Insects as Feed in West Africa
Final report
March 2022

1. Objectives

The main research hypothesis of the project was that fly larvae and termites are an economically, socially and environmentally viable source of protein for poultry and fish feed on smallholder farms in West Africa. The general objectives of the project were:

- To develop appropriate methods for fly larvae and termites' production and utilisation in smallholder farming systems in West Africa, based on waste material;
- To understand and ensure the social, economic and environmental sustainability of the proposed innovations;
- To validate and implement the innovations with the beneficiaries, and disseminate the project's findings to the stakeholders, general public, scientific community and policy makers.

The project was divided into seven research and development work packages (WP) that all have a specific objective (see section 3 below for details on these objectives). In general, the work has been carried out as planned and the general and specific objectives have not been modified.

2. Methods and approaches

The project was unique in the sense that, in contrast to the many other projects developing the use of fly larvae production for animal feed worldwide, this project had built simple systems for smallholder farmers and rural micro-enterprises. Furthermore, it also focused on termites, a source of protein for animal feed that is used by over 70% of the smallholder farmers in some West African regions but has very rarely been the target of research projects.

The seven Research and Development WPs encompassed various disciplines and involve various methodologies, which are described in section 3 (Results) below. The approach of the project was to consider different production systems (natural exposure of substrates, culture of adult flies, termite trapping) for different insect species (house fly (HF), black soldier fly (BSF), termites) and different users (mostly farmers of all sizes and micro-enterprises) in West Africa. All combinations were investigated but it appeared during the course of the project that some are more favourable than others and it is these ones that have been and continue to be disseminated in priority:

- Smallholder poultry & fish farmers: trapping termites and produce house fly larvae through the exposure of substrates on farm;
- Larger farmers: mainly BSF culture, in some cases exposure of substrates for house flies and termite trapping;
- Micro-enterprises producing feed and bio-fertilizers: mostly BSF culture.

3. Results

In this section we present the work carried out in the Research and Development WPs (WP1-7). WP8, covering dissemination and implementation, is presented in section 4. Since research activities were very diverse and carried out by over 40 PhD and MSc students, and considering the strict recommendations on report's length and content, this final report can only present a broad overview of the project. When data are available in one of the 80+ scientific papers, technical guidelines and other publications, we will simply refer to the number assigned to this publication in the Annex document. Almost all these documents, except theses, are available open access (see links to the publications on the project website www.insectsasfeed.org). At least 20 publications are still in progress and all data can be obtained upon request from the project's PI.

3.1. WP1. Improving fly larvae production for smallholder systems

The objective of WP1 was to develop efficient HF and BSF larvae production systems suitable for use by smallholder farmers, rural communities and micro-entrepreneurs, adapted to the various climatic zones and farming systems covered by the project. All the tasks planned in the project proposal have been fulfilled. This WP included a very high number of studies as part of PhD and MSc theses and only a brief summary of the main results can be presented here. However, in this WP, many publications and technical notes are already available and can be consulted for more details. The three main activities were as follows:

(a) Assessment of indigenous knowledge and use of fly larvae production in West Africa. The project started with surveys in the three countries to identify the present usage and knowledge of fly larvae as animal feed for feeding poultry and fish and the perception of the utilisation of fly larvae as animal feed (see also WP7). To our surprise, in the three countries, between 5 and 9% of the farmers have already produced HF larvae to feed their poultry, at least occasionally, by exposing various substrates [24, 32, 34, 44, 45]. Information on the production systems used by farmers was collected and integrated in the experiments on the development of production systems.

(b) *Identification of the best substrates to produce HF and BSF larvae.* A key factor for producing fly larvae is the quality and suitability of rearing substrates. Several studies were conducted to test the best substrates for HF larvae production through the exposure of substrates to naturally occurring flies (natural oviposition method) [19, 20, 25, 35, 43, 46 and many unpublished data in theses]. Over 150 substrates and mixtures of substrates were tested by IFWA partners for their suitability to produce house fly larvae through natural oviposition. Also the addition of attractant (e.g. blood, fish offal, etc.) was tested, as well as the importance of the container shape and material. At the same time, data were collected on the local availability and costs of the substrates. The most efficient, available and affordable substrates are cereal and legume bran, maize bran, poultry and pig manure, rumen content and blood. Some easily available substrates do not work alone but are efficient when mixed with a small quantity of another substrate or when an attractant is added, e.g. cow dung with maize bran and sheep manure with blood or fish offal. A study [20] has shown that the chemical and nutritional quality of larvae varies with the rearing substrate. However, the main output of the substrate evaluation for HF larvae production in smallholder systems is that many substrates, of both vegetal and animal origin, are potentially suitable, but their cost and availability are highly variable among regions and even villages within the same region. Thus, farmers should focus on substrates that are most available and free, or cheap, rather than on those that are most performant. A paper is in preparation that will list all substrates tested in IFWA and their respective performances. Tests on suitable substrates for BSF larvae have also been conducted but at a later stage and are still unpublished in theses [D9, M24, M29]. Many substrates were suitable for BSF larval development, but the most efficient substrates were pig manure, brewery waste, millet porridge mash and cotton cake. Of particular interest is the study in Ghana (D9, paper submitted) that showed that the substrates most preferred for BSF oviposition are not necessarily the most suitable for their larval development.

(c) *Identification of production techniques including egg production, extraction, drying and storing methods.* Besides substrates, other aspects of the HF and BSF larvae production have been studied. A container system for producing BSF larvae through natural oviposition has been studied [D9]. The conditions for rearing adult flies and produce eggs in cages have been studied for HF [18, D4, D5] and BSF [M29], testing oviposition receptors 'designs, adult food, etc. Systems for extracting HF larvae from the substrates have been tested, designed and built [43, 58, 59], as well as systems for killing, drying and conserving larvae [43, 49, D5]. Variation in HF productions with season have also been studied [25, 46] as well as natural enemies of HF in production systems [D4]. Several technical guidelines and other dissemination materials have been made that describe methods to produce fly larvae [e.g., 53-55, 60-67, 72, 75, 76].

3.2. WP2. Improving knowledge on termites as animal feed and collection systems

The objective of WP2 was to gather knowledge on the use of termites as animal feed in West Africa and to test, improve and select methods for promotion. All the tasks planned in the project proposal have been fulfilled. The two main activities were as follows:

(a) *First large-scale surveys on the use of termites for poultry feed in Africa.* These surveys were made at the beginning of the project in the three countries. Data for Ghana are available in [8] and for Burkina Faso in [12 ,42]. Data for Benin are in an unpublished document. Termites are widely used by smallholder farmers to feed poultry. In Burkina Faso, the use of termites as poultry feed varied between 49 and 83% between regions. In Ghana, it varied between 47 and 94% and between 2 and 84% in Benin. This shows that farmers are very familiar with this type of feed and its benefit to poultry but there were large geographic variations observed in the collection techniques. While most farmers break and collect termite mounds (and have increasing difficulties in doing so), a significant part of them use more sustainable trapping techniques as those developed in the project. In the Volta region, (South-East Ghana), termites are collected exclusively by breaking mounds and farmers were trained to use sustainable collection techniques [65]. In addition, in Burkina Faso, a taxonomic study was conducted with identifications of all termites used as feed in different regions, including toxic ones, as part of a PhD [D10].

(b) *Determination of the best and most sustainable techniques to trap and utilise termites.* Research was conducted in Burkina Faso, Benin and Ghana to define the best methods to trap termites, as opposed to destroying termite mounds. Studies focused on finding the best attractants, containers, time of day, duration of exposures, season, and habitat. Results are partly available in [13, 14] and more data will be published from theses [D9, D10, M3]. The containers that were most productive were invariably clay pots. However, the other factors varied with termite species and season. For example, *Macrotermes* species are better attracted with cereal stems or maize cobs whereas *Odontotermes* species are best attracted by mixtures including cow dung. Yields varied with season and differently among species. The best time of the day for collecting termites also greatly varies with season. IFWA has produced technical guidelines for training farmers in termite trapping [60, 67, 70, 71]. Although the use of termites as poultry feed is mainly suitable for smallholder farmers, larger producers in Burkina Faso and Benin are using termite trapping at a larger scale [60].

3.3. WP3. Evaluation of fly rearing residues

By-products of the fly rearing systems need to be valorised to ensure that the whole system is profitable. The objective of WP3 was to assess the quality of fly rearing residues as soil amendments. The two key activities were as follows:

(1) *Quality of fly rearing residues as bio-fertilizers.* A PhD thesis [D3, 2-7] is the most complete study produced so far of the chemical and physical properties of fly rearing residues as bio-fertilizers. The study involved 11 animal manures, three vegetal substrates and their mixtures and highlighted the high quality of the compost produced through the transformation by HF larvae. However, his results showed significant differences among substrates from which residues originate. Residues from manure can directly be used as soil amendment and can contribute to soil fertility and crop yield improvement. In contrast, residues originating from agricultural and agro-industrial substrates, without further composting, do not substantially improve soil chemical parameters even though significant yield improvement was noticed. For vegetables production enhancement and sustainable soil fertility management, results suggested that pig manure, mixture of poultry and sheep manure, and poultry manure biodegraded by HF larvae are the most suitable ones. In Burkina Faso, a study assessed the potential of smallholder farmers to produce organic fertilizers with HF larvae wit manure. It showed that that small poultry farmers with 30 to 100 adult chickens, could produce the equivalence of 100 to 300 kg of fertilizer (NPK (15-15-15)) in semi-confinement condition [10].

