development Agency (GIZ) in Shan State and Welthungerhilfe (WHH) who organized a visit to Thailand that sparked interest. The biggest obstacles for farmers seem to be lack of knowledge of the possibility of insect farming, lack of techniques, lack of capital availability, and the market perception that farmed crickets are inferior to crickets collected in the wild. Interviews with traders showed that current wild-collection value chains are large and very well organized. Operating alongside them is a significant online trading system. With more input on GAP for high quality food safety attention, the online market can be very satisfactory. The FGDs also revealed another constraint, the Buddhist religion, where people do not want to get involved in mass killing of insects believing that it could hurt their karma.

4. Discussion

The case studies and information retrieved from interviews, discussions and literature highlight not only the different preconditions that exist in the four countries but also the diverse states where the insect sectors stand.

Table 1 displays the challenges identified in the case studies and summarizes the most important aspects presented in the following discussion part structured according to the different dimensions.

4.1. Economic dimension

87 percent of the experts highlighted that the economic dimension is the most crucial one for setting up rearing systems sustainably so that they are viable beyond project periods, especially for known species for which technologies already exist. 53% of the experts explained that without a market, it makes no sense to produce any insects. The case study shows a so far successful example, Thailand, where the market

was created by the government through training of producers, processors and consumers. With currently over 25.000 cricket farmers, the market however, now seems to have reached saturation. In Kenya, the Flying Food project was more successful than the other projects in marketing the insect-based food products because the whole value chain was considered from the earliest design stage of the project, i.e., inclusion of small-scale processors, extension sector, microfinance institutions, etc. In Myanmar, it will be easiest to continue promoting insect rearing in the locations with close contact to Thailand's dynamic and successful sector because there people are accustomed to eating reared insects and e.g. the small cricket species. The three experts from Thai universities pointed out that it is an important lesson from Thailand that a taste for insects that are most suitable for rearing can be created through training, exposure, and tastings. This might also be relevant to convince consumers in Central Myanmar to try insects other than the giant crickets. In Madagascar, rearing infrastructure and concept need to be established from scratch. However, the expert from NGN explained on a field trip in Madagascar in 2019 the potential that she saw in high numbers of insect consumers and great need for affordable protein-rich and resource efficient foods, which makes it a promising destination for do-it-yourself insect kits, which could be used to rear insects on a small-scale in rural areas or in urban areas, for example in backyards, on balconies or rooftops.

The co-founder of one of the start-ups, producing black soldier flies in Uganda, explained that the most crucial aspect is having a functioning business model as a base for a project. Merely training farmers, handing out materials and hoping to get the ball rolling is prone to failure. The coordinator of the Flying Food project reported good experience in Kenya, where agreements were made with the farmers on participation and reporting before handing out materials. The most important aspect for success is finding pioneers who have a genuine interest and are able to and want to invest some own money. 20 percent of the experts also highlighted that at the same time, setting up role models for showing other farmers how the technology works is important. 53 percent pointed to the lack of investment as the biggest economic constraint in the sector, e.g., setting up any agricultural innovation in a resource-poor context such as Madagascar is proving difficulties, and might be one reason why the sector is still in a very early stage there. Farmers in Kenya had the problem that materials (crates, pinheads, etc.) were imported from Europe, and they had difficulty in continuing with local materials.

4.2. Resource/Ecological dimension

Sixty-seven (67) percent of the experts highlighted the importance of the resource/ecological dimension that sets all the preconditions and is very fragile. There are large research gaps regarding the environmental impact of insect production (Berggren et al., 2019). For initial production, the three most important aspects are where to source eggs and insects from, how to organize production and reproduction, and what sustainable feed sources are available. In Myanmar and Madagascar, it is quite a challenge to legally import eggs, larvae or adult insects. In the latter case, trials at university are done with local species of locusts (*Cyrtacanthacris tatarica*), crickets (*G. madagascariensis* and *Teleogryllus* spp.) and black soldier fly (*Hermetia illucens* – Diptera: Stratiomyidae), whereas in Myanmar insect material is brought by individual farmers from Thailand without official permission. Disease problems (viral, fungi) are already known in Thailand, but the first bacterial infection of insects, described in the case of Kenya, shows that future research will have to consider careful management that might include hygiene in design and handling of insect boxes and equipment, preparing and sterilizing feeds, using clean water and good quality eggs. Large farms can more easily handle upcoming diseases than small farms (Eilenberg et al., 2015). One of the experts suggested that farms and projects should spread risks by working with different species within one family (e.g., Gryllidae), while at the same time, genetically

Table 1
Multidimensional sustainability challenges in the four case study sites.