(2) *Field testing of rearing residues as bio-fertilizers.* The qualities of fly rearing residues were also tested in real conditions in Burkina Faso and Benin. In Burkina Faso, field tests with maize fertilized with fly rearing residues showed higher yields than the original chicken manure and other fertilizers [11]. In Benin, field tests on amaranth showed that residues from fly larvae production provide excellent yields, which strongly varied with the original substrates. The highest yields were obtained with a mixture of chicken and sheep manure and with pig manure alone. These two substrates provided yields more than six times higher than the control.

Residues from substrates of plant origin (soybean bran and maize teguments) provided lower yields but still 2-3 times higher than the control [M13]. Also in Benin, the residue of HF larvae production on jatropha seed cakes has proven to be an excellent compost for jatropha nurseries [54]. Technical guidelines on the use of fly larvae production residues as biofertilizers has been produced in the two countries [56, 68, 69].

3.4. WP4. Nutritional quality and suitability of fly larvae and termites

The objective of WP4 was to assess the nutritional value and suitability of fly larvae and termites as poultry and fish feed. The three main activities were as follows:

(a) *Suitability of fly larvae as poultry feed.* Many studies have been carried out in Benin and Burkina Faso to assess the suitability of HF larvae as feed for poultry (local laying hens, local broilers, guinea fowls, quails and ducks). Similar tests with BSF have been conducted in Ghana. They all indicate, without any exception, and on all poultry species, that fly larvae, with their high protein and mineral (Ca, P) contents, are highly suitable as replacement for conventional proteinic feed or as supplement for scavenging poultry flocks that were previously not fed with proteins. This confirms results gathered in other projects on the benefit of fly larvae for the exotic breeds of layers and broilers. Investigations focused on the acceptability and preference of the animals as well as the zootechnical performances (reproduction, growth). These tests are too numerous to be mentioned all here. They have been partly published in scientific publications [16, 17, 47, 48, 49] and technical notes [53, 54, 55, 61, 63,7 4]. Many data are still unpublished in PhD theses (D1, D2, D6, D7] and MSc theses. Several publications are in preparation and will be submitted in 2022. Results of supplementing poultry feed with fly larvae is particularly spectacular with semi-scavenging local chicken because comparisons are made with poultry that are not given any, or only low quality proteinic feed, not with good quality fish meal. For example, in a medium-scale farm in Benin, the number of eggs per brood increased from 7.2 to 12.5 when the low quality fish meal used by the farmer was replaced by dried house fly larvae. The average daily weight gain was 25g/d as compared to 20g/d for the usual diet (unpublished data). In smallholder farmers in Southern Benin, the average number of eggs per brood was increased from 7.8 to 10.3 per laying cycle by adding larvae to the non-proteinic diet, and decreased the interval between two cycles by 7% [17]. Interestingly, the improvements in reproduction were nearly the same when fly larvae meal was compared with local, low-quality fish meal [D6].

(b) *Suitability of termites as poultry feed.* In contrast to the quality of HF and BS as poultry feed, there was hardly any information in the literature on the nutritional qualities of termites as poultry feed. This topic was studied in Burkina Faso and Benin. In Burkina Faso studies showed that dry and fresh *Macrotermes* spp. are suitable animal protein ingredients that can substitute fishmeal in traditional chickens and guinea fowl feeding [38, D7). In Benin, two MSc theses [M11, M15] focused on the use of *Trinervitermes trinervius* in local chicken feed. They showed that feed containing termites had a high digestibility and were mostly efficient and financially favourable at the starting phase. An MSc thesis [M12] compared the nutritional composition of four termite species and found that *Odontotermes* spp. had the best nutritional composition followed by *Macrotermes subhyalinus* and *Trinervitermes* spp. Another MSc thesis [M3] showed that *Odontermes* and *Macrotermes* were better digested by local chicken and guinea fowls than *Trinervitermes*. The lower suitability of *Trinervitermes* is important because it is collected by breaking mounds whereas *Odontotermes* and *Macrotermes* are the species collected using the trapping systems developed in IFWA.

(c) *Suitability of HF larvae as catfish feed.* Experiments conducted in Ghana on using HF larvae to feed catfish have shown that the replacement of fish meal by HF larvae increases growth. In the first experiments, basins of $1m^3$ had been used and it had been shown that, while HF larvae meal increases growth (diet with 50-100% maggot meal replacement produced fish that were 50-60% bigger that those fed with diet with fish meal only), it also increased mortality through crack-head disease. This mortality is likely due to a deficiency in specific nutrients and/or to water quality. Efforts were made to identify these nutrients, but no conclusive result has been obtained. In the last year of the project, a trial was made in $4m^3$ containers with similar results, i.e., 35% increase in average weight gain was observed when fish meal was replaced by maggot meal. Crack-head disease was still present in all replicates, suggesting that it was not due to fly larvae. It must be noted that, in Ghana as well as Benin and Burkina Faso, less fish farmers produce catfish than tilapia, and experiments made in the framework of the previous project PROTEINSECT had showed that fly larvae are perfectly suitable for rearing tilapia. Thus, dissemination on the use of fly larvae to feed fish was made mostly

among tilapia farmers. Another experiment conducted in Ghana [M17] tested the use of HF larvae meal for catfish fries. These are usually reared with artemia, a highly proteinic marine arthropod that is extremely expensive. HF larvae meals made with larvae of different ages were compared with artemia in various growth performance parameters, feed conversion ratio, survival rate and cost. Although, for all parameters, HF larvae meals performed slightly less well than artemia, differences were not significant and, since fly larvae meal rations costed about 1/3 of the price of artemia, their use can be considered in the production of catfish fries.

3.5. WP5. Health, safety and environmental sustainability

The objective of WP5 was to assess the safety and environmental sustainability of the production methods, and of the use of fly larvae and termites as animal feed for animal and human health. Research in this WP started with a literature review of the knowledge on safety of using fly larvae for animal feed in small-scale productions [28]. The three main activities were as follows:

(a) Safety of feed products based on fly larvae and termites for poultry and consumers. Several studies, mostly conducted as part of a PhD [D8], were made to assess the safety of fly larvae and termites as feed for poultry. These show that the use of fly larvae as feed does not pose a particular concern for the animals and the consumers. The presence of heavy metals in substrates and fly larvae was investigated in Ghana. Pollution by heavy metal is a serious issue in Southern Ghana and the high concentration in heavy metals in substrates, in particular Hg, is a public health concern. However, there is no evidence that heavy metals particularly accumulate in fly larvae and poultry meat [29]. A similar observation was made for bio-contaminants found in substrates such as manure [30]. Another study investigated the effect of housefly larvae meal on blood cells, serum electrolytes and biochemical parameters of local chicken in Ghana. Hardly any differences were found when fish meal was replaced by maggot meal [31]. Another experiment, conducted in Benin [37], showed that three common rearing substrates for house flies contained a high amount total coliforms, faecal coliforms and total mesophilic aerobic flora before and after production but the maggots reared from these substrates had an acceptable microbiological quality with average microbial loads much lower than those of pre- and post-production substrates.

(b) Effect of HF production through natural oviposition on farm on HF populations. Several trials on-station and on-farm in the three countries assessed whether exposing small amounts of substrates, as recommended to smallholder farmers, increase adult HF populations and, consequently, the risk of diseases transmitted by flies. Partial results from Benin are found in [37], and the full study will be published soon. These experiments showed that HF are not caught in higher numbers beside containers with substrates than beside empty containers. In two of the three countries, more blow flies (often visiting substrates but rarely ovipositing) were collected but only at short distance from the containers. Field studies showed that, when traps were placed in living areas in villages with/without adopters, there was no sign of fly increase in villagers with adopters. In contrast, several adopters suggested that their activity was causing a local decline of house flies because the substrates were functioning as a sink. This needs to be confirmed. Nevertheless, we advise to avoid exposing substrates at less than 10 m from cocking/eating places.

(c) Environmental impact of the production and use of fly larvae as animal feed. An environmental life cycle assessment was carried out based on data gathered during the PROTEINSECT project (with input from IFWA) [41]. It compared a BSF system in Ghana and the HF production systems in Mali with conventional fish meal and soybean meal. The impacts were shown to be largely determined by rearing techniques and the environmental loads of rearing substrates, attesting advantages to the rearing of HF larvae on chicken manure and the use of natural oviposition as compared to systems based on adult rearing. However, the study also pointed out an important weakness of life cycle impact assessment tools, i.e. the difficulty to compare impact categories. In particular, these tools do not account for impacts related to the use of biotic resources. Thus, the main environmental impact of fish meal, i.e. overfishing, is not considered, nor is the biodiversity loss caused by extended soybean production in South America.

3.6. WP6. Economic assessment of potential project impacts at farm and enterprise level

The objective of WP6 was to assess and evaluate the economic viability of the proposed innovations on an individual farm and small-scale enterprise levels. The three main activities were as follows:

(a) Economic baseline studies to assess farm production systems and income have been produced for poultry farmers in the three countries and fish farmers in Ghana. See [50] for the study in Benin and the previous reports for the other studies. In addition, a life cycle cost assessment was published, based on data gathered during the PROTEINSECT project (with input from IFWA). It compared the BSF system at FFA in Ghana and the HF production systems in Mali with conventional fish meal and soybean meal. This study showed that the production of HF through natural oviposition as tested in Mali was competitive with the use of fish meal, but not soybean meal [40].

(b) Economic performances of fly larvae production systems for small enterprises. A PhD thesis [D2] is dedicated to economic assessments of integrating BSF larvae meal into feed for broiler production in Ghana. A first paper has been published [1]. After having assessed that, in the present market conditions, Ghanaian farmers are willing to pay GHS3.22 per kg of maggot meal, it showed how a BSF system can reach that selling price and favourably compete with conventional feed. However, to reach economic profitability, this study and [40] showed that for a system to be economically profitable in the long term, there are conditions, the main ones being (1) that by-products have to be valorised, in particular, residues need to be used or sold as bio-fertilizers; (2) that substrates are available in high quantity, at proximity and at low or no cost, and that their cost do not increase significantly when the demand for the substrate will increase. A technology profile business case has been produced in Ghana for BSF production and use as animal feed [52].

(c) Producing fly larvae is also economically viable for smallholder farmers. Several studies to assess the economic advantages of producing fly larvae for smallholders have been produced in Benin. A first study [36] estimated poultry farmers' willingness to pay (WTP) for fly larvae meal as animal protein source to feed local chickens in Benin. It found that 82% of poultry farmers are willing to pay for using fly larvae meal. The average WTP was estimated at €/kg 0.34, indicating a potential and reliable demand in fly larvae meal. Another study [17] found that the use of fresh maggots as a dietary supplement increases the number of eggs laid by free-range hens, reduces the interval between two layings and improves the income of poultry farmers by up to 42%. Another study in Benin [57] on the effect of the use of maggots on the gross margin of family poultry farms did not show a significant difference between production costs, gross margins and profitability of poultry farms whether or not using maggots in the diet of local chickens. However, maggots are good food substitutes in raising local chickens. An increase in the poultry herd and in gross margin of 19.71% were due to the use of maggots. In a "Réfétentiel technico-économique" [55] developed with the CIGs in pilot villages in Southern Benin, it was shown that the gross margin was 2'681'600 FCFA and net margin, or benefit, was 2'119'159 FCFA for the farmers using fly larvae, showing that the technology is economically profitable. Two major issues may hamper the economic results and, thus, the adoption of the technique. Firstly, poultry and, especially, chick mortality (which is not influenced by the use of fly larvae) is important and often decimates flocks, discouraging farmers in investing more in small-scale poultry farming. Secondly, free -or very cheap- substrates are not always easily available and, when the demand increases, they stop being free.

3.7. WP7. Understanding the social context and engaging local communities

The objective of WP7 was to engage with local communities and to understand the social context in the implementation villages, as a basis for locally and regionally adapted recommendations and dissemination strategy. The procedures described in the proposal were followed. Community Implementation Groups (CIG) have been set up at the beginning of the project in the pilot villages, as described in previous reports. They have played a key role in facilitating technology transfer and in coordinating project activities at village level, throughout the project Three participatory rural appraisals (PRA) were conducted. The first PRAs provided a baseline on current fish/poultry production and feeding systems, family and community work structure, key stakeholders and wealth distribution (see also WP6). The second ones were conducted to transfer the new results of the research activities to the SIGs and other adopters and to gather information on the implementation and the constraints of the fly larvae production in the villages. The final ones were conducted to assess and evaluate the systems and their implementation in the communities. On some occasions, they were conducted with workshops, although the final disseminations in villages were hampered by the restrictions due to the COVID-19 crisis. Besides this, two other main activities were carried out in the framework of WP7 as follows:

(a) Socio-anthropological follow-up and monitoring of the project. The study was conducted by anthropologists (a post-doc and three students from Switzerland) through direct observations of IFWA's activities and semi-directive interviews with key project actors. These resulted in three MSc theses and two publications [26, 27]. At the researcher's and academic level, they concluded that the IFWA project has enabled the establishment of innovative research themes in the scientific and socio-cultural landscape of the three countries. The project has contributed to the creation of an "epistemic community" (a structured network of researchers) and to the consolidation of links between the members of this group. National specificities still exist but transnational exchange spaces have been established. Many scientific actors, especially young doctors and newly trained engineers, have become specialists in emerging fields of research. At the level of the farmers targeted by the project, they observed that the use of insects as a resource for poultry feed has been enthusiastically welcomed in the villages targeted by the project. However, in some cases, the relevance of the use of these technologies remains unclear. After an initial period of excitement, the implementation of the technologies and their appropriation has not been as strong as one could have expected. Their observations show that the combination of all the daily activities of the rural populations involved in the project does not allow everyone to take up the IFWA project's proposals with the same degree of facility (depending on whether the activity is secondary/mainstream, extensive/intensive, etc.). Cumulative fieldwork also highlights constraints of the production of fly larvae (problems of access to substrates and materials, olfactory nuisances). As is often the case with the reception of socio-technical innovations, certain user profiles seem more likely to benefit from the project (actors in close contact with researchers, poultry farmers stereotyped as "serious", "motivated" or "professional"). The team also provided general perspectives and remaining questions for the future, which have been made available to partners and are available to others upon request

(b) Acceptability to consume chicken fed with fly larvae in urban and rural populations. While there is no doubt that rural populations are fully aware of the habit of poultry to feed on insects when scavenging, there were increasing signs that a significant part of the urban consumers may be reluctant to consume poultry fed with fly larvae, even though there is a general tendency among consumers to prefer local, scavenging poultry over exotic breeds. Since the socio-anthropological study was not covering consumers, a specific survey was carried out in Benin and Burkina Faso to assess the acceptability of consumers in three cities per country. In Benin [51], 38% of the consumers stated that they would refuse to eat chicken fed with fly larvae. The rejection rate even reached 55% in Cotonou. The reasons of rejection are described and discussed in [51]. This unexpected result suggests that dissemination and communication activities also have to target urban consumers. In Burkina Faso [unpublished], the rejection rate is lower than 10%, suggesting high regional variations in the perception of the use of insects as feed. Interestingly, several blind tasting tests were carried out in the framework of the project, and they all showed that poultry fed with maggots scores high or at least equally when compared to poultry fed with conventional feed. In contrast, all surveys among farmers made during the project showed a very high rate of acceptability in producing and consuming poultry fed with fly larvae [32 and unpublished data].

4. Implementation of communication and application strategy, set up of relevant stakeholder interactions and engagements

A full work package (WP8) was dedicated to technology transfer, community development, relation to stakeholders and implementation. During the project, we established strong relationships with various stakeholders and public groups.

The primary stakeholders in the project are smallholder families, including women and children who already play a vital role in poultry production in West Africa. A strong relation has been established with their representatives in pilot villages through the PRAs and the establishment of the CIGs, which also include other actors of the local poultry sector as well as representatives of the local authorities. Interactions with the pilot villages have been continuous during the project, in particular through several students who worked with villagers for their theses. Success stories in pilot villages, among others, can be found here [60, 63]. CIGs have also participated in the elaboration of technical guidelines such as [55] (in Benin Référentiel Technico-Economique - RTE), which implies the testing of the methodology by farmers who have contributed to its development.

Dissemination of the technologies outside the pilot villages started at a later stage, after we had confirmed that technologies are efficient and safe to use for the producers (WP5 and 6). In the last two years of the project, several workshops and other training events have been organised with farmers, extensionists and technical agents from various regions. For example, in Burkina Faso a five-day workshop has been organised to train 35 technical agents from all the country in the use of fly larvae and termites as poultry feed with the aim that the agents would themselves disseminate the technology. Physical and online training courses for farmers and organisations are also being organised after the end of the project [80]. In Ghana, a one-week training was organised to train 25 farmers and technical agents in the use of termite trapping in the Volta Region, where termites are collected only by destroying termite mounds. Also in Ghana, we organised, for a wide range of stakeholders (farmers, extensionists, entrepreneurs, media, students and researchers), a demonstration of the preparation of insect larvae meal and raising of broiler chicks from day-old to market size over an 8-week period. The demonstration ended with an organoleptic test by the participants. In Ghana, we also co-organised a knowledge sharing and learning symposium on alternative protein feed sources for poultry and fish. Research evidence was shared by IFWA teams with policy decision makers, extensionists, farmers and feed millers. In Benin, dissemination activities to farmers and the general public have been numerous. Besides farmers' organisations and NGOs, we also trained 630 students in agricultural schools throughout the country. Rural entrepreneurs and NGOs are among the main targeted groups and the IFWA partners are, still after the end of the project, supporting dozens of private and public initiatives to develop sustainable fly larvae production units, both HF and BSF, and both for poultry and fish feed. Some of these enterprises focus particularly on the production of fly larvae rearing residues as biofertilizers, with fly larvae meal as by-products. This is the case with Agri-Eco Services, a company that was founded by an IFWA student and now produces tons of fertilizers per week [78, 79]. The young entrepreneur received numerous international awards for his project. The IFWA teams were also key in the organisation of the R4D food system caravan [77], which was used to disseminate the IFWA results to a wide public in several countries in West Africa. We also organised the R4D Science Fair of West Africa in Benin in September 2021. Dissemination activities to farmers were not only conducted in the three countries. For example, fish farmers were also trained in the production of fly larvae in Togo, and Agri-Eco Services is also involved in training programmes in Togo and Chad. To support all these training and dissemination activities, nearly 30 technical guidelines and other dissemination material, including videos, have been produced and are available online [53-80].