	Kenya	Madagascar	Myanmar	Thailand
Economic	A market was to be newly established and business models developed	Extreme resource-poverty, Farmers refrain from taking loans	Huge potential for import/export with neighbors Thailand and China, but also competitive market	Cricket market saturated?
Ecological	Disease outbreak	Currently import of species difficult, research needed for local species, scarcity of feed	Legal import of species complicated, strong need for research on local species and feeds.	Intensified research for optimal production and sustainable feed sources needed.
Socio-cultural	Need for community approaches	No concept of rearing	Religious and regional reluctance for consumption and rearing.	Considerable number of Thai people do not eat insects.
Government support	Supportive.	Good, but implementation is lacking.	Limited, still unaware of potential for nutrition and livelihoods.	Very strong policy, training and funding support.

healthy populations need to be maintained and inbreeding be prevented by allowing natural selection and artificial selection and exchange of material for breeding (Jensen et al., 2017), which is not systematically practiced in the four countries. Labor division can also prevent diseases. Insect production is no rocket science but the reproduction part is most challenging. One idea is to give less responsibility to small farmers. According to the coordination of Flying Food, reproduction units can be set up by wealthier farmers, where eggs are produced and sold to the insect producers. The coordinator of AFFIA, explained that outsourcing the reproduction part is already successfully practiced by the private cricket sector in Thailand. Only development and research projects lag behind. Constant supplies of feed are the major bottleneck in sustainable insect production. Therefore, one member of IPIFF, who is running the largest German insect-producing company for beneficial insects and feed insects, predicts a stronger trend towards plant-eating insects in the sector. Insects need protein as feed, which could be consumed as it is (e.g., soya bean). Ideally feeds are obtained from residual streams. The most common feed for crickets and other reared insects while not very sustainable in the four countries is fishmeal, usually meant for chicken (Oonincx, 2017). If organic waste is not an option, there is a strong need for research on the availability of locally sustainable feeds. Other research will be required on local species suitable for rearing, ideal conditions for production, techniques of disease management, and traceability of insects.

4.3. Socio-cultural dimension

Fifty-three (53) percent of the experts mentioned the social/cultural dimension, which is context specific, as essential for overall adoption, acceptability and system sustainability. It is self-evident that in a country or community without a tradition of insect eating or where insects are considered unclean or backward foods, starting insect rearing and convincing people to eat or rear insects is more challenging than in an environment where a majority of people likes insects. But just because people consume insects they might not be familiar with the idea of rearing. The first and most important act is to create perception and to spread the idea that rearing is possible, necessary and attractive. In Myanmar, insect consumption has a regional and ethnic dimension but is also common across different social strata, so a large number of both poor and wealthier farmers collect insects to enrich their diets at home. At the same time, relatively expensive insects on the market find affluent customers. Insects are an attractive livelihood source especially for women in Kenya, Madagascar and Thailand because the associated activities are not physically difficult or time intensive, and can easily be practiced close to the house as rearing requires little space. However, it would be oversimplified to say that insects are a typical female livestock source (see case Myanmar). Religion and ethnicity can also be a constraint to insect rearing. In the example of Myanmar, Buddhist ways of thinking may possibly cause concerns about the mass killing of insects, which needs to be considered for up-scaling current activities. A focus could be put on targeting other religious/ethnic groups while awareness raising and informing on the overall potential of insect rearing and animal welfare (techniques that are considered less painful e.g. killing insects by cooling them down and freezing them), might reduce moral concerns regarding their killing (Gjerris et al., 2016). In Kenya, the existing superstition requires an inclusive project design, so that whole communities are trained or community approval is searched for. The last aspect to be mentioned here is strong institutional support. A conducive policy environment can help to push the insect sector and integrate rearing systems into sustainable food systems and food environments. As reported by one expert from the University of Wageningen, one of the most crucial factors was policy support and openness that enabled exceptions from regulations for innovations in an early stage of the development of the insect sector in the Netherlands. It enabled first research trials on isolating insect proteins with funds of Euro 1 million. The example of Thailand also shows how policy can manage the successful establishment of a globally recognized cricket sector. In Madagascar, edible insects have made it into the national nutrition plan, and now an implementation strategy needs to follow. It might also help to ask additional support from, for example, the FAO. In Myanmar, the first step of sensitization of the policy level is still to be done to create a fertile ground for the sector in Myanmar.