We also ensured the involvement of other stakeholders from the food chain (e.g. sellers, retailers, extension personnel, etc.) and these have also been reached through meetings. Similarly, policy makers have not been forgotten. The project is involved in the global policy dialogue regarding the use of insects as feed and food, following the leading role of the "mother" project PROteINSECT. Although, so far, there is no major legislation hurdle in the three target countries for the use of insects as feed, relationships have been established with policy makers in the three countries, through face-to-face meetings and workshops. Policy makers have been informed about important findings and results from the research and implementation throughout the project.

Another important stakeholder in this project is the international research community. At the end of the project, 49 scientific papers have been published in peer-reviewed journals, and many more are submitted, or about to be submitted. Almost all publications are open-access and are accessible through the IFWA website (see also the publication list in the annex to this report). More than 40 talks and posters have been presented at international and national conferences. From the 12 African PhD students funded by the projects, seven have successfully defended their thesis, three have submitted or are about to submit their thesis, and two will probably submit it before the end of 2022. The project also supported 33 MSc. theses (see list of theses on the website and in the annex). The project is also at the origin of the development of a Master programme at the University of Abomey Calavi in Benin called "Integrated systems in Agricultural production". Finally, the project also generates much attention in the media. IFWA was mentioned in several TV and radio interviews and programmes and in newspaper articles. IFWA partners have given presentations in high schools and agricultural schools and for various organisations.

5. Pathways to Impact

Results obtained in this project confirm the potential of insects as feed and the interest of poultry farmers for this kind of technology. The pathway to impact and theory of change described in the project proposal and in the previous reports are still largely valid and has already been partly confirmed, even though the results of the project will need to be upscaled to observe impact at national and regional levels.

Poultry and fish are an important source of food and protein for families as well as an important source of income. By producing cheap, safe, and nutritious feed, the health and vigour of household poultry and fish is increased thereby enhancing household nutrition. Provision of an inexpensive locally produced protein source for poultry and fish increases the quality and quantity of poultry/fish, which leads to improved family nutrition and income and improve household food security (WP4, 6). The methodologies for insect production developed in the project (WP1, 2) can be easily replicated and adopted by a high amount of farmers, among which many smallholders. It has been shown that the technologies developed in the project are safe (WP5). environmentally sound (WP5), economically viable (WP6), and culturally acceptable (WP7), enabling even the poorest families to provide a protein source for their poultry/fish. Methods have been developed for small animal feed enterprises in rural areas, focusing especially on young entrepreneurs. We showed that residues of the fly rearing systems are excellent organic bio-fertilizer which can be used to increase yield in household gardens and fields, or to increase income, improving household food security. Small enterprises have emerged from the project that specifically focus on the production of bio-fertilizers, with fly larvae as by-products (WP3). Results, skills and experiences acquired from IFWA are being used in other developmental projects focusing on BSF and HF larvae production or bioconversion of farmyard manure or agro-processing waste into compost.

The main stakeholders are smallholder families and rural entrepreneurs, members of the community implementing groups and the partners involved in the project. Local authorities as well as extension services play an important role. Ultimately, the most impoverished families benefit by being able to produce their own protein source for livestock; increase income and house-hold food security; and produce organic fertilizer for their own use. The project also trained many students from the South, increasing research capacity in the partner countries.

The knowledge gained from research has been transferred to stakeholders via CIGs, pilot farms and other means. The research findings have reached policy makers, and will continue to do so, to ensure an adequate allocation of resources is made available to enhance dissemination to the wider public. Potential negative impacts on animal and human health have been investigated (WP5) and social and cultural barriers have been evaluated (WP7). Research showed that the negative impacts on animal and human health are limited when the proposed protocols are followed. Surveys showed that cultural barriers to the consumption of animals fed with fly larvae are not negligible in some urban populations and this needs to be considered in future dissemination/communication activities. Losers may theoretically include commercial poultry and fish food suppliers who may lose business because of the new the source of protein that can be produced at home for free. However, the low amount of inputs used by the poultry farmers suggests that the looser category is limited.

6. Research Partnerships

We have followed the KFPE principles as far as possible during the building of the consortium and we continued to do so in the course of the project. (a) The project proposal and objectives were discussed and developed with all partners before writing the proposal (P1); (b) strong interactions have been established with stakeholders since the beginning of the project, including through PRA and CIG (P2); (c) Results are disseminated as much and as best as possible, through various means (P8); (d) capacities are enhanced, e.g. through the hiring of high numbers of students from the South (P6); (e) responsibilities are shared through WP leaderships (P3); (f) data are shared among partners when available, e.g. through the website and Dropbox (P7); (g) Shared authorship in publications has always been applied (P9), with most publications involving at least 2 and often 3 or more partners.

At the beginning of the project, a challenge in the collaboration was the difficulty in establishing WP leaderships and strong collaboration between South partners, in particular from different countries. This however, has largely improved. All partners have collaborated, including in staff visits, students' exchanges and students' co-supervision, joint publications and proposals, etc. However, exchanges have been more limited in the last two years due to the pandemic and travel bans. The number of PhD, MSc and BSc students is remarkably high for such project. Twelve PhD students have been involved in the project. Seven have defended and three will do it in early 2022. Over 30 MSc students have been involved (see the list of PhD and MSc students on the website). The number of undergraduate students involved in the project in a way or another (including BSc theses) has not been counted precisely but is impressive. All this shows that, in terms of scientific training and capacity building, the project has largely met its goals.

7. Sustainable Development Goals

The contribution of this project to the increase in income of smallholder farmers is in line with the drive to end poverty in all its form (SDG 1). Using the technologies developed to increase productivity of poultry and fish, and using the substrate residues to enrich the soil contribute to SDG 2 – ending hunger, achieving food security and improved nutrition while promoting sustainable agriculture. In the same vein, the research products contribute to ensuring sustainable consumption and production patterns (SDG 12) by building resilience in the production systems (livestock and crops), some of which are high value commodities for smallholders (poultry and vegetables). The results of WP3 contribute to reversing land degradation, which is a component of SDG 15. The partnership and governance system being developed in the project is contributing to strengthening the means of implementation of actions for sustainable development (SDG 17).

8. Gender sensitivity

Gender roles and issues have been explored early in the project to ensure that the project adopts a gender-balanced approach for application of research in the communities and designing appropriate training methodology. Through the PRAs and, especially, the numerous surveys carried out at the beginning of the project [e.g. 33, 36, 42, 45, 50, 51] assessments of gender roles have been made, touching on differences in responsibilities, tasks and workload between community members - men, women, children and elders. While it has not been possible to hire more than 2 female PhD students, mainly due to a lack of suitable candidates, over one third of the African MSc and BSc students were women.

A review, to be published soon, has been carried out by IFWA partners on gender roles in the harvesting, production, consumption, and marketing of insects used as food and feed in Africa. While, for the insect as food sector, much information is available in the literature, so far, gender issues have not yet been taken into consideration in the rapidly growing sector of insects as feed in Africa, and there is hardly any information on the role of women in the sector. Therefore, we used data extracted from various studies carried out as part of IFWA. We concluded that efforts should be made to ensure that this emergent activity will also provide business opportunities for women entrepreneurs. Another aspect that needs further consideration, as when any new industry emerges, is the acceptability of poultry and fish fed with insects by consumers, in particular women since they are usually those who buy and cook the products. While a better understanding of the gender division of labour in an expanding sector such as the one of insects as food and feed is important, more knowledge needs to be gathered to ensure that the development of this sector will be gender equitable. For example, in the field of poultry and fish feed, it is essential to understand how gender is embedded in livelihoods in poultry farmers and aquaculture communities. Studies of such communities, including the understanding of livelihoods and social and economic context are necessary, but are out of the scope of the IFWA project.

Insects as Feed in West Africa

Annex to the final report:

Publications, including technical guidelines and theses as in March 2022

Seventy-four scientific publications

Fourty-nine peer-reviewed publications

1. Affedzie-Obresi, S., Adu-Aboagye, G., Nkegbe, E.K., Asuming-Bediako, N., Ansah, K.O., Mensah-Bonsu, A., Sarpong, D.B., Amegashie, D.P.K., Kwadzo, G.T-M., Wallace, P.A. and Clottey, V.A. (2020) Black Soldier Fly (*Hermitia illucens*) Larvae meal as alternative protein in broiler production in Ghana. Ghana Journal of Agricultural Science 55: 1-13.
2. Bloukounon Goubalan, A.Y, Saidou, A., Clottey, V., Chrysostome, C.A.A.M., Kenis, M. and Mensah, G.A. (2017) Typology of organic residues attracting flies and their utilization in the agricultural sector in southern Benin. International Journal of Biological and Chemical Sciences 11: 2560-2572.
3. Bloukounon-Goubalan, A.Y., Saïdou, A., Togbé, E., Chabi, F., Babatoundé, S., Chrysostome, C.A.A.M., Kenis, M. and Mensah, G. A. (2017) Physical and Chemical Properties of Animals' Organic Residues Decomposed By *Musca domestica* and *Calliphora vomitoria* Larvae. Journal of Agriculture and Environmental Sciences 6: 92-104.
4. Bloukounon-Goubalan A.Y., Saïdou A., Chrysostome C.A.A.M., Kenis M., Amadji G.M., Igué A.M. and Mensah G.A. (2019) Physical and chemical properties of the agro-processing by-products decomposed by larvae of *Musca domestica* and *Hermetia illucens*. Waste and Biomass Valorization 11: 2735-2743.
5. Bloukounon-Goubalan A.Y., Saïdou A., Obognon N., Amadji G.M., Igué A.M., Clottey, V.A. and Kenis M (2019) Adin Y. Decomposition and nutrients release pattern of animal manures biodegraded by fly larvae in acrisols. Canadian Journal of Soil Science 99: 60-69.
6. Bloukounon-Goubalan A.Y., Saïdou A., Obognon N., Amadji G.M., Igué A.M., Clottey, V.A., Kenis M, and Mensah, G.A. (2019) Decomposition and nutrient release pattern of agro-processing by-products biodegraded by fly larvae in Acrisols. Archives Journal of Agronomy Science 65: 1610-1621.
7. Bloukounon-Goubalan A.Y., Saïdou A., Clottey, V.A., Coulibaly K., Erokotan, N., Obognon N., Chabi, F. and Chrysostome, C.A.A.M. (2021) Chapter 8: By-products of Insect Rearing: Insect Residues as Biofertilizers. In Hall, H., Fitches, E., Smith, R. (Eds.). Insects as Animal Feed. CABI, Wallingford, UK
8. Boafo, C., Affedzie-Obresi, S., Gbemavo, D.S.J.C., Clottey, V.A., Nkegbe, E., Adu-Aboagye, G. and Kenis, M. (2019) Use of termites by farmers as poultry feed in Ghana. Insects 10: 69
9. Coulibaly, K., Sankara, F., Pousga, S., Nacoulma, P.J.M., Nacro, H.B. (2018) Pratiques avicoles et gestion de la fertilité des sols dans les exploitations agricoles de l'Ouest du Burkina Faso. Journal of Applied Biosciences 127: 12770-12784.
10. Coulibaly, K., Sankara, F., Pousga, S., Nacoulma, P. J., Somé, M.B. and Nacro, H.B. (2020a). On station maggot production using poultry litter as substrate: assessment on the quantity and the chemical quality of the litter before and after maggot production in Burkina Faso. International Journal of Biological and Chemical Sciences, 14: 1689-1697.
11. Coulibaly, K., Sankara, F., Pousga, S., Nacoulma, P. J., Somé, M.B. and Nacro, H.B. (2020b) Effects of poultry litter and the residues of maggot's production on chemical fertility of a lixisol and maize (Zea mays L.) yield in western of Burkina Faso. Nigerian Journal of soil science 30: 2020 95-102
12. Dao, A.N.C., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J.F., Ouedraogo, S., Kenis, M. and Somda, I. (2020a) Traditional methods of harvesting termites used as poultry feed in Burkina Faso. International Journal of Tropical Insect Science 40: 109–118.
13. Dao, A.N.C., Nacambo, S., Sankara, F., Kenis, M. (2020b) Evaluation des méthodes de piégeage des termites au nord du Burkina Faso. International Journal of Biological and Chemical Sciences 14: 2556-2566.
14. Dao, A.N.C., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J.F., Somda, I. and Kenis, M. (2021) Sustainable use of Macrotermes spp. to improve traditional poultry farming through an efficient trapping system in Burkina Faso. Insects 13, 62.
15. Edénakpo, A.K., Kouato, O.G., Adjovi, N.R.A., Chrysostome, C.A.A.M., Mensah, G.A. (2019). Caractérisation morpho biométrique des poulets locaux élevés à Héssouhoué dans la commune d'Aplahoué au Sud du Benin. Bulletin de la Recherche Agronomique du Bénin 24-35.

16. Edénakpo, K.A., Ahoyo Adjovi, N.R., Pomalegni, S.C.B., Anato, C.H., Amagnide, A., Aboh, A.B., Chrysostome, C.A.A.M., Mensah, G.A. (2020[a]) Influence des rations alimentaires à base d'asticots sur la reproduction des poulets locaux au Bénin. Agronomie Africaine 32: 15– 24.
17. Edénakpo, K. A., Houndonougbo, P. V., Ahoyo Adjovi, N. R., Behingan, M. B., Houndonougbo, M. F., Chrysostome, C. A.A.M., Mensah G. A., (2020b) Influence du complément alimentaire d'asticots frais sur la productivité des poules locales et le revenu des aviculteurs au Sud-Ouest du Bénin. Journal of Animal & Plant Sciences 45: 7916-7930. https://www.m.elewa.org/Journals/wp-content/uploads/2020/08/4.Edenakpo-1.pdf
18. Ganda H., Abihona A.H., Zannou-Boukari E.T., Kenis M., Chrysostome C.A.A.M., Mensah G.A. (2020) Influence of adult diet on biological parameters of the housefly, *Musca domestica* L. (Diptera: Muscidae). The Journal of Basic and Applied Zoology. 81: 46
19. Ganda, H., Zannou-Boukari, H.T., Kenis, M., Chrysostome, C.A.A.M. Mensah, G.A. (2019) Potentials of animal, crop and agri-food wastes for the production of fly larvae. Journal of Insects as Food and Feed 5: 59–67.
20. Ganda, H., Zannou-Boukari, H.T., Kenis, M., Abihona, H.A., Houndonougbo, F.M., Chrysostome, C.A.A.M., Chougourou, D.C. and Mensah, G.A. (2020) Effect of the rearing substrate on the yield and the chemical composition of the housefly larvae, Musca domestica (Diptera: Muscidae). International Journal of Tropical Insect Science 42: 1331–1339
21. Jacobi, J., Llanque, A., Bieri, S., Birachi, E., Cochard, R., Depetris Chauvin, N., Eschen, R., Frossard, E., Guillaume, T., Jaquet, S., Kämpfen, F., Kenis, M., Delwende Innocent, K., Komarudin, H., Madrazzo, J., Manoli, G., Mukhovi, S.M., Rügger, C.S., Schneider, F., Tri Ngo, D., van Groote, P., Nguyen, V.T.H., Winkler, M., Zähringer, J., Pomalègni, C., Diebold, C., Robledo-Abad, C. (2020) Utilisation of transdisciplinary research knowledge in sustainable development pathways - Insights from a research for development programme. Environmental Science and Policy 103, 21-29. Doi: 10.1016/j.envsci.2019.10.00.
22. Kaya, C., Generalovic, T.N., Ståhls, G., Hauser, M., Samayoa, A.C., Nunes-Silva, C.G., Roxburgh, H., Wohlfahrt, J., Ewusie, E.A., Kenis, M., Hanboonsong, Y., Orozco, J., Carrejo, N., Nakamura, S., Gasco, L., Rojo, S., Tanga, C.M., Meier, R., Rhode, C., Picard, C.J., Jiggins, C.D., Leiber, F., Tomberlin, J.K., Hasselmann, M., Blanckenhorn, W.U., Kapun M., Sandrock, C. (2021) Global population genetic structure and demographic trajectories of the black soldier fly, *Hermetia illucens*. BMC Biology 19: 94. https://doi.org/10.1186/s12915-021-01029-w
23. Kenis, M., Bouwassi, B., Boafo, H., Devic, E., Han, R., Koko, G., Koné, N'G., Maciel-Vergara, G., Nacambo, S., Pomalegni, S.C.B., Roffeis, M., Wakefield, M., Zhu, F., Fitches, E. (2018) Small-scale fly larvae production for animal feed. In: Halloran, A., Flore, R. Vantomme, P. and Roos, N. (Eds.). Edible Insects in Sustainable Food Systems. Springer. Pp 239-261.
24. Kenis, M., Pomalégni, S.C.B., Sankara, F., Nkegbe, E.K., Koko, G.K.D. (2021) Chapter 10. Insect production and utilisation of insect products in Africa. In Hall, H., Fitches, E., Smith, R. (Eds.). Insects as Animal Feed. CABI, Wallingford, UK.
25. Koné, N'G. Sylla, M., Nacambo, S., Kenis, M. (2017) Production of house fly larvae for animal feed through natural oviposition. Journal of Insects as Food and Feed 3: 187–192.
26. Mégret, Q. (2019) Des protéines d'insectes pour la sécurité alimentaire? Ethnographie d'un projet de recherche pour le développement en Afrique de l'Ouest. Socio-anthropologie 39: 129-141.
27. Mégret, Q. (2021) Des insectes en guise de pharmakôn ? Les traductions de la « comestibilité » dans un projet de recherche pour le développement. Corps 1/19: 353-364.
28. Nkegbe, E.K., Adu-Aboagye, G., Affedzie, O.S., Nacambo, S., Boafo, A. B., Kenis, M., and Wallace, P. (2018) Potential health and safety issues in the small-scale production of fly larvae for animal feed – a review. Ghanaian Journal of Animal Science 9: 1-10.
29. Nkegbe, E.K., Adu-Aboagye, G., Affedzie, O.S., Boafo, H.A., Wallace, P., Clottey, V., Kenis, M., Nacambo, S., Karbo, N. and Aning, G.K. (2019) Chemical safety of biological substrates and their contamination factors associated with housefly larvae meal. Ghanaian Journal of Animal Science 9:148-151.
30. Nkegbe, E.K., Boafo, H.A., Adu-Aboagye, G., Affedzie, O.S., Wallace, P., Karbo, N., Clottey, V., Nacambo, S., Kenis, M. and Aning, G.K. (2019) Microbial isolates associated with potential housefly larvae meal production substrates in Southern Ghana. Ghanaian Journal of Animal Science 9: 135-140.
31. Nkegbe, E.K., Adu-Aboagye, G., Affedzie, O.S., Boafo, H.A., Wallace, P., Clottey, V., Kenis, M., Nacambo, S., Karbo, N. and Aning, G.K. (2019) Effects of housefly larvae meal on blood cells, serum electrolytes and biochemical parameters of grower phase indigenous coastal savanna ecotype chicken in Southern Ghana. Ghanaian Journal of Animal Science 9: 33-38.
32. Pomalégni S.C.B., Gbemavo D.S.J.C., Kpadé C.P., Babatoundé S., Chrysostome C.A.A.M., Koudandé O.D., Kenis M., Glèlè Kakaï R.L. and Mensah G.A. (2016) Perceptions et facteurs déterminant l'utilisation des asticots dans l'alimentation des poulets locaux (*Gallus gallus*) au Bénin. Journal of Applied Biosciences 98, 9330 – 9343.