5. Conclusions

The edible insect sector (including insects for feed) is not only dynamic in Western countries but also in the global south where new internal and external opportunities are emerging. However, it is argued that establishing insect production systems not only requires much more research on suitable local species, feeds and optimal production and processing conditions but also needs to include sound business models for initial investments and long-term viability and to consider the socio-cultural circumstances to enable adoption. It also shows that a conducive policy environment enables interested insect farmers to start a business, expand and stay in business. Potential insect farmers and entrepreneurs need access to knowledge and access to capital to start insect production, to insect material for the first generation and to feed – ideally for an insect species that is locally known and already consumed. This has been proven successful to target people who already consume insects frequently, also people who have knowledge on insects (e.g., beekeepers), and women because insects are an attractive livelihood source for them. All dimensions need to be considered in their own right for setting up sustainable mini-livestock systems in the future. During research, these aspects should find their way into extension materials, policy documents and university curricula of livestock and food processing departments.

Declaration of competing interest

The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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References

Berggren, A., Jansson, A., Low, M., 2019. Approaching ecological sustainability in the emerging insects-as-food industry. Trends Ecol. Evol. 34 (2), 132–138.

Dangles, O., Casas, J., 2019. Ecosystems services provided by insects for achieving sustainable development goals. Ecosyst. Serv. 35, 109–115.

Eilenberg, J., Vlak, J.M., Nielsen-LeRoux, C., Cappellozza, S., Jensen, A.B., 2015. Diseases in insecs produced for food and feed. J. Insects Food Feed 1, 87–102.

European Union, 2015. EU Regulation on novel foods. Internet Source. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2283&from=EN accessed 31.08.19.

Fao, 2013. Edible Insects – Future Prospects for Food and Feed Security. Forestry Paper 171. Rome.

Gahukar, R.T., 2016. Edible insects farming: efficiency and impact on family livelihood, food security, and environment compared with livestock and crops. In: Dossey, A.T., Morales-Ramos, J.A.M., Rojas, M.G. (Eds.), Insects as Sustainable Food Ingredients – Production, Processing and Food Applications. Elsevier, London, pp. 85–111.

Gjerris, M., Gamborg, C., Röcklinsberg, H., 2016. Ethical aspects of insect production for food and feed. J. Insects Food Feed 2 (2), 101–110.

Halloran, A., Hansen, H.H., Jensen, L.S., Bruun, S., 2018. Comparing environmental impacts from insects for feed and food as an alternative to animal production. In: Halloran, A., Flore, R., Vantomme, P., Roos, N. (Eds.), Edible Insects in Sustainable