33. Pomalégni, S.C.B., Gbemavo, D.S.J.C., Babatoundé, S., Chrysostome, C.A.A.M., Koudandé, O.D., Glèlè Kakaï, L.R., Mensah G.A. (2016) Synthèse bibliographique sur les insectes et autres invertébrés comestibles utilisés dans l'alimentation des animaux monogastriques d'élevage. Bulletin de la Recherche Agronomique du Bénin 80 : 43-53
34. Pomalégni, S.C.B., Gbemavo, D.S.J.C., Kpadé, C.P., Kenis, M., Mensah, G.A. (2017) Traditional use of fly larvae by small poultry farmers in Benin. Journal of Insects as Food and Feed 3: 177-186.
35. Pomalégni, S.C.B., Gbemavo, D.S.J.C., Gnanglè, P.C, Djossou, S.R., Kenis, M. Babatoundé, S., Glèlè Kakaï, L.R., Mensah G.A. (2018) Seed cake of *Jatropha curcas* (L.), potential substrate to produce maggots as food for reared monogastric animals. Journal of Animal and Plant Sciences (JAPS). 28: 1591-1596.
36. Pomalégni, S.C.B., Kpadé, C.P., Gbemavo, D.S.J.C., Clottey, V.A., Kenis, M., Mensah, G.A. (2018) Traditional poultry farmers' willingness to pay for using fly larvae meal as protein source to feed local chickens in Benin. Bio-based and Applied Economics 7: 117-138. DOI: 10.13128/BAE-22489.
37. Pomalegni, S.C.B., Kpera, G.N., Accombessi, F.D., Mensah, S.E.P. ; Bossou, A.F.A.D., Houngbo, E.N., Zannou, E. and mensah, G. A. (2021) Densité des populations de mouches et dissémination des agents pathogènes dans un système de production d'asticots pour l'élevage pendant l'harmattan. Agronomie Africaine 33: 319-330.
38. Pousga, S., Sankara, S., Coulibaly, K., Nacoulma, P., Ouedraogo, S., Kenis, M., Chrysostome, C. and. Ouedraogo, G.A. (2018) Effets du remplacement de la farine de poisson par les termites (*Macrotermes* spp.) sur les performances de croissance et les caractéristiques de carcasse de la volaille locale en système semi-intensif au Burkina Faso. African Journal of Food, Agriculture, Nutrition and Development 19: 14354-14371.
39. Roffeis, M., Almeida, J., Wakefield, M.E., Valada, T.R.A., Devic, E., Koné, N., Kenis, M., Nacambo, S., Fitches, E.C., Koko, G.K.D., Mathijs, E., Achten, W.M.J., Muys, B. (2017) Life Cycle Inventory Analysis of Prospective Insect Based Feed Production in West Africa. Sustainability 9:1697.
40. Roffeis, M., Wakefield, M.E., Almeida, J., Alves Valada, T.A.R., Devic, E., Koné, N'G., Kenis, M., Nacambo, N., Fitches, E.C., Koko, G.K.D., Mathijs, E., Achten, W.M.J. and Muys, B. (2018) Life cycle cost assessment of insect based feed production in West Africa. Journal of Cleaner Production 199: 792-806.
41. Roffeis, M., Fitches, E.C., Wakefield, M.E., Almeida, J., Alves Valada, T.A.R., Devic, E., Koné, N'G., Kenis, M., Nacambo, N., Koko, G.K.D., Mathijs, E., Achten, W.M.J. and Muys, B. (2020) Ex-ante life cycle Impact assessment of insect based feed production in West Africa. Agricultural Systems 178: 102710.
42. Sankara F., Pousga, S., Dao, N.C., Gbemavo, D.S.J.C., Clottey, V.A., Coulibaly, K., Nacoulma, J.P., Ouedraogo, S. and Kenis, M. (2018) Indigenous knowledge and potential of termites as poultry feed in Burkina Faso. Journal of insects as food and feed 4: 211-218.
43. Sankara, F., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J.P., Somda, I. and Kenis, M. (2021) Amélioration de techniques de production, d'extraction et de séchage des larves de mouches domestiques (Musca domestica Linnaeus, 1758) utilisées dans l'alimentation des volailles au Burkina Faso. Journal of Animal & Plant Sciences 50: 998-9013.
44. Sanou, A.G., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J.P., Kenis, M., Clottey, V.A., Nacro, S., and Somda, I. (2018) Indigenous practices in poultry farming using maggots in Western Burkina Faso. Journal of Insects as Food and Feed 4: 219-228.
45. Sanou, A.G., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J.P., Kenis, M., Clottey, V.A., Nacro, S., Somda, I. (2019) Farmers' perception of the use of fly larvae in poultry feed in Burkina Faso. African Entomology 27: 373 – 385.
46. Sanou, A.G., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J.P., Ouedraogo, I., Nacro, S., Kenis, M., Sanon, A., Somda, I. (2019) Production de masse de larves de *Musca domestica* L. (Diptera : Muscidae) pour l'aviculture au Burkina Faso: Analyse des facteurs déterminants en oviposition naturelle. Journal of Applied Bioscience 134: 13689 - 13701.
47. Traore, I., Pousga, S., Sankara, F., Coulibaly, K., Nacoulma, J.-P., Kenis, M., Mensah, G.A., Ouédraogo, G.A. (2020a) Étude du comportement alimentaire de la pintade locale (*Numida meleagris*, L.) à l'Ouest du Burkina-Faso. International Journal of Biological and Chemical Sciences 14: 154-169.
48. Traore, I., Pousga, S., Sankara, F., Zongo, Z.G., Coulibaly, K., Nacoulma, J.-P., Kenis, M., Mensah, G.A., Ouédraogo, G.A. (2020b) Influence des larves séchées de mouches domestiques (*Musca domestica*, L.) sur la prise alimentaire du poulet local (*Gallus domesticus*, L.) au Burkina Faso. Journal of Animal and Plant Sciences 45: 7884-7899.
49. Vignonzan, M.K.M., Pomalegni, S.C.B., Dakpogan, H., Accrombessi, D.F. (2021) Influence des méthodes de suppression de vie, du mode de séchage et de la durée de stockage sur la composition chimique des larves de mouches domestiques (*Musca domestica*) (2021). Agriculture Environnement et Sciences de l'Ingénieur 19: 129-141.