Food Systems. Chamm Switzerland. Springer International Publishing, pp. 163–180.
Hanboonsong, Y., Jamyanya, T., Durst, P.B., 2013. Six-legged Livestock: Edible Insect Farming, Collection and Marketing in Thailand. FAO. Internet Source. http://www.fao.org/3/a-i3246e.pdf accessed 13.8.2019.
Hanboonsong, Y., Rattanapan, A., 2001. Life history of short-tail cricket brachytrupes portentosus lichtenstein; Gryllidae: orthoptera. FAO. Original article in Thai language. Internet source: http://agris.fao.org/agris-search/search.do?recordID=TH2001003484 accessed 1.8.2019.
Jensen, K., Kriestensen, T.N., Heckmann, L.-H.L., Sörensen, J.G., 2017. Breeding and maintaining high-quality insects. In: van Huis, A., Tomberlin, J. (Eds.), Insects as Food and Feed – from Production to Consumption. Wageningen Academic Publishers, pp. 175–197.
Jongema, Y., 2017. List of edible insects of the world (April1, 2017) – WUR. Available at.
Kebs, 2016. Dried Insect Products for Compounding Animal Feeds. Kenya Bureau of Standards, Nairobi.
Kongsomboon, N., 2019. Cricket Farmers Information (Database). Director of the Economic Insect Promotion Group. Department of Agricultural Extension, Ministry of Agriculture and Cooperatives, Thailand.
Mayring, 2000. Qualitative Inhaltsanalyse. Grundlagen und Techniken. Deutscher Studien Verlag, Weinheim, Germany.
McNeish, H., 2018. Cricket-farming Hops Ahead as Kenyans Catch Superfood Bug. Thomson Reuters Foundation Internet Source. https://af.reuters.com/article/kenyaNews/idAFL5N1VS24F accessed 15.08.2019.
National Bureau of Agricultural Commodity and Food Standards, 2019. Scientific Dossier Progress. Insect as Food and Feed Workshop. 30-31 May, 2019. Kasetsart University, Bangkok, Thailand.
Onn, 2017. Plan National d'Action pour la Nutrition 2017-2021. (Antananarivo, Madagascar).
Oonincx, D.G.A.B., 2017. Environmental impact of insect production. In: van Huis, A., Tomberlin, J. (Eds.), Insects as Food and Feed – from Production to Consumption. Wageningen Academic Publishers, pp. 78–93.
Orinda, M., Magara, H., Ayieko, M., Nyakeri, E., Munke-Svendsen, C., Halloran, A., Roos, N., 2017. Insect production systems for food and feed in Kenya. Technical Brief 2. Internet Source. https://greeinsect.ku.dk/news/greeinsect-technical-brief-2-farming/GREEiNSECT_Technical_Brief_2_Farming_Systems.pdf accessed 19.8.2019.
Pambo, K.O., Okello, J.J., Mbeche, R.M., Kinyuru, J.N., 2018. Means-end chain approach explains motivations to consume insect-based food: te case of cricket-scones in Kenya. In: Halloran, A., Flore, R., Vantomme, P., Roos, N. (Eds.), Edible Insects in Sustainable Food Systems. Chamm Switzerland. Springer International Publishing, pp. 401–417.
Phankaew, C., 2019. Standard development of edible cricket production to Good Agriculture Practice of cricket farming for export. In: The 2nd of Progress Project Report, Department of Entomology, Faculty of Agriculture. Kasetsart University, Thailand.
Preteseille, N., Deguerry, A., Reverberi, M., Weigel, T., 2018. Insects in Thailand: national leadership and regional development, from standards to regulations through association. In: Halloran, A., Flore, R., Vantomme, P., Roos, N. (Eds.), Edible Insects in Sustainable Food Systems. Chamm Switzerland. Springer International Publishing, pp. 435–442.
Sirimungkararat, S., Saksirisat, W., Nopparat, T., Natongkham, A., 2010. Edible forest insects humans bite back. Edible product from eri and mulberry silkworm in Thailand. Food and Agriculture Organization of The United Nations, pp. 241pp.
The Queen Sirikit Department of Sericulture, 1994. History of Sericulture. The Queen Sirikit Department of Sericulture, Ministry of Agriculture and Cooperatives, Thailand.
Tonchow, A., 2017. Black Soldier Fly Production Manual. Natural Agriculture Research and Development Center, Maejo University, Thailand.
Van Huis, A., Oonincx, D.G.A.B., 2017. The environmental sustainability for insects as food and feed. A review. 37. Agronomy for Sustainable Development, pp. 43.
Van Huis, A., Tomberlin, J., 2017. The potential of insects as food and feed. In: van Huis, A., Tomberlin, J. (Eds.), Insects as Food and Feed – from Production to Consumption. Wageningen Academic Publishers, pp. 25–58.
Whittle, J., 2016. Investigating Red Palm Weevil Farming Practices in Thailand. Project Report, New Colombo Plan Thailand Fellow BNSc, Sustainable Agriculture and Food Security. Western Sydney University, Australia, pp. 61. www.wur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences/Laboratory-of-Entomology/Edible-insects/Worldwide-species-list.htm accessed 01.08.2019.
Yhoung-Aree, J., Viwatpanich, K., 2005. Edible insects in the Laos PDR, Myanmar, Thailand, and Vietnam. In: Paoletti, M.G. (Ed.), Ecological Implications of Minilivestock. Science Publishers, New Hampshire, pp. 415–440.