<u>Three non peer-reviewed publications</u>

50. Kpadé, C.P., Kpenavoun, S., Gbemavo, D.S.J.C., Pomalegni, S.C.B., Vissoh, P., Chrysostome, C.A.A.M., Mensah, G.A. (2017) Étude de référence du projet "Insects as feed in West Africa" Rapport technique de Recherche & Développement, Cotonou, Bénin.
51. Kpadé C. P., Gbèmavo D. S. J. C., Pomalégni S. C. B. Mensah G. A. (2018) Acceptabilité de la consommation de la viande des poulets bicyclettes nourris avec des larves de mouche (asticots) par les consommateurs au Bénin. Document Technique et d'Informations. INRAB/MAEP. 33 p. Dépôt légal N° 10802 du 09 novembre 2018, Bibliothèque Nationale (BN) du Bénin, 4ème trimestre. ISBN : 978-99919-75-53-5.
52. ARI and CABI (2021) Technology profile business case. Black soldier fly larvae production and use as an alternative protein source for poultry feed.

Twenty-two technical guidelines

Benin

53. Edenakpo, K.A., Djimenou, D., Accombessi, F.D., Atchade, G.S.T., Hedegbe, R., Vignonzan, M.K.M., Ahoyo Adjovi, R.N., Mensah, G.A. (2021) (2021) Technique de préparation des rations alimentaires à base de farine d'asticots et d'ingrédients locaux pour l'aviculture familiale au Bénin. Fiche technique. Dépôt légal N° 12764 du 07/01/2021, Bibliothèque Nationale du Bénin, 1er trimestre.
54. Edenakpo, K.A., Ahoyo Adjovi, R.N., Pomalegni, S.C.B., Mensah, S.E.P., Vignonzan, K.M., Tanpinou, M.K., Ouenssou, J.M.O., Chrysostome, M.A.A.C., Mensah, G.A. (2021) Technique adaptée à la production des asticots en milieu rural au Bénin. Fiche technique. Dépôt légal N° 12759 du 05/01/2021, Bibliothèque Nationale du Bénin, 1er trimestre.
55. Edénakpo K. A., Houedjofonon M. E., Pomalegni S. C. B., Djinadou A.K.A., Ahoyo Adjovi N.R., Chrysostome C. A. A. M., Adjanohoun A. et Mensah G. A. (2021) Améliorer la reproduction des poulets locaux par une alimentation enrichie aux asticots au Bénin. Référentiel Technico-économique (RTE). INRAB/MAEP/Bénin. 57 p. Dépôt légal N°13546, de 1er décembre 2021, 4ème trimestre, Bibliothèque Nationale (BN) du Bénin. ISBN : 978-99982-62-91-1.
56. Gnangle, P.C., Pomalegni, S.C.B., Acrombessi, F.D., Djossou S.R., Gbemavo, C.D.S.J., Djimenou, D., Mensah, G.A. (2021) Valorisation des résidus du tourteau de Jatropha curcas pour la production des asticots et la levée des plants en pépinière Dépôt légal N° 13259 du 27 / 08 / 2021, Bibliothèque Nationale du Bénin, 3ème trimestre, ISBN : 978-99982-0-977-0.
57. Houedjofonon M. E., Sossou C.H., Kpenavoun Chogou S., Pomalegni S. B. C., Edenakpo K. A., Ahoyo Adjovi N. R., Chrysosotome A. A. M. C. et Mensah G. A. (2021) Avantages économiques de l'utilisation des asticots dans l'alimentation des poulets locaux au Bénin. Document Technique et d'Informations (DT&I).
58. Pomalegni S.C.B., Vignonzan, C-M., Tankpinou, M.K., Dassou, B.B.D., Gbemavo, D.S.J.C., Kpade C.P., Mensah G.A. (2017) Fiche technique: Technique de récolte des larves de mouche par un extracteur pour l'alimentation animale.
59. Pomalegni S.C.B., Vignonzan, C-M., Tankpinou, M.K., Dassou, B.B.D., Gbemavo, D.S.J.C., Kpade C.P., Mensah G.A. (2017) Fiche technique: Mise au point du prototype d'un extracteur de larves de mouche.
60. Pomalegni S.C.B., Sankara F. Pousga S. Coulibaly K., Nacoulma J-P, Gbemavo D.S.J.C., Kpade C.P., Kenis M., Chrysostome C., Mensah G.A. (2017) Document Technique et d'Information: Technique de récolte de termites pour l'alimentation de la volaille locale à Siniéna (Ouest du Burkina Faso).
61. Pomalégni S. C. B., Sankara F., Pousga S., Chrysostome C. A. A. M., Kenis M., Mensah G. A. (2018). Production et utilisation des asticots dans les rations alimentaires destinées aux poulets locaux au Bénin. Document Technique d'Information présenté au 50ème Anniversaire de l'Ecole Inter-Etats des Sciences et Médecine Vétérinaire (EISMV) – 26 au 30/11/2018 à Dakar (Sénégal) Dépôt légal N° 10801 du 09/11/2018 Bibliothèque Nationale (BN) du Bénin, 4ème Trimestre – ISBN: 978-99919-75-52-8.
62. Pomalegni S.C.B. 2018. Des asticots pour volailles. Afrique Agriculture / Technique de Production Animale N°426 Septembre-Octobre 2018.
63. Pomalegni S.C.B. (2021) Success story: Amélioration de la productivité des poulets locaux dans la Commune de Djéléhoué (Département du Couffo) à l'actif de l'intervention du Projet Insects as Feed in

West Africa (IFWA) au Bénin. Présenté aux Journées scientifiques du CRA-Agonkanmey du 30 mars au 1er avril 2021

Ghana

64. CABI and ARI (2019) Suitable substrates for production of black soldier fly larvae
65. ARI and CABI (2019) Guidelines for the production of black soldier fly larvae
66. ARI and CABI (2019) Guidelines for the production of housefly larvae meal for the smallholder poultry farmer in Ghana
67. CABI (2021) Collection of termites using baited containers (Termite Trapping). CABI & R4D

Burkina Faso

68. Coulibali et al. (2021) Les résidus de production d'asticots, substrats organiques pour une gestion durable des terres au Burkina Faso
69. Coulibali et al. (2021) Qualité agronomique des résidus de production d'asticots au Burkina Faso
70. Dao et al. (2021) Pratiques endogènes de collecte des termites pour la nutrition aviaire au Burkina Faso
71. Dao et al. (2021) Méthode de piégeage et de tri des termites pour leur valorisation dans l'alimentation de la volaille au Burkina Faso
72. Sankara et al. (2021) Techniques de production de larves (asticots) de Musca domestica pour l'aviculture au Burkina Faso
73. Sankara et al. (2021) Méthodes d'extraction et de séchage des larves de mouches domestiques pour l'alimentation animale au Burkina Faso
74. Traoré et al. (2021) Moment propice pour une complémentation protéique efficiente utilisant des larves de mouche domestique (Musca domestica, L) en alimentation de la volaille locale

Six videos

75. CABI and ARI (2019) Fly larvae production in Ghana for use as livestock feed. Presentation of the IFWA result
76. CABI and ARI (2020) Exploring Insect Larvae as a sustainable alternative for protein feed and waste management.
77. Presentation of IFWA by the Food systems caravan (2020).
78. Agro-Eco Services (2021) Production d'un engrais organique, le maggot-compost, au Bénin
79. Agro-Eco Services (2021) Production de Maggot compost
80. IDR/UJAT (2022): Formation sur la production des asticots

Seven PhD theses

D1. Pomalégni, S.C.B. (2017) Perceptions, performances zootechniques et qualité nutritionnelle de la viande de poulets locaux (Gallus gallus) nourris avec des rations alimentaires à base de larves de mouche (Musca domestica, Linnaeus 1758) au Bénin. PhD thesis, University of Abomey-Calavi, Abomey-Calavi, Benin.

D2. Afedzie-Obresie, S. (2018) Economic assessment of integrating black soldier fly larvae meal into feed for broiler production in Ghana. PhD thesis, CSIR-Animal Research Institute, Ghana.

D3. Bloukounon Goubalan A. (2019) Contribution of maggots to the improvement of organic fertilisers, soil fertility and productivity of vegetable production. PhD Thesis, University of Abomey-Calavi, Abomey-Calavi, Benin

D4. Sanou, A.G. (2019) Systems for mass production of house fly larvae, Musca domestica (Diptera: Muscidae) in the Sudanian zone of Burkina Faso. PhD Thesis, University of Nazi Boni, Bobo-Dioulasso, Burkina Faso.

D5. Ganda, H. (2020) House flies (M. domestica L. 1758) larval potential production on crops and livestock substrates or by-products and their sustainable conservation methods assessment. PhD Thesis, University of Abomey-Calavi, Abomey-Calavi, Benin

D6. Edenakpo, A.K. (2020) Influence of maggot-based food rations on the reproductive performance of local chickens (Gallus gallus domesticus LINNAEUS 1758) and socio-economic effects among traditional poultry farmers in Benin. PhD Thesis, University of Abomey-Calavi, Abomey-Calavi, Benin.

D7. Traoré, I. (2022) Evaluation of the nutritional quality of housefly larvae (Musca domestica, L.) and termites (Macrotermes sp.) used in the diet of local chickens (Gallus domesticus, L.) and guinea fowls (Numida meleagris, L.) in Burkina Faso. PhD Thesis, University of Nazi Boni, Bobo-Dioulasso, Burkina Faso.

Three PhD theses submitted or close to submission:

D8. Nkegbe, E.K. Use of housefly (Musca domestica) larvae to improve poultry production in smallholder farms in Ghana; health and safety implications. Submitted to the University of Ghana

D9. Boafo, H.A. Development of insect rearing systems for use by small-holdser poultry and fish farmers to produce insects as a feed. Submitted to the University of Ghana

D10. Dao, A,N,C. Analyse des pratiques de collecte de termites et optimisation des techniques de piégeage pour l'alimentation de la volaille au Burkina Faso. Close to submission to the University of Nazi Boni, Bobo-Dioulasso, Burkina Faso.

Thirty-two MSc theses

M1. Abihona, H.A. (2017) Systèmes d'élevage de la mouche domestique (*Musca domestica* L., Diptera: Muscidae) : Implications pour une production d'asticots à moyenne échelle au Bénin. MSc thesis, Université of Abomey-Calavi, Benin.

M2. Accombressi François Darius (2020) Dynamique des populations de mouches et dissémination des agents pathogènes dans un système de production d'asticots pour l'élevage. MSc thesis, Laboratoire d'Ecologie Appliquée (LEA), Faculté des Sciences Agronomiques (FSA)- Université d'Abomey-Calavi.

M3. Adinanon, René Tognon (2021) Moment idéal de collecte dans la journée de trois espèces de termites (*Trinervitermes trinervius, Macrotermes subhyalinus* et *Odontotermes* spp) et leurs digestibilités chez les coquelets et les pintades au Bénin. MSc thesis, Laboratoire d'Ecologie Appliquée (LEA), Faculté des Sciences Agronomiques (FSA)- Université d'Abomey-Calavi.

M4. Allodehoun Appélété Arnaud (2018) Evaluation des larves de mouche domestique (*Musca domestica*) comme source de protéine pour la pintade locale (*Meleagris numida*). MSc thesis, Université of Abomey-Calavi, Benin.

M5. Bamogo, W.J.M. (2017) Optimisation des systèmes de production en masse de larves de mouche domestique (*Musca domestica* L., 1758), à l'Ouest du Burkina Faso. MSc thesis, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso.

M6. Chabi, F. (2017). Evaluation des propriétés physico-chimiques des résidus organiques décomposés par les larves de mouches (Diptera). MSc thesis, Université of Abomey-Calavi, Benin.

M7. Dao, N.A.D. (2016) Inventaire et optimisation des techniques de collecte et de production de termites dans trois régions du Burkina Faso: Centre Ouest, Plateau Central et Nord. MSc thesis, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso.

M8. Dao, N.A.D. (2018) Conception de système de collecte et de tri des termites du genre *Macrotermes* à l'Ouest du Burkina Faso. MSc thesis, Institut du Développement Rural, Université Nazi Boni de Bobo-Dioulasso.

M9. Dassu, B.B.D. (2018) Détermination des taux d'ingestion de trois formes physiques de larves de mouche (*Musca domestica*) présentées aux poulets locaux d'écotypes Holli (*Gallus gallus*) au Bénin. MSc thesis, University of Abomey-Calavi, Benin (carried out at INRAB)

M10. Djossou, S.R. (2016) Utilisation du tourteau de *Jatropha curcas* et de ses résidus pour la production des asticots en élevage et la levée des plants en pépinière. MSc thesis, University of Abomey-Calavi, Benin (carried out at INRAB).

M11. Dokui Faustin (2018) Evaluation of bio-economics performances of cockerels supplemented with termites *Trinervitermes trinervius* in starter phase. MSc thesis, University of Abomey-Calavi, Benin.

M12. Engoang Enyene Gildas Karl Valorisation des termites en alimentation de la volaille : systèmes de piégeage pour la collecte et compositions bromatologiques. MSc thesis, Laboratoire d'Ecologie Appliquée (LEA), Faculté des Sciences Agronomiques (FSA)- Université d'Abomey-Calavi.

M13. Erokotan Norbert (2018) Effet des substrats organiques biodégradés par les larves de mouche sur la production et la nutrition minérale de l'amarante (*Amaranthus cruentus*) sur sol ferralitique au Sud Bénin. MSc thesis, University of Abomey-Calavi, Benin.
M14. Gambada Mérodak Eudes Syllas (2018) Influence of ingredient-based diets with probiotic properties and maggots (*Musca domestica*) on the zootechnical performance of two strains of Japanese quail (*Coturnix coturnix* japonica). MSc thesis, University of Abomey-Calavi, Benin.
M15. Gandjeto Mahugnon Martine (2017) Evaluation of the effect of the termites *Trinervitermes trinervius* (Rambur) used as a feed supplement on digestibility of diet and bioeconomic performances of growing of broilers). MSc thesis, University of Abomey-Calavi, Benin.
M16. Hahi Moussa Abdoul (2019) : Evaluation de la productivité des larves de BFS dans une ferme et leur effet sur la croissance des poulets locaux. MSc thesis, University of Abomey-Calavi, Benin.
M17. Lartey Nicholas: Evaluation of growth performance and survival of African catfish (*Clarias gariepinus* But hell, 1822) fed with instars of housefly larvae. MSc thesis in industrial animal nutrition and feed production from CSIR College of Science and Technology (Ghana)
M18. Lokossou, Elisabeth Gbahoué (2018) Etude des conditions optimales d'acceptabilité de l'utilisation des asticots dans l'alimentation de la volaille villageoise : cas de la commune de Bopa. MSc thesis, University of Abomey-Calavi, Benin.
M19. Mikolajewski, R. (2019) Insects as Feed in West Africa (IFWA) Bénin : Analyse compréhensive des mécanismes de construction, d'intervention et de réception d'un projet de recherche et développement. MSc thesis, Institute of Anthropology, University of Neuchâtel.
M20. Odjo Zossou, Crésus Vignon (2017) Rentabilité potentielle et perspectives d'adoption des insectes en aviculture villageoise à Ouaké. MSc thesis, University of Abomey-Calavi, Benin.
M21. Oppliger, J.-M. (2018) Des asticots pour la sécurité alimentaire et économique : Étude du processus d'adoption d'une innovation en aviculture dans le projet IFWA (Burkina Faso). MSc thesis, Institute of Anthropology, University of Neuchâtel.
M22. Ouédraogo S. (2016). Contribution à l'étude sur l'utilisation des termites (*Macrotermes* sp) en aviculture traditionnelle au Burkina Faso. MSc thesis, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso.
M23. Sankara, F. (2017) Co-construction de techniques de production, d'extraction et de séchage de larves de mouche domestique à l'Ouest du Burkina Faso. MSc thesis, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso.
M24. Sankara, F. (2020) Apport de l'entomofaune dans l'aviculture à l'Ouest du Burkina Faso: cas de la mouche soldat noire (*Hermetia illucens* L.). MSc thesis, Institut du Développement Rural, Université Nazi Boni de Bobo-Dioulasso.
M25. Sanou, H. F. (2018) Analyse des perceptions des aviculteurs sur la production et l'utilisation des insectes (asticots et termites) dans l'alimentation de la volaille dans les villages de Siniéna et de Gombélédougou au Burkina Faso. MSc thesis, Institut du Développement Rural, Université Nazi Boni de Bobo-Dioulasso.
M26. Somé. B.M. (2017) Effets de litières de volailles et de résidus de production d'asticots sur la fertilité du sol et la production du maïs (*Zea mays* L.) dans l'Ouest du Burkina Faso. MSc thesis, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso.
M27. Sourokou, Simé Mazouk (2018) Contribution de l'aviculture villageoise aux revenus des ménages et à la lutte contre l'insécurité alimentaire dans la commune de Boucoumbé, Bénin. MSc thesis, Université of Abomey-Calavi, Benin.
M28. Tobgé, Mathilde (2019) Analyses de systèmes villageois d'élevages des poulets locaux dans la commune d'Aplahoué. MSc thesis, Université of Abomey-Calavi, Benin.
M29. Viaho Honorine (2020) Productivité de quelques substrats d'origine végétale en larves de mouches soldates noires *Hermetia illucens* (Diptera : Stratiomyidae). MSc thesis, Université of Abomey-Calavi, Benin.
M30. Vignonzan, M.K.M. (2021) Influence des méthodes de suppression de vie, des modes de séchage et de la durée de conservation sur la valeur nutritionnelle des larves de la mouche domestique (*Musca domestica*). MSc thesis, Université of Abomey-Calavi, Benin.

M31. Wütrich, J. (2018) La participation et l'articulation de la recherche et du développement dans le projet IFWA au Ghana. MSc thesis, Institute of Anthropology, University of Neuchâtel.
M32. Zongo, Z.G. (2017) Contribution à l'étude sur l'utilisation des larves de mouches (*Musca domestica*) dans l'alimentation des poulets locaux au Burkina Faso. MSc thesis, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso.