Gembloux Agro-Bio Tech
Université de Liège

# COMPARATIVE STUDY OF EDIBLE INSECT ACCEPTANCE BETWEEN VIETNAM AND BELGIUM AND POTENTIALITY OF CRICKET BREEDING IN SOUTHERN VIETNAM (HO CHI MINH CITY)

**LOÏC DETILLEUX**

**TRAVAIL DE FIN D'ÉTUDES PRÉSENTÉ EN VUE DE L'OBTENTION DU DIPLÔME DE MASTER BIOINGÉNIEUR EN SCIENCES AGRONOMIQUES**

**ANNÉE ACADÉMIQUE 2015-2016**

**CO-PROMOTEURS: PR. FRÉDÉRIC FRANCIS & LE CAO LUONG**

[1] Dans ce cas, l'autorité académique est représentée par le(s) promoteur(s) membre(s) du personnel enseignant de GxABT.

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# ABSTRACT

Humanity has to face major problems such as population growth, forcing humans to find food alternatives. Insect consumption is part of these alternatives and this work aims to study production and consumption aspects of this practice. On the one hand, eight diets, made of feed (chicken or fish feed) alone or with an extra feed (elephant grass, carrots or sweet potatoes), were tested in Vietnam during a breeding of *Gryllus bimaculatus* De Geer 1773 (Orthoptera: Gryllidae). The goal of this study was to find a diet at the lowest cost which could provide the best results in terms of mortality, final weight, fertility and protein, lipid, ash and carbohydrate contents. On the other hand, insect tasting sessions were organised both in Vietnam and in Belgium in order to study and to compare consumer acceptance and to determine the development potential of this practice in each country. The results of the breeding show that no experimental diet differentiate clearly from others when all factors were taken into account and extra feed did not bring nutritional advantage. Concerning consumption aspect, Vietnamese and Belgian respondents seemed to be ready to consume insects in the future. Surrounding insects with a fritter dough allowed to improve a series of parameters as taste, texture, smell and aspect of the preparation. The benefit of tasting sessions was also highlighted because they allow participants to make their own opinion which was generally positive in this study.



**Key-word**: entomophagy – Vietnam – Belgium – breeding – tasting session – *Gryllus bimaculatus.*



# RÉSUMÉ

L'humanité doit faire face à des problèmes majeurs tels que la croissance démographique qui l'oblige à trouver des alternatives pour se nourrir. La consommation d'insectes fait partie de l'une d'entre elles et ce travail vise à étudier le volet production et consommation de cette pratique. D'une part, huit régimes alimentaires, constitués d'un aliment (nourriture pour poisson ou pour poulet) seul ou accompagné d'un supplément (herbe à éléphant, carotte ou patate douce), ont été testés au Vietnam durant un élevage de *Gryllus bimaculatus* De Geer 1773 (Orthoptera: Gryllidae). Le but de cette étude était de trouver un régime alimentaire qui apporterait les meilleurs résultats en termes de mortalité, poids final, fertilité et contenu en protéines, lipides, cendres et hydrates de carbone tout en étant le moins cher possible. D'autre part, une dégustation d'insectes a été organisée à la fois au Vietnam et en Belgique afin d'étudier et de comparer l'acceptation vis-à-vis de cette nourriture et ainsi déterminer la potentialité de développer cette pratique dans chacun de ces pays. Les résultats de l'élevage montrent qu'aucune diète expérimentale ne se différenciait clairement des autres lorsque tous les facteurs mesurés étaient pris en compte et le supplément alimentaire n'apportait pas d'avantage nutritionnel. Par contre, en ce qui concerne le volet consommation, les répondants, que ce soit en Belgique ou au Vietnam, semblaient être prêts à consommer des insectes dans le futur. Le fait d'enrober ces insectes d'une pâte à frire permettait d'améliorer une série de paramètres tels que le goût, la texture, l'odeur ou l'aspect du produit. Le bienfait des dégustations a également été souligné car elles permettent aux participants de se faire leur propre opinion qui était, dans ce cas, généralement positive.



**Mots-clés** : entomophagie – Vietnam – Belgique – élevage – dégustation – *Gryllus bimaculatus.*

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# ABBREVIATIONS

| | |
|---|---|
| HCMC | Ho Chi Minh City |
| USD | United States Dollar |
| GDP | Gross Domestic Product |
| BCE | Before Common Era |
| WHO | World Health Organization |
| FCR | Feed Conversion Ratio |
| CFU | Colony-Forming Unit |
| NLU | Nong Lam University |
| RPM | Rotation Per Minute |

# INTRODUCTION

Worldwide population will reach 9 billion in 2050 and this increase will be accompanied by several problems as climate change, lack of food leading to malnutrition and starvation, increase in food and feed prices,… (Chen et al., 2009; Durst et al., 2010; Gahukar, 2013; van Huis, 2013). Regarding agriculture, it is often associated with land exhaustion, pollution and deforestation (Ramos-Elorduy, 1997). Seeing this expected future and harmful features of agriculture, it is important to find an alternative to the current food resources (Ramos-Elorduy, 1997; Chen et al., 2009).

Among these solutions, insects can be a source of nutrients both for humans and livestock which may provide economic, nutritional and ecological benefits. Present from thousands of years, insect consumption by humans is widespread in tropical and subtropical areas. Currently, more than 2000 species are consumed in the world and they are either harvested or bred. However, harvesting techniques are related to a possible overexploitation which can lead to extinction of these overexploited insects. For some species as crickets, this problem can be avoid with breeding techniques which will also allow to have a constant production throughout the year.

Despite benefits associated with this consumption, edible insects are uncommon in the Western menu and they are subject to a food neophobia, a refusal to taste novel food. However, several studies highlight that most Western participants who take part in insect tasting session are ready to consume edible insects in the future.

This master thesis investigates this Western food acceptance on the basis of a study in Belgium. The same study took place in Vietnam, a country where insect consumption is recorded but not fully investigated, in order to compare the two perceptions related to entomophagy and to measure the development potential of this practice in each country.

As mentioned above, edible insect supply can be done through rearing and one part of this work focus on the breeding of *Gryllus bimaculatus* De Geer 1773 (Orthoptera: Gryllidae). This cricket breeding aimed to find the most suitable and cheapest diet in Vietnam according to targeted objectives (protein content, weight gain,…).

# BIBLIOGRAPHY

## 1 Study area: Vietnam

Vietnam, or its full name Socialist Republic of Vietnam, is a country located in Southeastern Asia and it has borders with Laos, Cambodia and China. With its S-shape, this country has 3444 km of coastline and is bordered by the Gulf of Thailand, Gulf of Tonkin, and South China Sea (Bich Luu, 2010; CIA, 2016) (Figure 1). This country has a tropical climate in the South and a monsoonal climate in the North with a dry season (November-April) and a rainy season (May-October) (Philipp et al., 2015; CIA, 2016).


*Figure 1. Map of Vietnam* (Nations Online, 2016).

Vietnamese population was estimated on July 2015 to 94 348 835 people, which leads the country to the fifteenth rank of the most populated countries (this classification includes European Union as whole), and this population is distributed over 58 provinces and 5 municipalities which are on an equal footing. These municipalities correspond to the main cities: Hanoi (capital of Vietnam), Ho Chi Minh City (HCMC), Can Tho, Da Nang and Hai Phong (CIA, 2016; Nations Online, 2016). Situated in the Southern part of the country, HCMC is considered as the biggest town of Vietnam and the economic lung of Vietnam by creating one-fifth of the national GDP and attracting foreign industry to invest in this area (Eckert et al., 2009; Dao et al., 2015).

Vietnamese area reaches 330 951 km² and is devoted to different uses like forest (142 570 km² in 2011) or agriculture (107 933 km² in 2011). Concerning the latter, there were three main crops in 2011 which are paddy rice (42 398 344 tonnes), sugar cane (17 539 572 tonnes) and cassava (9 897 913 tonnes). They produced also, in 2011, almost 7 billion of eggs and just over 3 million tonnes of pig meat (FAO, 2015; CIA, 2016).

During these last decades, economy of Vietnam has changed with decision of Communist government to adopt "*doi moi*" policy in 1986 and this policy consists of measures (liberalisation of trade with other countries, decollectivisation, private ownership,…) allowing Vietnam to stop its centrally-planned economy (Turner et al., 2005). Success of this policy can be illustrated with the statistics. Indeed, GDP has multiplied by three between 1990 and 2008 and in these circumstances, Vietnam exports different product (rice, coffee, seafood, clothes,…) in 2015 with an estimated value of close to 160 billion USD (CIA, 2016; United Nations, 2016). Edibles insect are another commodity that could be exported from Vietnam in the future. Some insect farms already exist in Vietnam and their products could be consumed in Vietnam or exported in countries as Thailand or Laos where insects are often consumed (Durst et al., 2015; Vietnamnet bridge, 2015).

# 2 Entomophagy

## 2.1 Definition

The word entomophagy comes from Greek language and more specifically from terms "entomos" and "phagein" which can be translated by eating of insects (Gahukar, 2013). Insectivory is another word that could be used to refer to a more exclusive insect consumption by other species than human. (Meyer-Rochow, 2010). Moreover, when insects are for human consumption, appellations micro-livestock and mini-livestock can be used (Gahukar, 2013).

## 2.2 Through history

Although most studies on prehistoric food are focused on meat, and hunting associated with, there are some proofs that insects have been consumed by humans for thousands of years (Van Itterbeeck et al., 2012). Among these evidences, Bequaert (1921[2] cited by Gahukar, 2013) highlights the relation between insects and humans with representations, dating back to 9000 – 30 000 BCE, of collection of bee pupae and larvae in Spanish caves. Coprolite analyses also show also that early American Indians consumed termites and predaceous diving beetles (up to

[2] Bequaert J., 1921. Insects as food: How they have augmented the food supply of mankind in early and recent times. Nat. Hist. 21, 191–200.

9 500 B.P.) and in Mexico (>5400 B.P.), people ate other kind of insects like ants or caterpillars (Sutton, 1995[3]; Elias, 2010[4] cited by Van Itterbeeck et al., 2012).

This topic is also discussed in texts of different religions (Islam, Judaism and Christianity). For example, in the Jewish text, use of locust, probably the desert locust (*Schistocerca gregaria* Forskål 1775; Orthoptera : Acrididae), in people diet is presented (Van Huis et al., 2013). In non-religious literature, Aristotle (384–322 BCE) speaks about cicada as food in *Historia Animalium* and gives some advice for the best time to consume them while Diodorus of Sicily (second century BCE) uses appellation "eaters of locusts and grasshoppers" to talk about Ethiopian people. Asia is not left out with for example China which approaches entomophagy in ancient literature and it is considered as one of oldest country where people eat insects (Chen et al., 2009). In these conditions, it is assumed that humans ate or eat insects on every continent, except Antarctica (Tommaseo-Ponzetta, 2005[5]; Bodenheimer, 1951[6] cited by Schabel, 2010).

## 2.3 Today

Appeared more than 400 million years ago, insects live in a range of habitat and are divided into a large number of species, estimated between 7 and 30 million, while a lot of these species are still to discover (Schabel, 2010; Van Huis et al., 2013). Indeed, currently, almost three-quarters of discovered species on Earth are insects and every year, 6000 additional species of insects are identified (Schaffner, 2004; Van Huis et al., 2013).

Among these species, Ramos-Elorduy (2009) considers that, at least, 2086 are consumed by 3071 ethnic groups spread over 130 countries in the world. This result is actually approximate as commonly, species are described by several vernacular names and most of layperson are not able of using Linnaean nomenclature (Van Huis et al., 2013). It is therefore necessary to confirm the numerous lists that different societies own with the aim of using this information for a survey (Yen, 2009a).

Insect consumption is widespread in tropical and subtropical areas and more particularly in developing countries because poor people eat insects instead of expensive meat. However, in some countries, middle classes have also insects in their diets while in other countries, they become luxurious food for rich people (Ramos-Elorduy et al., 1996[7] cited by Ramos-Elorduy, 1997; Ramos-Elorduy, 1997; Gahukar, 2013). In these conditions, African and American people consume the largest variety of insect species. Nevertheless, there is a need of information on this specific topic for Asia. Consequently more insect species could be eaten in Asia than data supplied by these surveys (Ramos-Elorduy, 1997; Ramos-Elorduy, 2005[8] cited by Johnson, 2010). In the Western world, this practice is uncommon even if entomophagy has been recorded in France, Germany, United States,… (Ramos-Elorduy, 1997; Yen, 2009a). The topics discussed in literature follow the same trend and are principally focused on America, Africa

[3] Sutton M., 1995. Archaeological aspects of insect use. J Archaeol Method Th 2, 253–298.
[4] Elias S., 2010. The use of insect fossils in archaeology. In: Elias, S. ed. Advances in Quaternary Entomology. Amsterdam, 89–121.
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[6] Bodenheimer F.S., 1951. Insects as human food.
[7] Ramos-Elorduy J. & Conconi M., 1996. Insectos Comestibles Platillo de Gourmets.
[8] Ramos-Elorduy J., 2005. Insects: a hopeful food source. In: Paoletti, M.G. ed. Ecological Implications of Minilivestock. Enfield, 263–291.

and Asia (Yen, 2009a). Moreover, Ramos-Elorduy (2009) also underlines the fact that edible insects become an interesting topic for media, with an increased number of publications on entomophagy.

## 2.4 Which insect on your menu?

Insects for human consumption are generally terrestrial and belong to five main orders: Coleoptera (representing 31% of edible insects species), Lepidoptera (18%), Hymenoptera (14%), Orthoptera (13%) and Hemiptera (10%) (Ramos-Elorduy, 1997; Van Huis et al., 2013). Most of them are used for entomophagy before the mature stage (eggs, larvae and pupae), when exosqueleton is still soft, but adults are also consumed (Ramos-Elorduy, 1982[9] cited by Ramos-Elorduy, 1997). The Figure 2 shows these two food preferences.

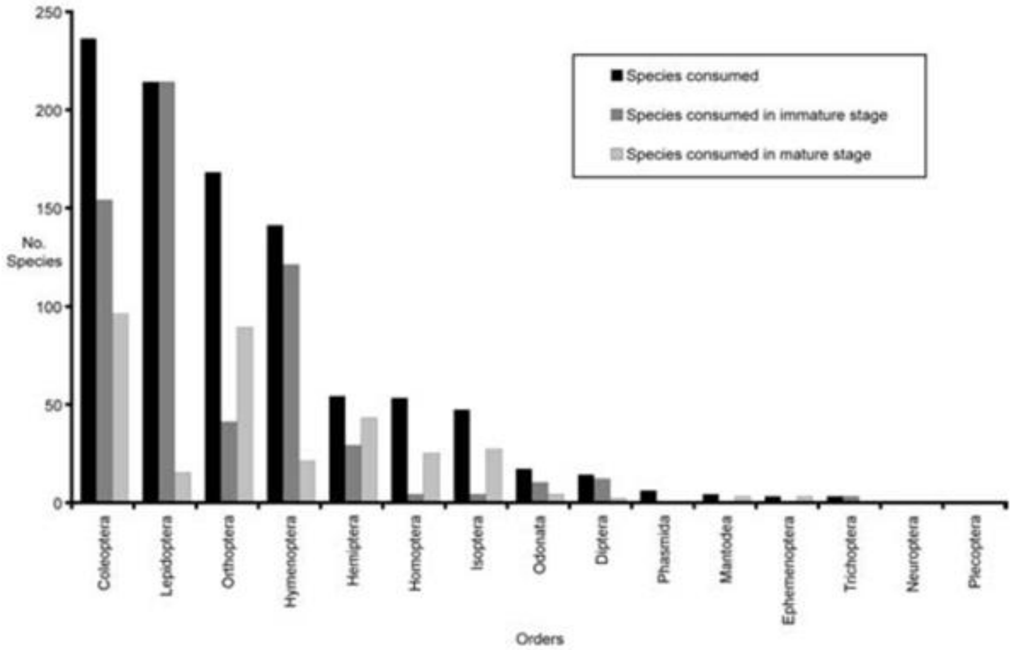


*Figure 2. Number of edible insect species in relation to their order and the stage when they are eaten* (Cerritos, 2009).

### 2.4.1 Coleoptera

Nowadays, 25% of all described species on Earth are beetles and this order represents, as discussed above, almost one-third of edibles insects (Hunt et al., 2007; Van Huis et al., 2013). Among them, most insects are terrestrial but 78 aquatic species, principally Dytiscidae, are also consumed in several countries like Mexico, Gabon or also United States (Ramos-Elorduy et al., 2009). As other insects, beetles are mainly consumed during their immature stage (Cerritos, 2009; Van Huis et al., 2013).

Among these edible beetle, palm weevils from genus *Rynchophorus* (Curculionidae) are often consumed in the tropics while they represent a threat for the palm of which they are pests. Beside these insects, there are also mealworms, from Tenebrionidae family, that is reared in the Netherlands and Belgium for food and feed. Currently, a part of the Belgian industry is supported by Entomofood, a spin-off created in 2015 with the help of the entomology unit of Gembloux Agro-Bio Tech (Van Huis et al., 2013; Remits, 2015).

[9] Ramos-Elorduy J., 1982. Los Insectos Como Fuente de Proteínas en el Futuro.

### 2.4.2 Lepidoptera

This order is represented by butterflies and moths that are mainly eaten as larvae even if adult consumption is also possible but uncommon (Van Huis et al., 2013). For example, several countries in Africa (Zimbabwe, South Africa, Angola,…) mostly consume the mopane caterpillar (*Gonimbrasia belina* Westwood 1849; Saturniidae), which becomes an important income and a source of nutrients (Ghazoul, 2006; Van Huis et al., 2013). Moreover, also in Africa, larva of *Cirina forda* Westwood 1849 (Saturniidae) constitutes both a pest for sheabutter tree (*Vitellaria paradoxa* C.F.Gaertn. 1807; Ericales: Sapotaceae) and a good source of protein and other elements (Akinnawo et al., 2000).

### 2.4.3 Hymenoptera

As in two previous orders, Hymenoptera are mainly consumed at immature stages (Cerritos, 2009). Among them, wasps are consumed by Japanese people and more particularly the yellow jacks wasps (*Vespula* and *Dolichovespula* spp.; Vespidae) during their larval stage (Van Huis et al., 2013). Wasp is also eaten in Northern Thailand where it represents, with honey bee, the most famous edible insect. This success explains that it is common to see honey bee on the menu of urban restaurants (Chen et al., 1998).

Ants are also consumed and are classically harvested in nature and sold by several families on market around the world. This concerns a range of ant species and their uses in human diet are sometimes linked to the search of beneficial medicinal effects (Rastogi, 2011). Indeed, since 1996, China has listed about thirty health products which contain ants (Van Huis et al., 2013).

### 2.4.4 Orthoptera

Edible Orthoptera, namely grasshopers, locusts and crickets, are mainly eaten as adult (Cerritos, 2009; Van Huis et al., 2013). Some species (*Sphenarium purpurascens* Charpentier 1842; Pyrgomorphidae - *Locusta migratoria* Linnaeus 1758; Acrididae - *Brachytrupes membranaceus* Drury 1770; Gryllidae) were firstly considered as pests and mainly controlled by large amounts of insecticides. However, their possible uses as food and feed have allowed to set up harvesting programs which have reduced insecticide treatments. This change remains a good alternative to decrease the density of pests with for example, in Mexico, an annual collection of 75 ton of *S. purpurascens* in the wild (Scanlan et al., 2001; Cerritos et al., 2008; Alamu et al., 2013; Mohamed, 2015). In order to obtain edible Orthoptera, rearing of insects can also be considered like in Thailand with *Gryllus bimaculatus* De Geer 1773 (Gryllidae) and *Acheta domesticus* Linnaeus 1758 (Gryllidae) (Van Huis et al., 2013).

### 2.4.5 Hemiptera

*Ioba*, *Platypleura* and *Pycna* (Cicadidae), *Agonoscelis versicolor* Fabricius 1794 (Pentatomidae) or also *Encosternum delegorguei* Spinola 1850 (Tessaratomidae) are edible Hemiptera that African people eat (Van Huis et al., 2013; Dzerefos et al., 2014). Just as Orthoptera, this order is generally consumed during the mature stage (Cerritos, 2009). However, in Mexico, it's not adult Hemiptera that people eat but eggs from an aquatic Hemiptera. This food, which is called "ahuahutle", is even seen as the Mexican caviar (Van Huis et al., 2013).

## 2.5 Nutritional content

Despite the importance of insects in terms of diversity and number, as mentioned above, knowledge about their nutrient composition is restricted (Nowak et al., 2014). However, restricted does not mean inexistent. Indeed, van Huis (2013) estimates that there are more than fifty published studies on this subject. These researches showed that insects are nutritious by providing large amount of proteins, fat, vitamins, minerals and energy according to several parameters such as species, habitat, diet, season, development stages,… All of these factors explain the significant variation which may exist in the nutritional contents (Chen et al., 2009; Oonincx et al., 2012; Rumpold et al., 2013; Van Huis et al., 2013; Yi et al., 2013; Nowak et al., 2014).

### 2.5.1 Energy

Edible insects have an average caloric contribution from 409.78 to 508.89 kcal/100 g of dry matter. Lepidoptera are generally insects with high value of energy as they contain high percentage of fat (Rumpold et al., 2013). For example, Ramos Elorduy et al. (1997) have shown that larvae of *Phassus triangularis* Edwards 1885 (Lepidoptera: Hepialidae) could have an energy content up to 762 kcal/100 g with 77% of lipid.

### 2.5.2 Protein and amino acid

Protein is the main nutrient in insects with an average content, between 35.34% (Isoptera) and 61.32% (Orthoptera), which is higher than most of plants and sometimes than meat and eggs (Chen et al., 2009, 2010; Rumpold et al., 2013). These proteins have a digestibility from 76 to 98% which can be improved by removing chitin, a nitrogenous carbohydrate of exoskeleton, with an alkali extraction (Ozimek et al., 1985; Bukkens, 1997; Ramos Elorduy et al., 1997). Concerning its composition, proteins of insects generally meet the essential amino acid requirements (mg/g) set by WHO, as can be seen in Figure 3 (Rumpold et al., 2013).

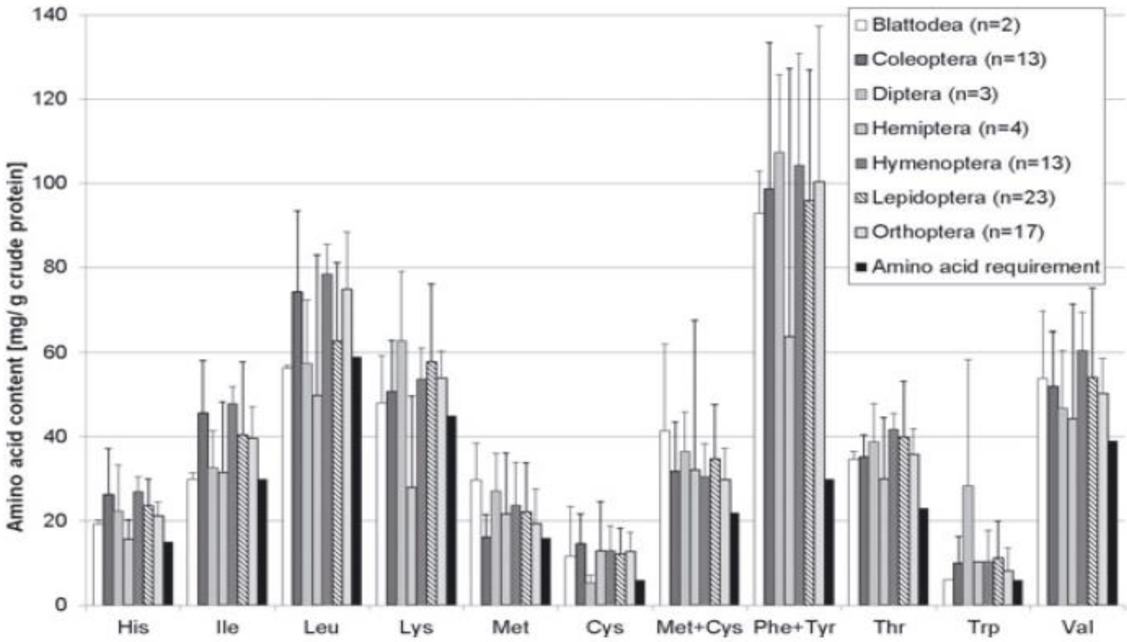


*Figure 3. Mean amino acid content per insect order and amino acid requirement set by WHO* (Rumpold et al., 2013). n represents the number of insects for each order whose their amino acid content was studied in the literature.

### 2.5.3 Lipid

Just as proteins, lipids are a major component of the body of the insect and these two compounds are inversely related with regard to percentage of body mass (Oonincx et al., 2012; Rumpold et al., 2013). In insects, fat represents from 10 to 30% of the fresh weight and this amount is lower during the adult stage (DeFoliart, 1991; Chen et al., 2009).

In comparison with poultry and fish, insects have a similar percentage of saturated fatty acids (less than 40%) but a higher proportion of linoleic acid and linolenic acid, two essential fatty acids. These polyunsaturated fatty acids can each represent more than a quarter of all fatty acids in some insects species (Fast, 1970[10] cited by DeFoliart, 1991 ; DeFoliart, 1991).

Concerning cholesterol, insects cannot produce it *de novo* and consequently, they receive it by their diet or with symbionts' help. In these conditions, it estimates that insects contain one milligram of sterols per gram of tissue (Ritter, 1990).

### 2.5.4 Vitamin

Even if studies on insects as a supplier of vitamins are not numerous, insects are considered as rich in these organic compounds and especially in vitamins B (Bukkens, 1997; Chen et al., 2010). Thus, for example, vitamin B2 content of insect is between 0.11 and 8.9 mg/100 g of dry matter when requirement for this vitamin amounts to 1.5 mg/day for an adult male (Nubel, 2011; Bukkens, 2005[11] cited by Van Huis et al., 2013). However, concerning vitamin A, insects show low quantity of this compound (Oonincx et al., 2012).

### 2.5.5 Mineral

Generally, insects provide a low quantity of calcium, sodium and potassium but a significant amount of copper, manganese, iron and zinc (Michaelsen et al., 2008; Rumpold et al., 2013). It should also be noted that insects have larger amount of iron and calcium than conventional meat and concerning zinc, Orthoptera seems to be particularly interesting as supplier of this mineral (Bukkens, 1997; Sirimungkararat et al., 2010; Rumpold et al., 2013).

### 2.5.6 Carbohydrate

In insects, carbohydrates (including chitin) are present in low proportions (from 1 to 10 %), which is the case of other animals (Chen et al., 2009; Nowak et al., 2014). This chitin has long been considered as indigestible but researches have allowed to discover the presence of chitinase in human gastric juices (Paoletti et al., 2007[12] cited by Van Huis et al., 2013).

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[10] Fast P.G., 1970. Insect lipids. In: Holman, R.T. ed. Progress in the Chemistry of Fats and Other Lipids. Oxford, 181–242.

[11] Bukkens S.G.F., 2005. Insects in the human diet: nutritional aspects. In: M.G. Paoletti ed. Ecological Implications of Minilivestock; Role of Rodents, Frogs, Snails, and Insects for Sustainable Development. New Hampshire, 545–577.

[12] Paoletti M.G., Norberto L., Damini R. & Musumeci S., 2007. Human gastric juice contains chitinase that can degrade chitin. Ann. Nutr. Metab. 244–251.

## 2.6 Why eat insects?

### 2.6.1 Nutritional aspects

As discussed above, insects are considered as very nutritious and able to provide the total nutrients of a healthy diet (Durst et al., 2010; Gahukar, 2013). These characteristics could help in resolving nutritional problems like hunger and malnutrition (Ramos-Elorduy, 2009; Ekpo, 2011). Thus, for example, high zinc and iron contents of insects can be interesting when we know that deficiencies in these minerals affect respectively 2 billion and 1 billion people in the world (Müller et al., 2005; Michaelsen et al., 2008).

### 2.6.2 Environmental aspects

Insects can be fed with a greater diversity of plants than animals regularly reared but above all, insects can be fed with organic matter, including organic waste like manure or compost (Ramos-Elorduy, 1997; Durst et al., 2010; Van Huis et al., 2013). Once ingested, this feed is particularly well converted into tissues and Feed Conversion Ratio (FCR; i.e. the amount of feed that an animal must receive to gain 1 kg) can estimate this conversion. This parameter depends on types of animal, feed quality, rearing practices, environmental factors,… (Durst et al., 2010; Robinson et al., 2010; Van Huis et al., 2013). But, under similar breeding conditions, it has been shown that insects' FCR is better than other animals (Smil, 2002; Collavo et al., 2005). This result could be simply explained by a poikilothermic way of thermoregulation in insects where food energy is not allocated in controlling body temperature (Ramos-Elorduy, 1997). Moreover, this advantage becomes even more important when percentage of edible weight is taken into account because, once again, insects have higher percentage than conventional animals. These data are included in the table below (Table 1) in which can be seen that insects are more than 10 times more efficient than beef when FCR and edible portion are joined together (van Huis, 2013).

*Table 1. Comparison of Feed Conversion Ratio (FCR), edible portion and feed between cricket and conventional meat (van Huis, 2013).*

| | Cricket | Poultry | Pork | Beef |
|---|---|---|---|---|
| FCR (kilogram feed/kilogram liveweight) | 1.7 | 2.5 | 5 | 10 |
| Edible portion (%) | 80 | 55 | 55 | 40 |
| Feed (kilogram/kilogram edible weight) | 2.1 | 4.5 | 9.1 | 25 |

In comparison with livestock, insects are also advantageous for two main resources: water and land. Firstly, almost three-quarter of water is currently used by global agriculture whether for plants (ex: 1000 litres of water/kilogram of cereal grain) or for livestock (ex: 43 000 litres/kilogram of beef) (Pimentel et al., 2004). Such data do not exist for insects but they will probably be lower as, some species like mealworms, are drought-resistant and don't need supply of water to develop (Van Huis et al., 2013). Secondly, insects can be reared on a smaller area (Durst et al., 2010). Indeed, according to Van Huis et al. (2013), 1 kg of insect protein needs ten times less surface than the same amount of beef protein.

Finally, concerning greenhouse gases, 1.1 and 14.8 kg of $CO_2$ equivalent are respectively emitted during the production of 1 kg of chicken and 1 kg of beef. In these conditions, emissions of greenhouse gases by livestock represent almost 20% of global human emissions (Steinfeld et al., 2006). Oonincx et al. (2010) compared environmental impact of livestock and insect productions and have shown that most insect species have lower emissions of greenhouse gases and $NH_3$ than conventional livestock. Production of these gases varies between insects with species, temperature and stage of development.

### 2.6.3 Production aspects

As discussed previously, insects show a large diversity for habitats and species. It is therefore easy to harvest many of them in the same place (Ramos-Elorduy, 1997). Next to this technique, there is insect breeding which is generally easy, cheap and has a shorter production duration than other animal breeding (Ramos-Elorduy, 1997; Caparros Megido et al., 2014). During insect breeding, the issue of animal welfare is not a problem because unlike livestock, density is less important for insects because they are usually gregarious (van Huis, 2013). These insects could be a source of income for a lot of families in the world (Ramos-Elorduy, 1997; Durst et al., 2010).

## 2.7 Edible insects are not perfect food

### 2.7.1 Nutritional aspects

Edible insects can contain anti-nutrient components, like phytate or tannin, which have different effects. For example, tannins reduce the availability of proteins by creating insoluble complexes with them (Adeduntan, 2005).

### 2.7.2 Environmental aspects

Consumption of edible insects may include overexploitation which can lead to extinction of these species while several years before, insects were considered as an unlimited resource (Schabel, 2006; Ramos-Elorduy, 2009). This overexploitation can be due to an increasing demand of edible insects or to a harvesting not properly executed by unskilled people for example (van Huis, 2013). Nevertheless, it exists solutions to reduce this risk as mass rearing or legislation on harvesting (van Huis, 2013; Shelomi, 2015).

### 2.7.3 Production aspects

From season to season, insects vary with rainfall or other climatic conditions like drought leading to unpredictable supply. But this risk can be managed by insect breeding even if Cohen (2001) had observed a lack of professionalism in some of these farms (Yen, 2009a; Sileshi et al., 2010). Production of insects has also to face the absence of a clear food and feed regulation which constitutes an obstacle for investors (Van Huis et al., 2013).

### 2.7.4 Sanitary security aspects

As for any other living organisms, insects can be colonized by microorganisms and they even constitute a favourable environment for this microbial population thanks to their high nutrient and moisture contents. Insects show similar level of microorganisms than food which have been in contact with soil ($10^7$ cfu/g Total Viable Count, $10^4$-$10^6$ cfu/g Enterobacteriaceae and $10^2$-$10^4$ cfu/g sporeforming bacteria) and it seems that a high microbial population is related to poor conditions of storage, transportation, marketing,… (Hardouin, 1995; Klunder et al., 2012; Testa et al., 2016). Nevertheless, most microorganisms are not a danger for consumers because they are not human pathogens (Van Huis et al., 2013).

Next to these microorganisms, edible insects, mainly from non-European countries, can also contain full range of human parasites like intestinal flukes (ex: *Plagiorchis javensis* Sandground 1940; Plagiorchiida: Plagiorchiidae), nematodes (ex: *Gongylonema pulchrum* Molin 1857; Spirurida: Gongylonematidae), protozoa (ex: *Entamoeba histolytica* Schaudinn 1903; Amoebida: Entamoebidae),… (Graczyk et al., 2005; Molavi et al., 2006; Chai et al., 2009).

Another sanitary risk, associated with harvesting, is contamination of insects with pesticide (Belluco et al., 2013). Indeed, pesticide treatment can affect insects in two ways: direct contact between animal and product (1) or consumption by insects of plants which contain pesticide (2). Once contaminated, insects become unhealthy for humans (Gahukar, 2013). Insects can also contain toxic compounds which are either produced by the insect itself or can be bio-accumulated. In the first case, we talk about phanerotoxic and such insects can cause problems for humans during ingestion while in the other case, insects are problematic after the ingestion and they are called cryptotoxic (Belluco et al., 2013).

Finally, the consumption of Arthropods, including crustaceans (shrimp, crab, lobster,…) and insects, is associated with plenty of allergic reactions (eczema, dermatitis, rhinitis,…) (Ayuso, 2011; Van Huis et al., 2013; Barre et al., 2014; Dutau et al., 2014). However, allergens of insects have not been studied sufficiently in order to develop a good knowledge of their nature, their resistance and their evolution with time (Barre et al., 2014). Moreover, reflecting taxonomic proximity between insects and crustaceans (or other Arthropods as mites), they probably own common allergens which are associated with a risk of cross-reactive allergies (ex: arginine kinase and tropomyosin). That is why it is recommended to avoid the consumption of insects for people with crustaceans allergy (Barre et al., 2014). To conclude with this topic about allergies, Testa et al. (2016) consider that this risk is real but its impact is not higher than other current food like shellfish.

## 2.8 Where to find edible insects?

In order to obtain edible insects, three main ways are used: harvesting techniques, semi-domestication and breeding (Durst et al., 2015).

The first way consists of harvest, the most traditional practice, which requires knowledge about life cycle and habits of insects because these parameters influence availability and tools used to harvest insects. Indeed, on the one hand, some species can be found seasonally (*Oecophylla smaragdina* Fabricius 1775; Hymenoptera: Formicidae) while other are available over the year (*G. bimaculatus*). On the other hand, according to life cycle and habits of insect, different tools are used as nets, baskets or glue. This knowledge is often transmitted from one generation to another and can facilitate the domestication of insects (Hanboonsong et al., 2013, 2014; Van Itterbeeck et al., 2014; Durst et al., 2015). However, as mentioned above, harvesting techniques are associated with some risks as overexploitation, presence of pesticide,...

The second practice, semi-domestication, aims to improve and to control the production of insects by promoting their food and managing their habitat. For this purpose, farmers of ants put bridges made of vine between trees to facilitate transfer for one tree to another in order to avoid predators. Beekeeping is also a good example which illustrates this practice (Schabel, 2010; Yen, 2014; Durst et al., 2015).

Lastly, breeding can be used to provide edible insects even if this technique is not possible with all species. Breeding has existed for centuries but it has developed in recent decades with the help of research, training, market development efforts,… It's particularly the case for Thailand, considered today as the main country of insect breeding. Moreover, even if edible insects remain the main products, farmers can also sell other products as insects' eggs or waste to create fertilizer. As in shown in Figure 4 with example of crickets in Thailand, these sales concern many actors like other farmers or retailers (Hanboonsong et al., 2013; Durst et al., 2015). Same scheme can be found for other countries or insects.

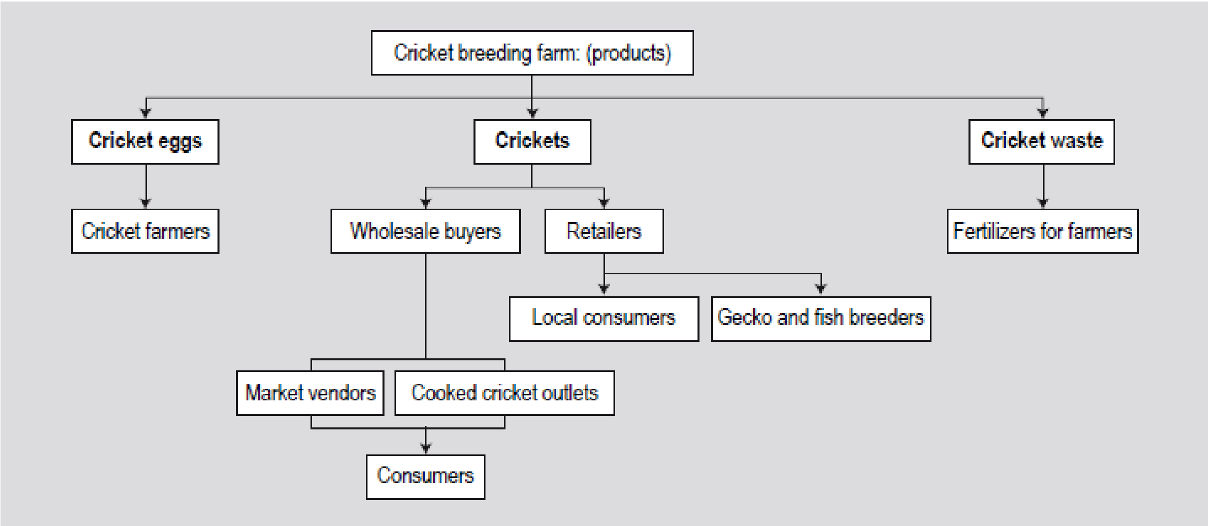


*Figure 4. Actors of cricket sector in Thailand* (Durst et al., 2015).

## 2.9 Cricket breeding

Among the insects reared, crickets (*A. domesticus*, *G. bimaculatus*,…) are commonly used and a presentation of this insect breeding will be made here with a focus on *G. bimaculatus* because this species has been studied during this work. However, it should be noted that generally, farmers prefer to rear house crickets (*A. domesticus*) because this cricket species is tastier (Hanboonsong et al., 2013; Lundy et al., 2015).

### 2.9.1 *Gryllus bimaculatus* De Geer 1773 (Orthoptera: Gryllidae)

Two-spotted cricket (in french: le grillon provençal) is widespread in Africa, in one part of Asia and it can be also found in Mediterranean countries. Similar to *Gryllus campestris* Linnaeus, C.N. 1758 (Orthoptera: Gryllidae), *G. bimaculatus* is black with two yellow spots at the base of each elytron and has wings longer than these elytra, while it is not the case for *G. campestris*. Two-spotted crickets, which are generally found under rocks, measure from 20 to 32 mm and males stridulate, particularly in the twilight, to attract female for mating (Guyot, 1990). After that, female can lay eggs which require approximately 10 days to hatch. The result is a first instar nymph which is similar to adults but without wings or ovipositor. This nymph has to moult eight times before becoming a sexually mature adult (Donoughe et al., 2016). Table 2 illustrates the development time of each step of the two-spotted crickets' life at 30°C.

*Table 2. Development time of different stages of G. bimaculatus at 30°C* (Guyot, 1990).

| Stage | Duration |
|---|---|
| Eggs | 9 - 12 days |
| From hatching to moult of imago | 7 – 12 weeks |
| Adult's longevity | 2 – 3 months |
| Sexual maturity | After 1 – 2 weeks |

### 2.9.2 How breed Gryllus bimaculatus?

First of all, a high density of individuals can easily be applied for crickets but there is a difference between *A. domesticus* and *G. bimaculatus* because the second species is bigger and more cannibal. In these conditions, it is recommended to have 1000 adults of *A. domesticus* or 600 adults of *G. bimaculatus* in a box of 40 x 40 x 40 cm (Guyot, 1990). A higher density could lead to an increase of cannibalism and a decrease of access for water, food and resting place (Clifford et al., 1976).

Then, a wide variety of containers can be used to rear crickets: concrete pens, plywood boxes, plastic boxes,… (Hanboonsong et al., 2013; Durst et al., 2015). These containers need openings with nets to ventilate while avoiding entrance of predators or exit of crickets. Inside, some stands like egg cardboards can be put to enable crickets to hide during the moult for example (Guyot, 1990; Durst et al., 2015). Next to these hiding places, water supply is also important and this resource is provided *ad libitum* in a container which avoids drowning of insects (Clifford et al., 1976; Guyot, 1990). Concerning food, this intake is generally the main cost for a farm and it is provided to crickets in a shallow container (ex: cover). Reflecting omnivorous diet of crickets, they can feed with a wide diversity of food: bread, oat flake, fruit, vegetable,… However, the main food that farmers use is high-protein commercial chicken feed which is accompanied sometimes with vegetables in order to reduce cost and to have tastier insects (Guyot, 1990; Hanboonsong et al., 2013; Durst et al., 2015). Concerning *A. domesticus*, an experiment of Nakagaki et al. (1991) shows that food associated with the largest crickets has this following composition: 30.5% of crude protein, 5.2% of crude fat, 5.1% of ash and 2.8% of crude fibre.

Moreover, when male crickets begin to stridulate, farmers have to put laying nest (ex: bowl with sand and husk) and ensure that these containers remain damp during the laying which lasts between one and two weeks (Guyot, 1990; Hanboonsong et al., 2013). Concerning living conditions, Guyot (1990) estimates that a temperature close to 30°C allows a good development of crickets.

Finally, facilities and equipment determine, in practice, the technique used to rear insects but Caparros Megido et al., (2015) highlight the importance of using local material in order to reduce the cost of breeding (Clifford et al., 1976).

## 2.10 Ready to eat insects?

As already mentioned in this work, entomophagy is present in many parts of the world except Western countries where it can be considered as a new concept (Caparros Megido et al., 2014; Lensvelt et al., 2014; Hartmann et al., 2015). However, edible insects have to face several negative thoughts: they are dirty, scary or even unhealthy, they can transmit diseases, their use as food is barbarian and primitive,… (Mignon, 2002; Chen et al., 2009; Ramos-Elorduy, 2009; Durst et al., 2010; Gahukar, 2013). Edible insects are also associated with food neophobia which can be defined by a refusal to taste novel food (Pliner et al., 2006). With insects, Rozin et al. (1980[13] cited by Caparros Megido et al., 2014) explain food neophobia by the knowledge of insects' origin and fear of problems after ingestion. This possible Western rejection impacts non-Western countries that try to follow Western habits. In this situation, the result is consequently a reduction in consumption of insects in the world and a loss of associated benefits (DeFoliart, 1999; Illgner et al., 2000)

Accepting to eat or not a product can be explained by the consumer acceptance and depends on this product, social trusts and norms, and psychological aspects (Siegrist, 2008; Lensvelt et al., 2014). On the basis of these three categories and literature related to this topic, Lensvelt et al. (2014) have identified factors which influence consumer acceptance of entomophagy. These factors are presented in the Table 3 below.

*Table 3. Factors influencing food acceptance of insects* (Lensvelt et al., 2014).

| Factors related to product | Social trust and norms | Psychological factors |
| --- | --- | --- |
| Price and quality | Trust in institutions and producers | Cultural factors |
| Perceived benefits | Trust in persons doing research | Personal importance of naturalness |
| Perceived risks | Trust in persons using the product | Food neophobia |
| Perceived naturalness | Prior attitude | Environmental attitudes |
| Availability of product | | Available information about hazards |
| Fit with consumers need | | |

In order to improve this consumer acceptance for entomophagy, Caparros Megido et al. (2014) propose to inform, for example, people about proximity between crustaceans and insects. Another solution consists in incorporating insects in traditional food because people prefer generally to eat meals with known flavours as paprika, vanilla,… (Wansink, 2002; van Huis, 2013; Caparros Megido et al., 2014; Hartmann et al., 2015). This change allows also to hide insects in food in order to decrease fear which can exist on seeing these arthropods (Lensvelt et al., 2014). Schösler et al. (2012) showed this preference with a survey in the

[13] Rozin P. & Fallon A., 1980. The psychological categorization of foods and non-foods: A preliminary taxonomy of food rejections. Appet. 1 193–201.

Netherlands where people prefer insects covered with chocolate rather than insects without preparation. Finally, it seems interesting to organize more often events where edible insects are offered because the opinion of people about entomophagy seems to be more positive after the first tasting (Looy et al., 2006; Caparros Megido et al., 2014; Lensvelt et al., 2014).

## 2.11 Situation in Vietnam and in Southeast Asia

Entomophagy is widespread in many countries of Southeast Asia, especially in Thailand and Laos where people have eaten insects for a long time (Hanboonsong et al., 2013, 2014; Durst et al., 2015). This food habit has spread across Asian countries with the help of internal migration, intermarriage, trade links,… Figure 5 shows this phenomenon between countries from Asia and Oceania. On this figure, broken arrows represent previous contacts while question marks are speculations about the direction of the spreading (Yen, 2009b; Meyer-Rochow, 2010).

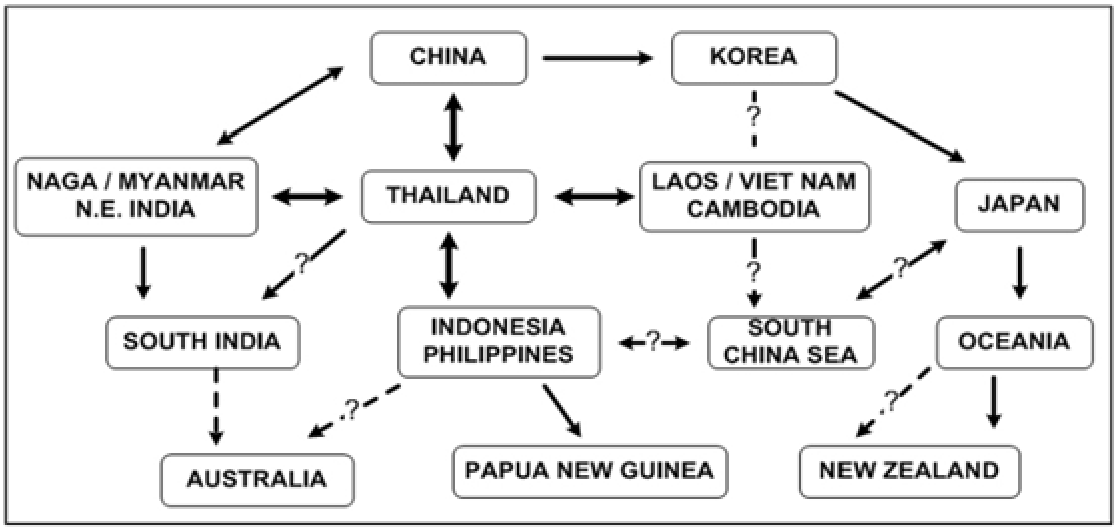


*Figure 5. Spread of entomophagy practice through Asia and Oceania* (Meyer-Rochow, 2010).

As seen in the previous figure, insects are eaten in Vietnam but literature has not yet fully investigated this topic. Consequently, this part will be more particularly focused on Thailand and Laos because they are close to Vietnam and they provide more information about entomophagy. These countries consume up to 200 insect species including cricket, cicada, locust, caterpillar,… (Yhoung-Aree et al., 1997; Hanboonsong, 2010; Hanboonsong et al., 2013, 2014). But, recently, a change in consumption patterns has been observed with the appearance of rural and urban styles. The first, rural style, follows the traditional trend where insects are one main component of the meal while urban style offers insects as a snack and is consequently closer to modern cuisine (Yhoung-Aree et al., 1997; Hanboonsong, 2010; Yhoung-Aree, 2010; Durst et al., 2015). Next to this change, production patterns have also evolved with growth of import, export and breeding of insects. Farmers of insects use few species as house crickets, two-spotted crickets, mealworms or palm weevils and techniques of breeding are quite similar between Asian countries (Hanboonsong et al., 2013, 2014; Van Huis et al., 2013; Durst et al., 2015). In these conditions, Hanboonsong et al. (2013) estimate that there are almost 20 000 farms of insects in Thailand.

Concerning Vietnam, scientific publications about entomophagy are few, as mentioned earlier, but some web pages speak about this topic. In this way, insect consumption is more present in rural areas than in the cities and crickets, bee larvae or silk worms are most often consumed as fried food (Bray, 2010; Clark, 2014). Web pages also report problems related to insect consumption in Vietnam. One of them concerns the use of cicada nymphs as food contaminated with toxic fungi that killed some people. After these deaths, government published a warning about eating insects because it can be associated with toxic compounds (Clark, 2014; Thanh Nien News, 2014; Viet Nam News, 2014).

# MATERIAL AND METHODS

## 3 Cricket breeding

The first activity consisted of cricket breeding in which eight different diets were proposed in order to find the most suitable feed according to targeted objectives (protein content, weight gain,…). This cricket breeding took place in Vietnam and more particularly on Nong Lam University (NLU) campus (HCMC).

### 3.1 Interviews

Before starting cricket breeding, some information about this activity were collected from Mr Taofic Alabi and Mr Lê Thanh Tùng. Mr Taofic Alabi belongs to the entomology unit of Gembloux Agro-Bio Tech and has taken care of some insect breeding (mealworms, crickets,…). As for Mr Lê Thanh Tùng, he has had a cricket farm, including *G. bimaculatus*, in a district of HCMC for fifteen years. These two people gave information about feed, density, lifecycle,… in order to develop a breeding of *G. bimaculatus* (choice of materials, feed,…).

### 3.2 Mass rearing

Mass rearing had been set up to obtain a large number of eggs and to test one part of materials which would be used for the main breeding. This mass rearing took place in a wooden box (100 x 50 x 50 cm) which was put outside, under a shelter, except in the evening and on Sundays, where the box was kept indoor to avoid thefts. This box had sticky paper on the top of each wall and a cover made with a metal net (mesh: 0.2 x 0.2 cm) and pieces of wood to avoid that crickets escaped and predators went inside.

In every corner of the box, containers were placed with alternatively either fish feed or chicken feed. In addition, two small containers with carrots and three drinking troughs (maximum content: 350 ml) were disposed in the box. These drinking troughs consisted of a jar with a lid where crickets could drink without drowning, thanks to gravels placed in these lids. Ten bamboo baskets were also put to enable crickets to hide and four of them were placed over containers with feed. In the middle of the box, dried grass was put in order to increase cricket hiding places. Figure 6 shows materials and device explained above.

*Figure 6. Distribution of material in the wooden box for mass rearing (Photograph taken by author).*

Mass rearing had started with 1000 larvae of *G. bimaculatus* bought from the Vietnamese farm of Mr Lê Thanh Tùng. During this activity, no data was measured except the weight of crickets for the two last weeks. Every 3 or 4 days, carrots were changed and small containers were cleaned. Concerning the other resources, water and fish/chicken feed, they were replaced every week and their containers were also cleaned.

This first breeding began on 17/03/16. Three weeks and a half later, the entire box needed to be cleaned and grass was removed because of ants. Laces with oil were also placed on support feet of the box to prevent that ants went inside again. Concerning laying support, it was placed three days after the appearance of stridulation and it was humidified each day with a water sprayer. This support consisted of soil[14] put in a container and every two days, the container was removed in order to put a new one. Once removed from the box, all containers with eggs were placed in a cardboard box. Mass rearing finished on 29/04/16.

## 3.3 Preliminary experimental breeding

A second breeding was done before the main experiment. The same diets, materials, environment and box disposition as for the main breeding were provided in order to observe eventual problems that these factors might cause. Boxes for this breeding were plastic boxes (30 x 20 x 15 cm) and three openings had been done for ventilation: one in the cover (12.5 x 8.5 cm) and two in each big side (15 x 6 cm). These openings were covered by plastic net (mesh: 0.10 x 0.15 cm). All boxes were placed on metallic shelf of lab and support feet of this shelf were covered with engine fat to prevent ants.

In each box there were: one sponge (4 x 6.5 x 3 cm) soaked in water and placed on a plastic stand, one soda plastic lid (diameter: 9 cm) for chicken/fish feed, one slightly carved soda plastic lid (9 x 6 cm) for extra feed and two egg cardboards for cricket hiding places. The sponge replaced drinking trough with gravels because during mass rearing, a lot of crickets had drowned during the larval stage (see results of mass rearing).

As mentioned above, height diets were tested (Table 4):

*Table 4. Diet (main feed + extra feed) available for crickets with their associated number.*

| Number of diet | Main feed | Extra feed |
|---|---|---|
| 1 | Chicken feed | / |
| 2 | Chicken feed | Elephant grass |
| 3 | Chicken feed | Carrots |
| 4 | Chicken feed | Sweet potatoes |
| 5 | Fish feed | / |
| 6 | Fish feed | Elephant grass |
| 7 | Fish feed | Carrots |
| 8 | Fish feed | Sweet potatoes |

[14] This soil was make from crushed coconut peel and humus coal.

Chicken and fish feed were purchased in the street market while carrots and sweet potatoes were bought in a Vietnamese stall where many kinds of food were sold. Concerning elephant grass, it was cut from a neighbouring field. Each diet had three replicates (A, B and C) and the 24 boxes (8 diets x 3 replicates) were split into a randomized block. Block A and B were on the same level of the metallic shelf while block C was on the upper floor, just above block A. Distribution of these boxes is presented in the Figure 7.

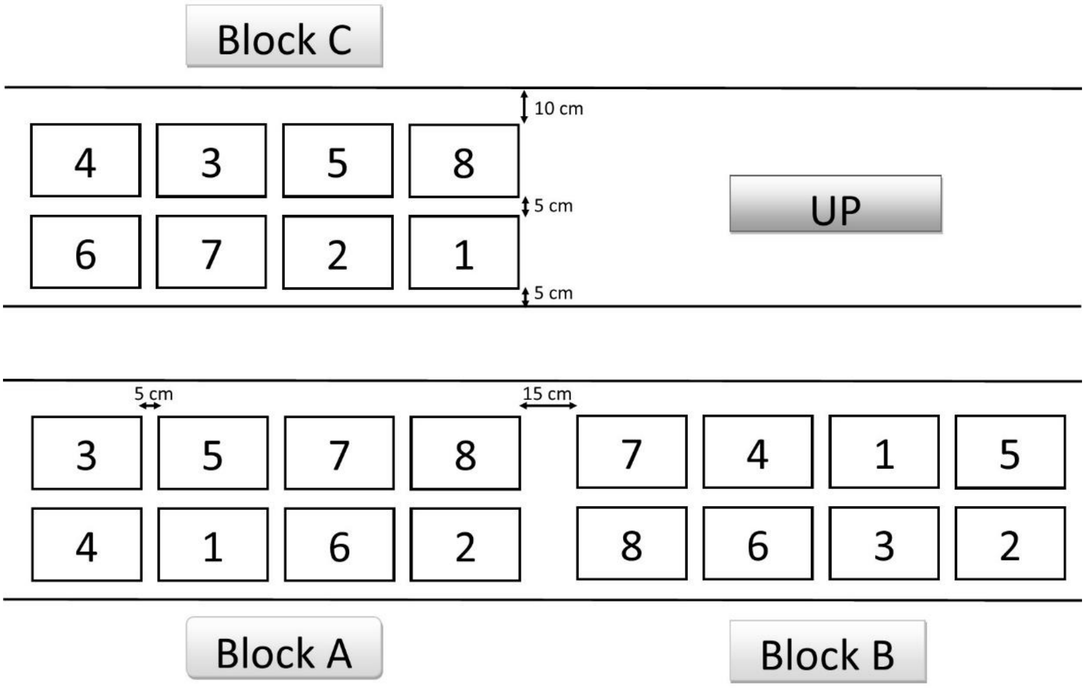


*Figure 7. Distribution of plastic boxes on metallic shelf of the lab.*
Each rectangle represents one box and it is accompanied with its number of diet. Blocks A and B were on the same level of the shelf while block C was on upper floor.

As for mass rearing, larval stage of *G. bimaculatus* was used and was coming from the farm of Mr Lê Thanh Tùng. Once bought, these crickets were put in a similar wooden box than for mass rearing with some chicken feed, water and grass. One day later, twenty crickets were put in each small plastic box with the help of a brush in order to push crickets of the wall into the plastic box. After that, the 24 boxes were transported to the lab where materials (sponge, feed and extra feed) were placed.

Five days after the beginning of this breeding, a lot of crickets were dead and in order to continue the evaluation of diets and other parameters, the remaining purchased larvae from the wooden box were transferred in the 24 boxes with a new method. Indeed, the technique with brush was replaced by a method in which a dustpan was used. For this new method, crickets of the wall were pushed by hand in the dustpan. Boxes were filled again to obtain twenty crickets in each box.

This activity lasted 13 days (from 14/04/16 to 27/04/16) and during one part of this period, weight and number of alive crickets were measured. However, no statistical test has been done with these data because this activity allowed only to have an idea of the qualities of materials and diets that have been used. Other tasks were also done and they concerned water and feed supply. Indeed, sponge was humidified every two days and chicken/fish feed were changed every week. Concerning extra feed, they were changed every two days and new extra feed were cleaned and cut into small pieces. All feed, either chicken/fish feed or extra feed, were given *ad libitum*.

## 3.4 Experimental breeding

Experimental breeding used the same plastic boxes as the preliminary experiment but a metal net (mesh: 0.2 x 0.2 cm) was put on the previous net of the side walls following appearance of hole in the plastic net during the preliminary experiment (see results of preliminary experiment). Moreover, materials (sponge, its plastic stand and egg cardboards), diets (as well as their origin and preparation), number of replicates, distribution of boxes and living environment were also similar to the preliminary experimental breeding.

However, for this rearing test, environmental conditions (temperature and relative humidity) were monitored using a datalogger which had a temperature and humidity sensor (SHT10, Sensirion, Stäfa, Switzerland). This datalogger measured parameters every four hours (12 am, 4 am, 8 am, 12 pm, 4 pm and 8 pm) and transferred these data on a website by 3G/GSM. Figures 8 and 9 illustrate the evolution of temperature and relative humidity over time and these parameters had respectively a mean value of 32.81°C and 67.30%. The datalogger was placed beside block B throughout the breeding.

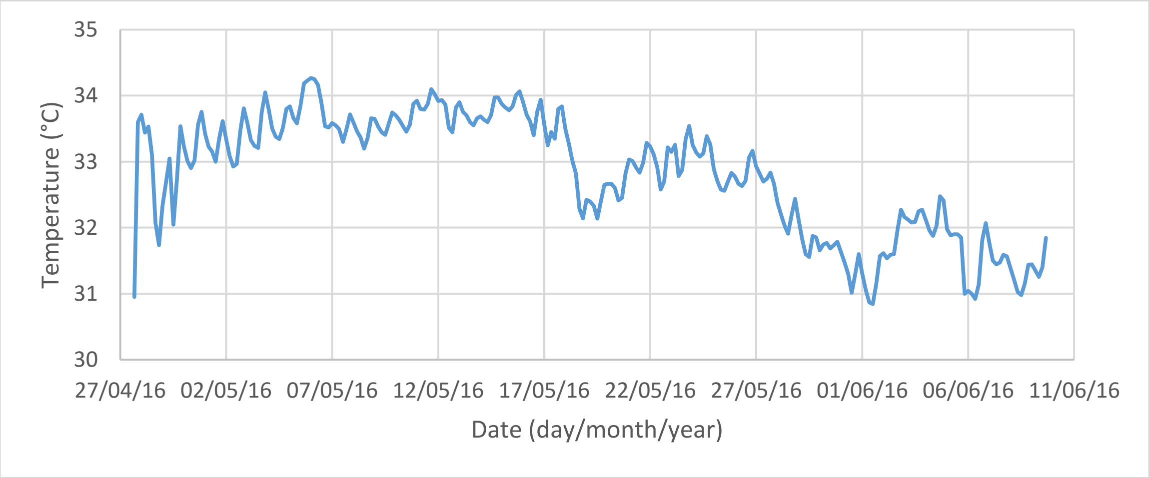


*Figure 8. Temperature monitoring during the experimental breeding (from 27/04/16 at 4 pm to 09/06/16 at 4 pm).*

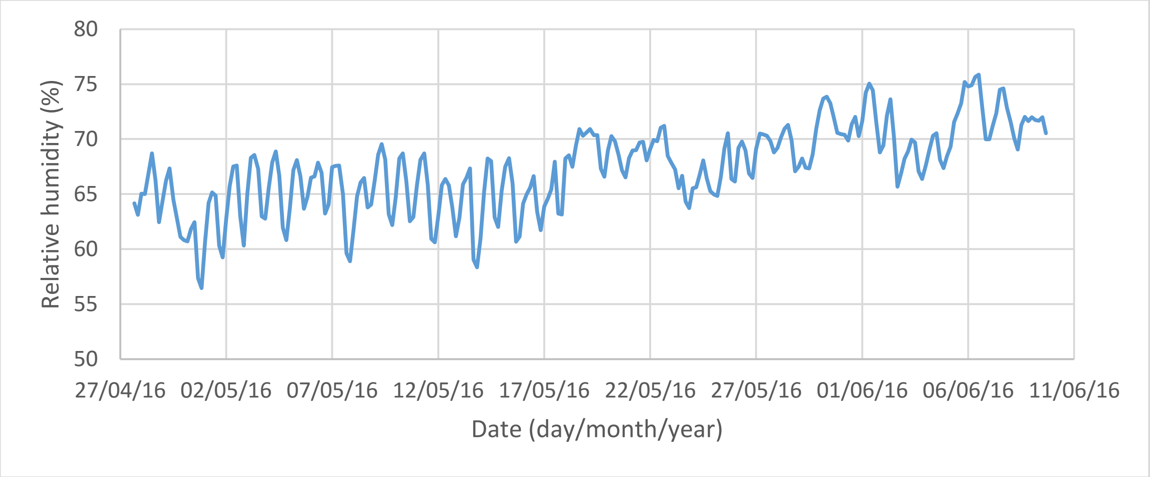


*Figure 9. Relative humidity monitoring during the experimental farming (from 27/04/16 at 4 pm to 09/06/16 at 4 pm).*

Breeding began with eggs collected the same day from mass rearing. They were placed in a plastic container (10 x 10 x 3.5 cm) filled with the same soil as laying support. Each container contained 50 eggs which were transferred from the laying support with the help of paintbrush and needle. Moreover, soil and eggs were still daily humidified.

All plastic boxes were implemented on 27/04/16 and contained sponge and its stand, container with 50 eggs, chicken/fish feed and egg cardboard. This egg cardboard was partly put in the container with eggs to help larvae to go out. Figure 10 shows the first distribution of materials in the plastic box. After egg hatching, elements were centrally replaced to avoid escape of first instar larvae from nets with too small meshes (Figure 10).

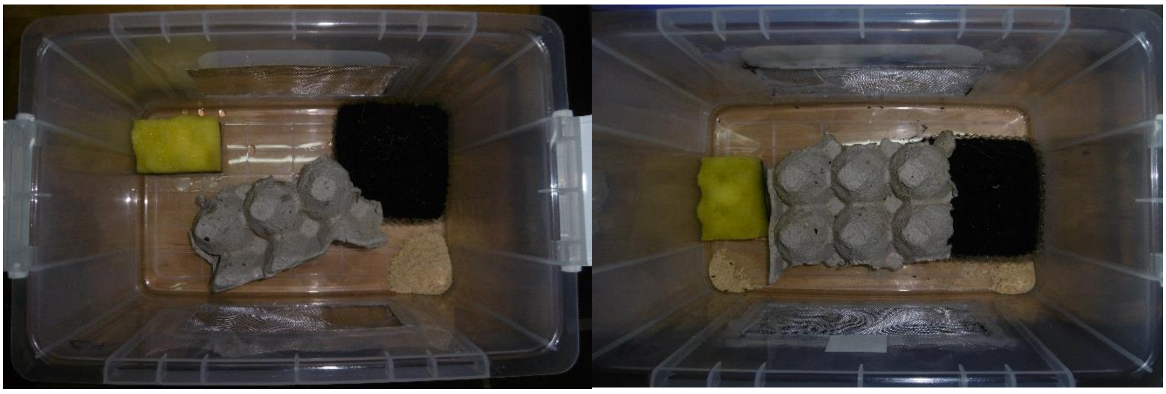

*Figure 10. Distribution of materials at the beginning of the experimental breeding (left) and after hatching (right) (Photographs taken by author).*

Currently, only chicken/fish feed was supplied on two different places in the box without stand in order to facilitate access for larvae. Three days after the first egg hatching, containers with soil and eggs were removed and extra feed was put or not according to diet. Some activities were then accomplished following different intervals: humidify sponge and change extra feed every two days. Every week, crickets were counted, weighed, all materials were cleaned and chicken/fish feed were replaced. As for preliminary breeding, all feed were given *ad libitum*.

Once the oldest crickets reached ten days, an additional egg cardboard was put in each plastic box to increase the number of cricket hiding places. Then, one week later, sponges were replaced by drinking troughs with gravels (see "mass rearing") while soda plastic lids of preliminary breeding were used for chicken/fish feed and extra feed. These changes gave the disposal presented in Figure 11.

*Figure 11. Distribution of materials after having put additional egg cardboard, drinking trough and soda plastic lids (Photograph taken by author).*

After appearance of mature crickets, metallic net was also placed on the cover opening because a hole in the plastic net of one breeding box has been observed (see results). Moreover, having adults means also appearance of ovipositor for females which allows to differentiate and to count male and female. This counting was done twice during this breeding.

A last parameter, egg number, was measured during this main activity. For this purpose, a laying support (the same container and soil that in the beginning) was added after the first male stridulation (Figure 12). This support was humidified with a water sprayer and checked every day for egg appearance. When eggs were found, the container was removed to count egg (only one quadrant multiplied by four). This estimation was done for maximum three containers for each box.

*Figure 12 Last distribution of material for laying (Photograph taken by author).*

After final weight (08/06/16), crickets were starved one day and then killed in freezer. All of these crickets and extra feed were finally dried in oven (60°C – 2 days) to bring back in Belgium for analysis. Concerning crickets, the three replicates for each diet were merged.

## 3.5 A cricket breeding…but at what price?

In order to compare eight diets from an economic point of view, a survey was conducted in different Vietnamese markets of HCMC (Thu Duc market, 18$^{st}$ market, Nong Lam market and Dau Moi market). Questionnaire (attached in annex 1) was translated into Vietnamese and was then submitted to sellers with the help of a Vietnamese student. This student asked questions himself and filled the survey as the sellers answered. Concerning chicken and fish feed, the price was the only sought parameter and information was also collected on different websites because of the small number of sellers. Conversion factor used to change price from Vietnamese dong to USD was 22 300.

## 3.6 Chemical analysis

Crickets, chicken/fish feed and extra feed were brought from Vietnam to Belgium for analysis. Three main analyses were performed with these materials which had previously been ground with a blender (M20, IKA, Staufen, Germany). Three replicates were done for each analysis except for the dry matter and ash that only required two replicates.

### 3.6.1 Dry matter and ash contents

The first task of this analysis was to put numbered crucibles in drying oven (Memmert® UM500, Memmert, Schwabach, Germany) at 105°C for one hour. These dried crucibles were then cooled in a desiccator to weigh them and to add 1 g of sample (for crickets fed with diet 4, it was 0.75 g because of small amount of crickets). Once added, each sample in its crucible was put again in drying oven at the same temperature but for twelve hours. After that, crucibles were cooled in a desiccator and weighed in order to determine dry matter content (final weight – empty weight of crucible). This content was used to express results of ash, protein and lipid content in terms of dry matter.

These crucibles and their contents were kept for ash analysis. For this purpose, they were put in muffle furnace in which temperature was gradually increased (100°C per 30 min) to reach 550°C. This temperature was maintained during five hours. After that, once cooled in desiccator, crucibles were weighed and ash contents were calculated by subtracting these values from empty weights of crucibles.

### 3.6.2 Crude protein contents

Dumas method was used to analyse crude protein content of crickets, feed and extra feed. 200 mg of each sample were prepared as capsule forms by using paper without nitrogen (Elementar®, Hanau, Germany). The same preparation was also done for aspartic acid (L-Aspartic acid reagent grade ≥98%, Sigma-Aldrich, Darmstadt, Germany) and flour to calibrate the equipment, a Rapid N Cube (Elementar®, Hanau, Germany).

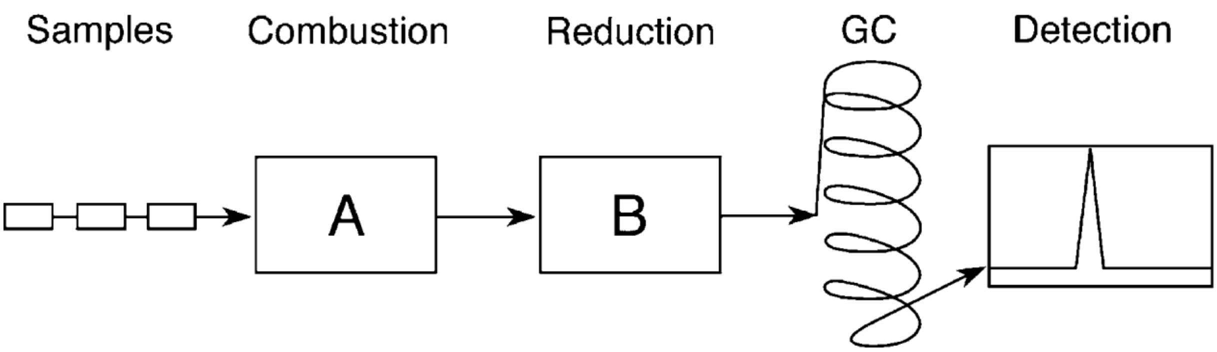


*Figure 13. Scheme of Dumas method* (Chang, 2010).
GC is used for Gas Chromatography.

Figure 13 summarizes functioning of this Rapid N Cube. Once in the device, samples underwent high temperature (960°C) in the presence of oxygen flow (170 ml/min during 80 s). In these conditions, carbon dioxide was created from carbon of samples and some components with nitrogen were also produced. Among them, there were nitrogen oxides which were then reduced in nitrogen at lower temperature (815°C). After that, gas chromatography quantitated total nitrogen and this amount was used to estimate protein content by using a conversion factor (6.25) (Chang, 2010).

### 3.6.3 Fat contents

Another method was used for this analysis and it was called Folch method. According to available total amount, from 1 to 5 g of samples were put in Teflon tubes and 25 ml of 2:1 (v/v) chloroform (AnalaR NORMAPUR®, VWR, Radnor, USA) - methanol (EMPARTA® ACS, Merck KGaA, Darmstadt, Germany) were added. These tubes were agitated on orbital shaker during 10 minutes at 350 turn/min and after that, they were centrifuged during the same length of time at 3000 RPM (Avanti® J-E, Beckman Coulter, Indianapolis, USA). Supernatant was then filtered in separating funnels which had filter (Whatman® prepleated qualitative filter paper 595 1/2 with pore size 4-7 µm, Sigma-Aldrich, Darmstadt, Germany) on the top. The procedure described above was repeated two more times. Once done, 25 ml of 2:1 (v/v) chloroform-methanol were used to wash filter and 30 ml of NaCl (0.58%) were added in each separating funnel. Separating funnel agitation was then necessary in order to put two phases in contact without forgetting to degas.

After twenty hours of decantation, lower organic phases were collected in weighed 500 ml flasks. 40 ml of chloroform were then added in separating funnels which were agitated to put again two phases in contact and were degassed. After that, a waiting time of five hours was necessary before collecting again lower organic phases. The solvent present in flasks was then vacuum evaporated with Rotavapor® R-210 (BÜCHI Labortechnik AG, Flawil, Switzerland) at 40°C and if this evaporation was not sufficient, remaining solvent was removed by applying a nitrogen flow. Then, all the flasks were put in desiccator during 30 minutes before weighing them in order to determinate fat content (final weight – empty weight of flask). Remaining fats of each flask was finally put in Teflon tubes for future analysis.

### 3.6.4 Carbohydrate contents

This content was not determined by analysis but it was estimated by a calculation provided by Lopez et al. (1998):

Carbohydrate (%) = 100 – (% of ash + % of protein + % of fat + % of moisture)

As each percentage will be based on dry matter, the term moisture could be removed from the calculation above.

# 4 Tasting session

This second activity concerned both Vietnam and Belgium where three insects were proposed for a tasting session: mealworm larva (*Tenebrio molitor* Linnaeus, 1758; Coleoptera: Tenebrionidae), silkworm pupa (*Bombyx mori* Linnaeus 1758; Lepidoptera: Bombycidae) and adult cricket (*G. bimaculatus*). Mealworms came from the rearing laboratory of Gembloux Agro-Bio Tech, the origin of silkworm pupae was Vietnam while crickets were bought in each country just before the tasting session. Transport from one country to another for mealworms and silkworms was done after drying insects in oven. Concerning crickets, they were bought as fresh insect and then, they were starved during one day before being killed in freezer. For the tasting session, each insect was sautéed with oil or dough coated and fried (made with crispy fry mix[15]). Consequently, six types of food were proposed and each preparation was associated with an identification number, a three-digit number which was randomly selected. All preparations were given once except for mealworm where participants received simultaneously three insects (Figure 14).

[15] Crispy fry mix is a Vietnamese product which contains these ingredients: rice flour, wheat flour, corn starch, tapioca starch, food additives (Disodium diphosphate and sodium hydrogen carbonate). 150 g of this product is combine with 160 ml of water and each item is soaked into the batter before to cook it in order to obtain a fritter dough surrounding each item.

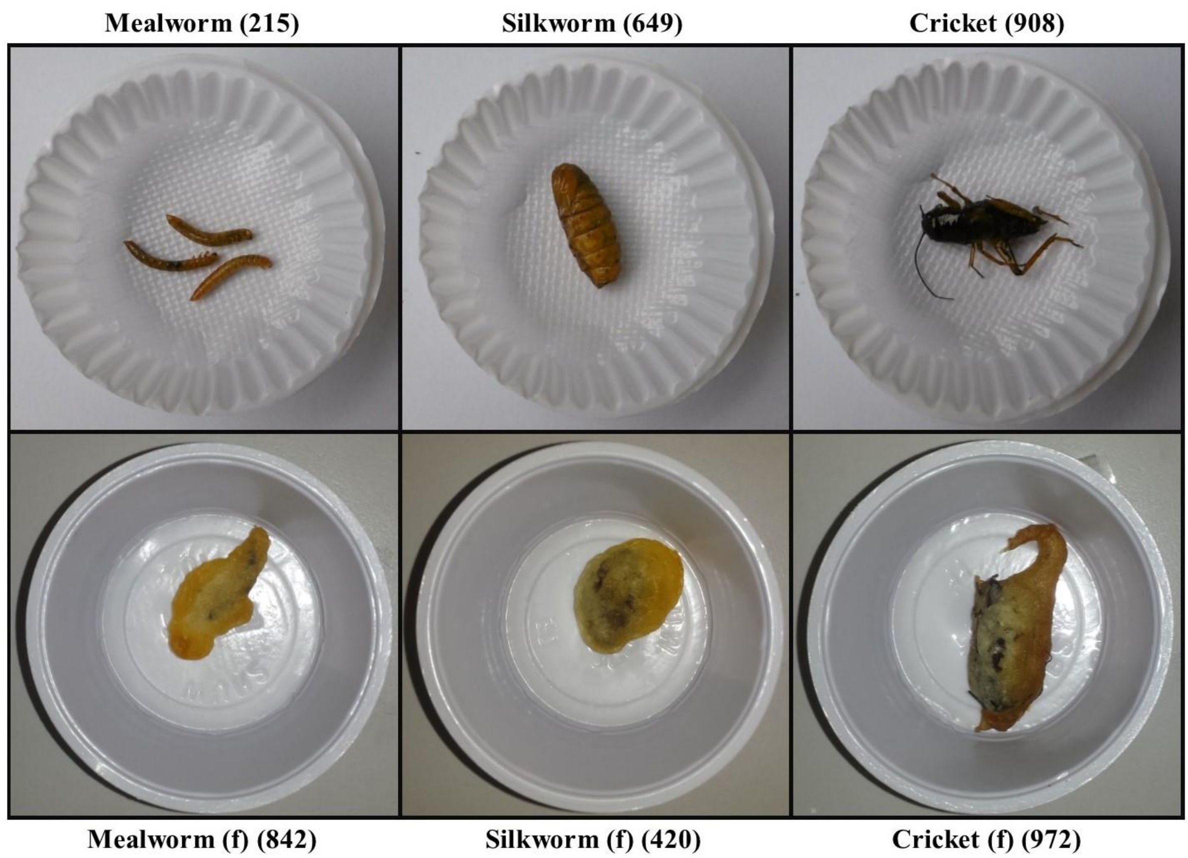


*Figure 14. Insect preparations for tasting session with their identification number (Photograph taken by author).*
(f) means “dough coated and fried”.

During this tasting session, people filled questionnaire (attached in annex 2) divided into three parts: the first part (page 1) focused on personal information (sex, age,…) and experience with entomophagy, the second part (page 2 to 7) concerned the hedonic test and the last part (page 8) included preference of insect origin, feeling about future insect consumption,… Every question was translated each time into the language of the country where the activity took place.

Before the beginning of the activity, some instructions were given to people. The first instruction discouraged people with crustacean allergy to take part in tasting session. Secondly, it was requested to answer personally to the questions and to give back a complete page of questionnaire before receiving another. The last remark consisted of advising people to eat biscuit and drink water between each preparation.

However, some differences were observed between the two countries and they will be presented below.

## 4.1 Vietnam

The tasting session took place on 02/06/16 on NLU campus, in front of the university building. This event was announced with a banner where it was written in Vietnamese “tasting of insects” and people walking in the street were also asked to take part in this experiment

The six preparations were put in different plates which were covered to avoid that participants saw plate content. These plates were disposed on two table rows and each table row was designed by a letter (A or B). The order in which insects were given was randomly determined for one table row while the other table row had the reverse order. Each preparation present in plates was given in small blank cup by Vietnamese students (Figure 15).

Figure 15. Tasting session in Vietnam (Photograph taken by author).

Once someone arrived to take part in the tasting session, he received the first page of the questionnaire and a random identifier with an identification number and the table row where he had to go. Consequently he went to the appropriate table row where he received both food preparation and associated pages of questionnaire. For every preparation, he had to give back the filled page of questionnaire and the small blank cup (empty or not) before receiving the next. After tasting all food, participant received the final page by a Vietnamese student.

At the end of tasting session, all questionnaires were manually encoded on Excel in order to analyse them later.

## 4.2 Belgium

This part of the experiment lasted two days (27/06/16 and 28/06/16) and took place in the sensory analysis room of the food science and formulation unit of Gembloux Agro-Bio Tech. This event was announced on the internet by sending an email to students and staff of Gembloux Agro-Bio Tech and by posting messages on different Facebook groups of students.

Each participant, identified by a number, was isolated in tasting booth (Figure 16) and received food in a different order depending on days. Indeed, the order in which insects were presented was randomly determined for the first day while participants of the second day received insects in the reversed order.

Figure 16. Tasting session in Belgium (Photograph taken by author).

Pages of questionnaire were given one by one and were accompanied or not by a food preparation put in a small blank cup. Once completed, these pages were removed. Following the tasting session, questionnaires were encoded by scanning pages thanks to a computer program (Fizz, Biosystemes, Couternon, France).

# 5 Survey

This last activity took place in Vietnam during two days (04/06/16 and 08/06/16) and consisted in a survey related to entomophagy. Questionnaires (attached in annex 3) were similar to previous questionnaires of tasting session but without questions about actual tasting. This survey was proposed to people in HCMC, in front of a supermarket (Co.opxtra of Thu Duc) or in markets (Viet thang market, Linh Trung market, Thu Ducc market and Dau Moi market). The questionnaire was translated in Vietnamese and participants had the choice to complete the paper by themselves or with the help of a Vietnamese student. All questionnaires were manually encoded in Excel.

# 6 Statistical analysis

Collected data were analysed with Minitab® v.16 software (http://www.minitab.com/fr-FR/default.aspx). One-way ANOVAs were applied to compare weight, mortality, number of eggs and nutritional content (protein, lipid and ash) collected from the mass rearing and Tukey method was then applied. When assumptions of the one-way ANOVA (normality of populations and equality of variances) were not met, Kruskal-Wallis method was used, followed by a comparison of specific samples pairs with Mann-Whitney test.

Concerning tasting session and survey, one-way ANOVA with Tukey method or Kruskal-Wallis with Mann-Whitney test (if assumptions of the one-way ANOWA were not met) were used to analyse quantitative data (questions about strange food, aspect evaluation, taste evaluation,…). For hedonic tests, a generalized linear model test was performed to analyse variances of 2 (country) x 5 (strange) x 2 (sex) x 2 (experience) 6 (product). Finally, Chi-square was applied for quantitative data (question with yes or no as answers, about favourite food,…).

# RESULTS

# 7 Cricket breeding

## 7.1 Interviews

According to Mr Alabi, crickets have to be able to eat, drink, hide and lay during their breeding. Concerning food, its composition has to be close to the following requirements: at least 20% of proteins, from 50 to 60% of carbohydrates and under 6% of fat. The first days of cricket life, food is placed without stand in breeding box to facilitate access by small insects and later, a container can be used. Moreover, food has to be placed at a sufficient distance from the water in order to avoid any mixture. Water supply is also different between cricket development stages with use of two different materials: sponge for larvae and drinking troughs with gravels for other stages. Finally, Mr Alabi has advised to use egg cardboards for hiding places and moist sand or soil (60% of humidity) as laying support.

In Vietnam, Mr Lê Thanh Tùng rears his crickets in plastic cylinders (diameter: 50 cm and height: 35 cm) with density of 2000 crickets/m². His crickets can hide thanks to bamboo baskets (Figure 17) and they are fed with chicken feed and either vegetables or fruits, depending on the availability of each. Once adults, crickets have a mean weight of 1.61 g and every females lay on average from 400 to 500 eggs. Mr Lê Thanh Tùng estimates cricket lifetime at four months while 45 days are required to obtain adults from larvae.

*Figure 17. Breeding container for crickets from the farm of Mr Lê Thanh Tùng (Photograph taken by author).*

## 7.2 Mass rearing

As mentioned above, this activity did not focus on measured parameters and its main goal was to obtain eggs even if some interesting observations were done. Indeed, during the first days of cricket life, a lot of them died in the water of drinking troughs despite gravels. Then, crickets seemed to prefer fish feed than chicken feed because crickets were more numerous in the fish feed containers and amount of this feed decreased more rapidly than chicken feed. Concerning average cricket weight, it reached 0.982 g on 21/04/16 and 1.163 g on 28/04/16.

## 7.3 Preliminary experimental breeding

As mentioned earlier, this activity allowed only to have an idea of the qualities of materials and diets that have been used. Moreover, this breeding knew a high level of mortality which disturbed the measurement of parameters. For these reasons, no statistical test has been done.

The first five days of this second breeding was associated with a large amount of dead crickets which led globally the mean mortality to 61.25 ± 13.21 %. For this reason, results presented in this part concern the period after this event. More precisely two days after that more crickets have been added in order to reach twenty crickets per box again (from 21/04/16 to 27/04/16).

A second event disturbed results of this activity and it concerned box A7[16]. Indeed, on 27/04/16, a hole was observed in the plastic net of this box and it was accompanied by a loss of six crickets. In order to avoid that event influenced result, this box was removed for the analysis related to mortality but it was kept for weight study.

Mortality rates of crickets reached less than 30% and they are consequently lower than the overall mean of the first five days. Generally, crickets fed with fish feed tended to have more alive individuals than those which were received chicken mash. Over this period, fish feed accompanied with elephant grass seemed to have lowest values of cricket mortality (Figure 18) and one box fed with this diet, box A6, did not even have dead cricket.

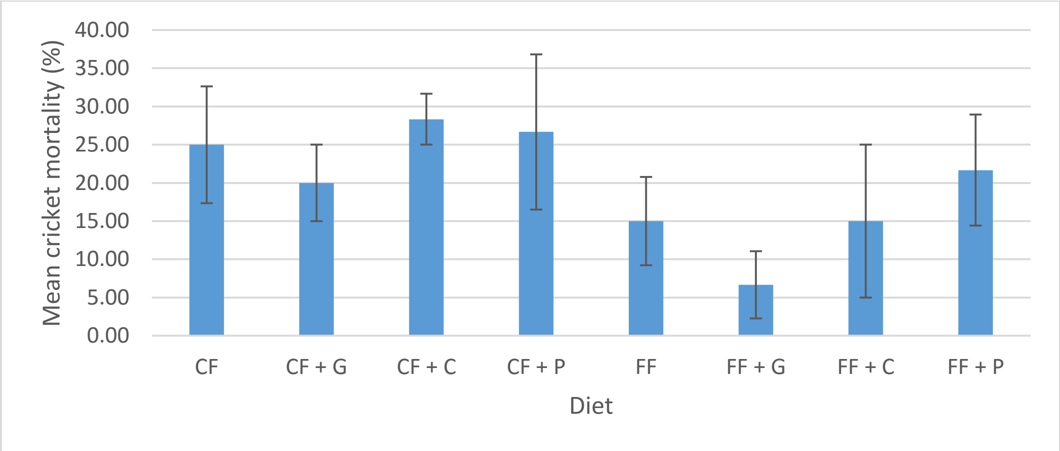


*Figure 18. Mean cricket mortality during 7 days (from 21/04/16 to 27/04/16) in relation to cricket's diet.*
The bars indicate the mean ± the standard error of the mean.
Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

[16] Box A7 means that it was present in the block A and crickets were fed with diet number 7.

Concerning weight, all crickets followed the same trend with an increase in this parameter during the 7 days of monitoring (Figure 19) but this growth seemed to be different between diets. Once again, diets containing fish feed and elephant grass sounded to have the best value in terms of weight gain (Figure 20).

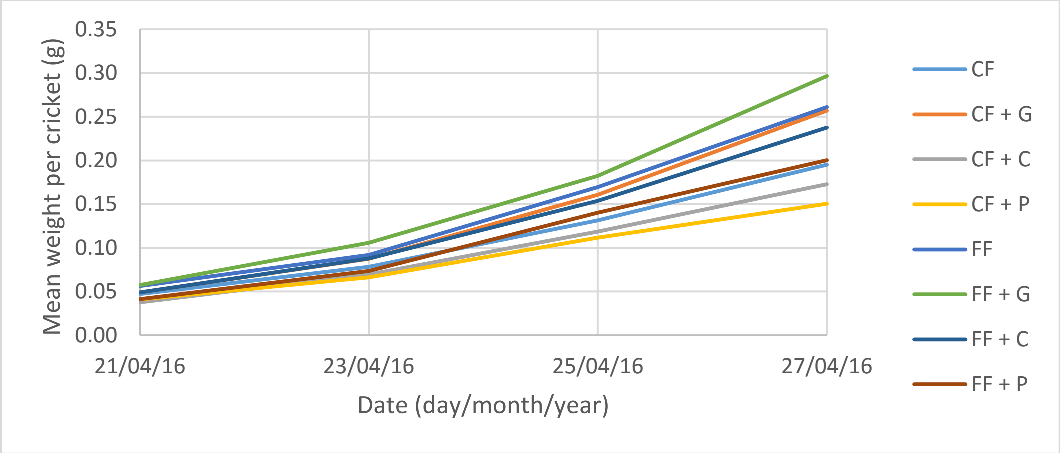


*Figure 19. Evolution of mean weight per cricket over time.*
Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

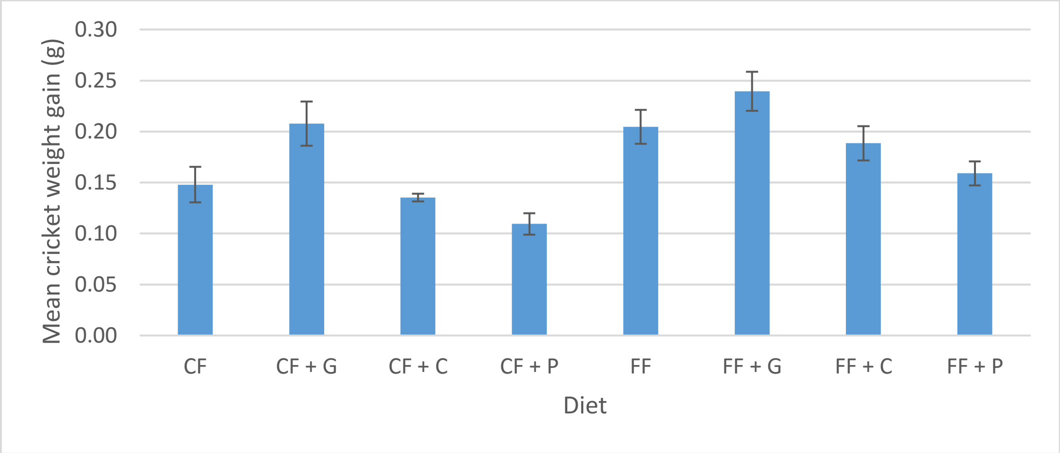


*Figure 20. Mean cricket weight gain during 7 days (from 21/04/16 to 27/04/16) in relation to cricket's diet. The bars indicate the mean ± the standard error of the mean.*
Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

## 7.4 Experimental breeding

As for preliminary experimental breeding, a hole in plastic net was observed for one box (box C5) and it was accompanied by the loss of nine crickets. This box was removed for the analysis related to mortality but was kept for weight studies.

During this experimental breeding, all crickets gained weight and the same trend than for preliminary experimental breeding was observed with fish feed accompanied with elephant grass producing biggest crickets. Moreover, crickets fed with chicken feed and sweet potatoes seemed to diverge from other crickets in terms of weight gain (Figure 21).

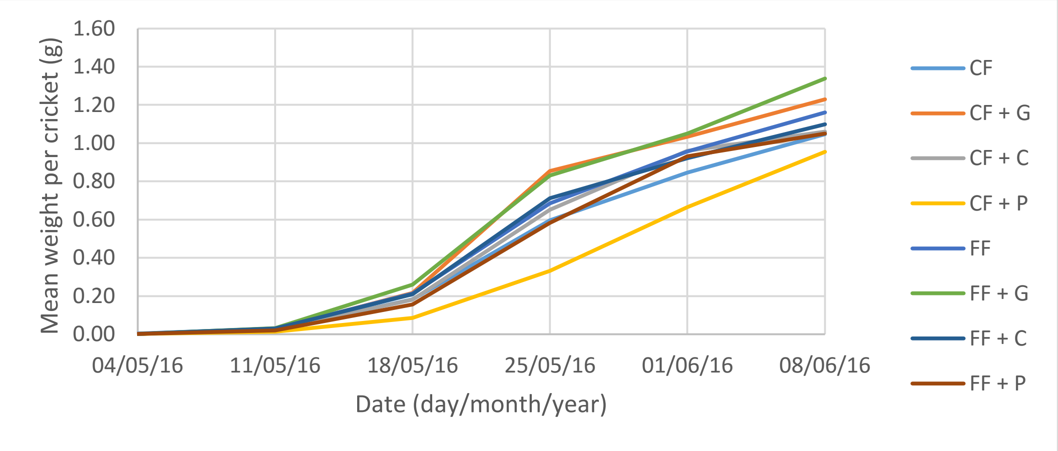


*Figure 21. Evolution of mean weight per cricket over time.*
Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

Concerning analysis of final weight, it showed that crickets fed with fish feed and elephant grass were bigger than those that received chicken feed and sweet potatoes ($F_{7,16}$ = 2.65; $p$ = 0.050; Table 5) while mortality rates of crickets, they did not differ between diets ($H_{7,23}$ = 12.50; $p$ = 0.085; Table 5).

*Table 5. Mean mortality and mean weight per cricket in relation to the experimental diet (feed + extra feed) (± standard deviation).*

| Diet | N | Mean mortality (%) | Mean weight per cricket (g) |
|---|---|---|---|
| CF | 3 | $70.59 \pm 8.11^{a}$ | $1.05 \pm 0.13^{ab}$ |
| CF + G | 3 | $57.93 \pm 4.11^{a}$ | $1.23 \pm 0.03^{ab}$ |
| CF + C | 3 | $65.01 \pm 3.20^{a}$ | $1.06 \pm 0.10^{ab}$ |
| CF + P | 3 | $79.33 \pm 5.41^{a}$ | $0.95 \pm 0.10^{b}$ |
| FF | 3 (2 for mortality) | $50.38 \pm 27.74^{a}$ | $1.16 \pm 0.25^{ab}$ |
| FF + G | 3 | $63.82 \pm 5.45^{a}$ | $1.34 \pm 0.07^{a}$ |
| FF + C | 3 | $69.79 \pm 5.60^{a}$ | $1.10 \pm 0.09^{ab}$ |
| FF + P | 3 | $73.24 \pm 9.18^{a}$ | $1.05 \pm 0.13^{ab}$ |

Different superscript letters indicate a significant difference for the traits. N is the number of replicates.
Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

No statistical difference was observed for egg production between diet ($H_{7,22}$ = 6.53; $p$ = 0.480). It should be noted that two boxes (A4 and B8) were removed for this analysis because there was not any couple and consequently no eggs. Table 6 illustrates this analysis related to diet.

*Table 6. Mean number of eggs per couple and per day in relation to cricket diet (from 02/06/16 to 08/06/16).*

| **Diet** | **N** | **Mean number of eggs per couple and per day** |
|---|---|---|
| CF | 3 | 123.1 ± 148.2[a] |
| CF + G | 3 | 191.5 ± 99.9[a] |
| CF + C | 3 | 122.5 ± 77.5[a] |
| CF + P | 2 | 517 ± 18.4[a] |
| FF | 3 | 91.9 ± 45[a] |
| FF + G | 3 | 256.7 ± 327.8[a] |
| FF + C | 3 | 120.9 ± 14.5[a] |
| FF + P | 2 | 114.0 ± 109.5[a] |

Different superscript letters indicate a significant difference for the traits. N is the number of replicates.
Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

## 7.5 A cricket breeding…but at what price?

### 7.5.1 Extra feed

Elephant grass was generally collected in wild for free or it was bought at small price to owner of grass field (0.09 USD/10 kg) because this resource is abundant in Vietnam.

Concerning other extra feed, 17 sellers on Vietnamese market accepted to answer to questionnaire (attached in annex 1). Mean price per kilogram of carrots and sweet potatoes were respectively of 0.76 ± 0.23 USD and 0.73 ± 0.23 USD. These values were not statistically different ($H_{1,29}$ = 0.06; $p$ = 0.810). All sellers interviewed indicated that the price of these product varied (until 0.65 USD/kg) throughout the year for several reasons. Among them, the main important was weather condition (Figure 22).

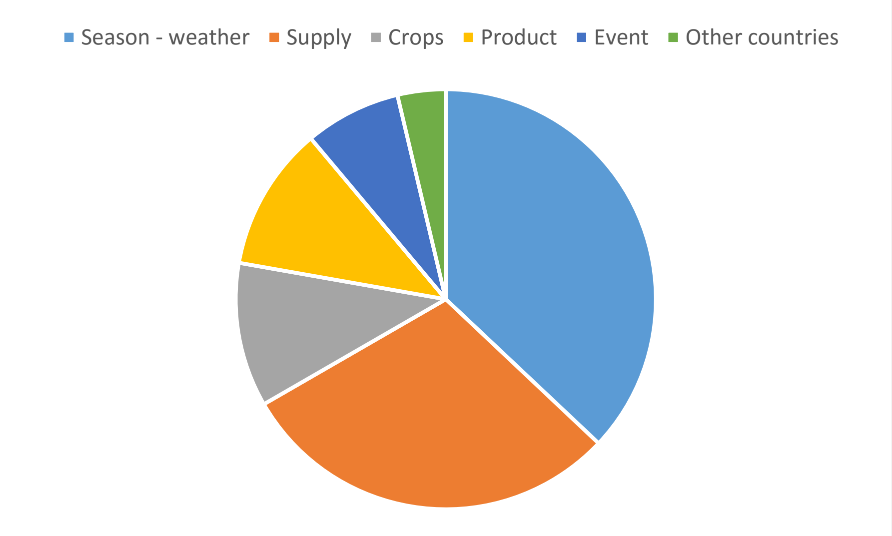


*Figure 22. Causes of price variation for carrots and sweet potatoes (16 respondents).*
Supply refers to buying price and quantity that supplier proposed; crops refers to own seller production; product is associated with quality and size of product; event refers to increase in price during important event; other countries is associated with influence of these countries on Vietnamese price (ex: when Chinese eat one product, price increases).

Most people interviewed (94.12%) sold carrots and sweet potatoes over the year and unsold products were mainly junked but they could also be used to feed animals (Figure 23).

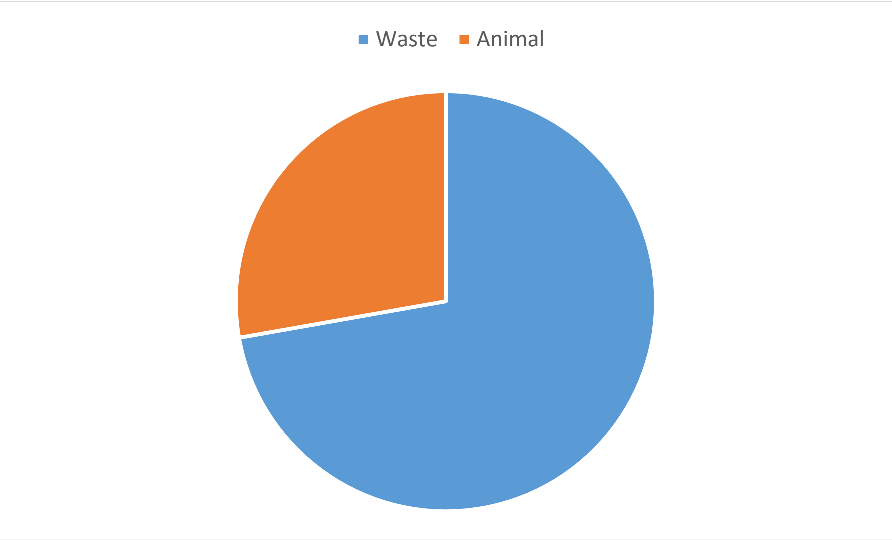


*Figure 23. Future of unsold carrots or sweet potatoes.*

As alternative for these unsold products, 70.59% of sellers were ready to give them for free to an insect farm and 100% accepted to sell unsold products for a cheaper price.

### 7.5.2 Feed

Prices of chicken and fish feed mainly depended on the protein content of these feed. For chicken feed, price varied from 0.50 to 0.58 USD/kg while fish feed had a bigger variation (from 0.51 to 2.47 USD/kg). For all cricket breeding of this work, chicken feed amounted to 0.54 USD/kg and fish feed 1.35 USD/kg.

## 7.6 Chemical analysis

### 7.6.1 Cricket

Reared *G. bimacul*atus were different in terms of protein ($H_{7,24} = 20.21$; $p = 0.005$) and lipid content ($H_{7,24} = 20.53$; $p = 0.005$) but not for ash content ($H_{7,16} = 10.68$; $p = 0.153$). The protein level of reared *G. bimaculatus* was the highest when they received one of the two main feed alone or when chicken feed was accompanied with carrots. Crickets fed with chicken feed and sweet potatoes were the fattest while carbohydrate content of reared crickets varied from 18.51 to 29.80% of dry matter (Figure 24, Table 7).

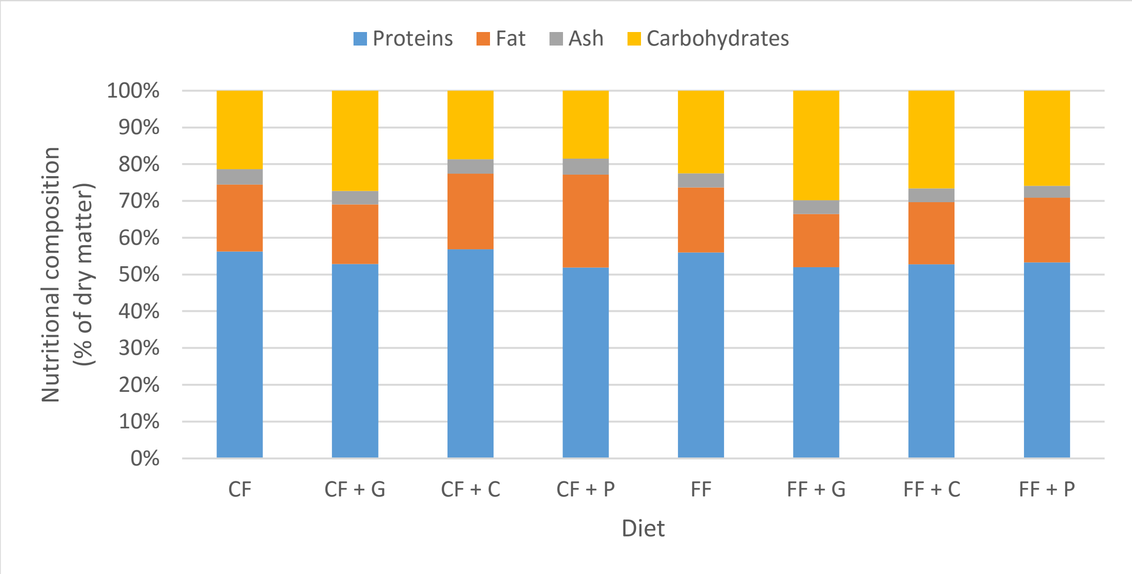


*Figure 24. Nutritional composition of reared crickets in relation to the experimental diet (feed + extra feed) (Based on dry matter).*

Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

*Table 7. Nutritional composition of reared crickets in relation to the experimental diet (feed + extra feed) (Based on dry matter; ± standard deviation).*

| **Diet** | **Proteins (%)** | **Fat (%)** | **Ash (%)** | **Carbohydrates (%)** |
|---|---|---|---|---|
| CF | $56.23 \pm 0.24^{a}$ | $18.24 \pm 0.61^{bc}$ | $4.22 \pm 0.16^{a}$ | 21.32 |
| CF + G | $52.84 \pm 0.12^{bc}$ | $16.20 \pm 0.34^{cd}$ | $3.70 \pm 0.03^{a}$ | 27.26 |
| CF + C | $56.84 \pm 0.88^{a}$ | $20.60 \pm 0.96^{b}$ | $3.92 \pm 0.42^{a}$ | 18.63 |
| CF + P | $51.93 \pm 0.46^{c}$ | $25.22 \pm 2.30^{a}$ | $4.34 \pm 0.34^{a}$ | 18.51 |
| FF | $56.02 \pm 0.21^{a}$ | $17.67 \pm 0.60^{bc}$ | $3.83 \pm 0.13^{a}$ | 22.48 |
| FF + G | $51.95 \pm 0.55^{c}$ | $14.46 \pm 0.85^{d}$ | $3.80 \pm 0.02^{a}$ | 29.80 |
| FF + C | $52.72 \pm 0.56^{bc}$ | $16.96 \pm 1.03^{cd}$ | $3.71 \pm 0.47^{a}$ | 26.61 |
| FF + P | $53.29 \pm 0.09^{b}$ | $17.56 \pm 0.60^{c}$ | $3.27 \pm 0.07^{a}$ | 25.88 |

Different superscript letters indicate a significant difference for the contents.

Abbreviation: CF: Chicken Feed; FF: Fish Feed; G: Elephant Grass; C: Carrots; P: Sweet potatoes.

### 7.6.2 Feed

Fish feed and chicken feed were different in terms of protein ($H_{1,6}$ = 3.86; $p$ = 0.05) and fat contents ($H_{1,6}$ = 3.86; $p$ = 0.05). Fish feed had a higher protein content while chicken feed contains more lipids. For ash, these feeds did not show a significant difference ($H_{1,4}$ = 2.40; $p$ = 0.121) (Figure 25, Table 8).

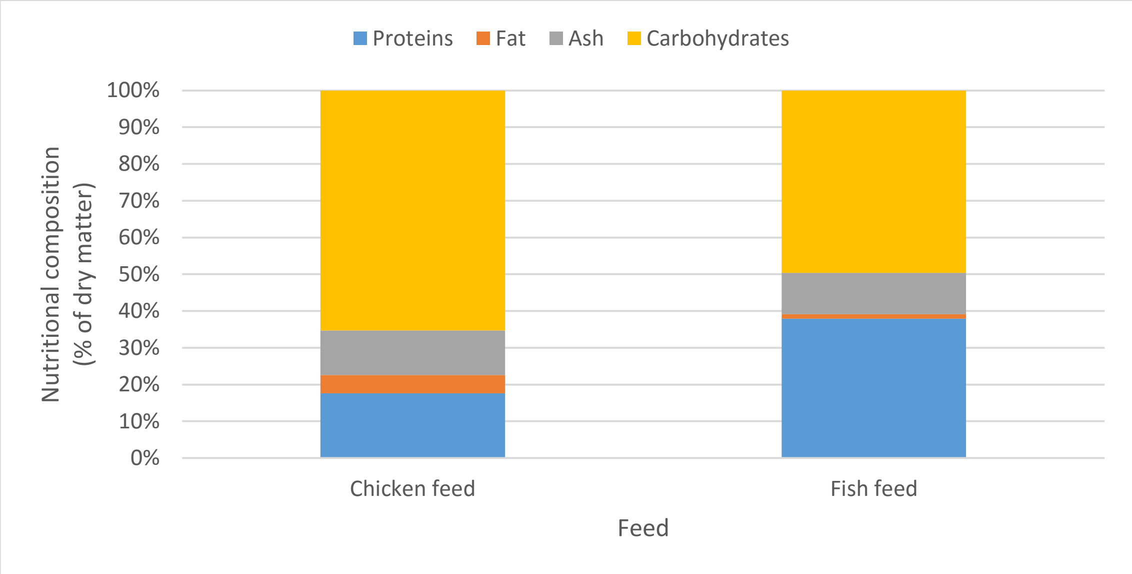


*Figure 25. Nutritional composition of feed used for cricket breeding (Based on dry matter).*

*Table 8. Nutritional composition of feed used for cricket breeding (Based on dry matter; ± standard deviation).*

| Feed | Proteins (%) | Fat (%) | Ash (%) | Carbohydrates (%) |
|---|---|---|---|---|
| CF | 17.64 ± 0.12[b] | 4.98 ± 0.34[a] | 12.06 ± 0.52[a] | 65.33 |
| FF | 37.95 ± 0.18[a] | 1.20 ± 0.21[b] | 11.22 ± 0.04[a] | 49.63 |

Different superscript letters indicate a significant difference for the contents.
Abbreviation: CF: Chicken Feed; FF: Fish Feed.

#### 7.6.3 Extra feed

Three extra feeds had different compositions regarding contents whether proteins ($H_{2,9}$ = 7.20; $p$ = 0.027), lipids ($H_{2,9}$ = 7.20; $p$ = 0.027) and ash ($F_{2,3}$ = 1100.30; $p$ < 0.001). These contents were highest in elephant grass and lowest in sweet potatoes. Concerning carbohydrates, they were more than 75% in each extra feed (Figure 26, Table 9).

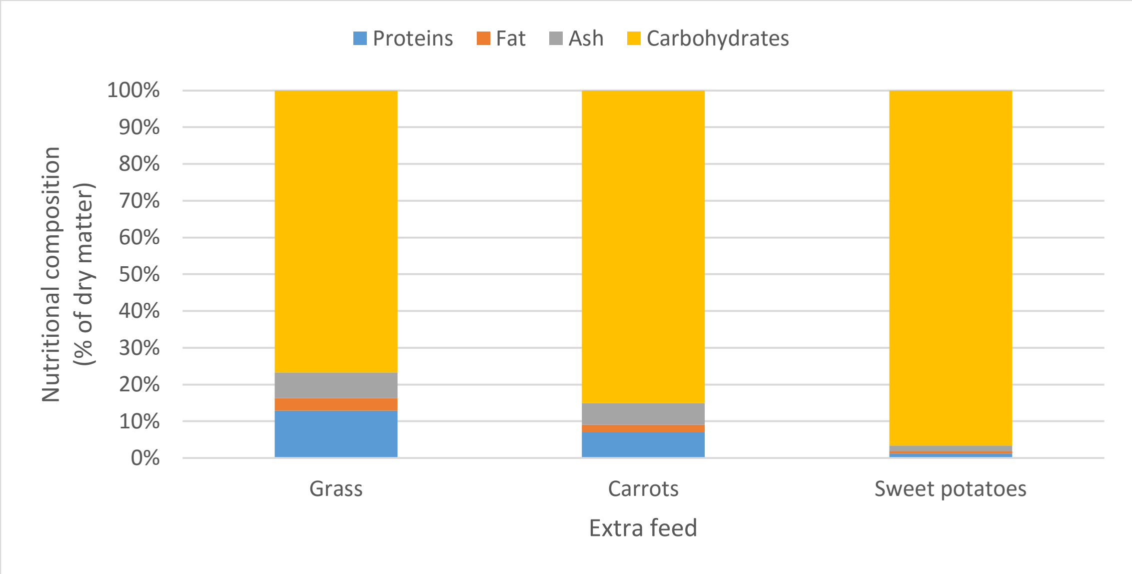


*Figure 26. Nutritional composition of extra feed used for cricket breeding (Based on dry matter).*

*Table 9. Nutritional composition of feed used for cricket breeding (Based on dry matter; ± standard deviation).*

| Extra feed | Proteins (%) | Fat (%) | Ash (%) | Carbohydrates (%) |
|---|---|---|---|---|
| G | 12.91 ± 0.41[a] | 3.37 ± 0.62[a] | 7.00 ± 0.07[a] | 76.72 |
| C | 6.97 ± 0.08[b] | 2.14 ± 0.31[b] | 5.84 ± 0.01[b] | 85.06 |
| P | 1.20 ± 0.12[c] | 0.77 ± 0.31[c] | 1.48 ± 0.20[c] | 96.55 |

Different superscript letters indicate a significant difference for the contents.
Abbreviation: G: Elephant Grass; C: Carrots; P: Sweet potatoes.

# 8 Tasting session

## 8.1 Who participated in this activity?

After deleting incomplete surveys, a total of 120 questionnaires were analysed (61 from Vietnam and 59 from Belgium). Gender parity was almost reached with 55% of men and 45% of women. During tasting session, 78.33% of the respondents were between 18 and 25 years old while other people were older (26-35 years: 15.83%; 36-65 years: 5.83%). Another main characteristic concerns the level of study because more than 90% of the respondents (91.67%) had a university degree.

The number of respondents who had eaten insects before tasting session was statistically different between countries ($\chi^2$ = 7.396; $p$ = 0.007). Indeed, more Belgian people (76.27%) had already consumed insects than Vietnamese participants (52.46%). Even though no difference was noticed between two groups regarding their tendency to try strange food ($H_{1,120}$ = 0.02; $p$ = 0.885; Table 10).

Table 10. Percentage of each answer for following question: "I like to try strange food". Do you agree with this proposal?

| Country | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Belgium | 0.00% | 3.39% | 18.64% | 40.68% | 37.29% |
| Vietnam | 3.28% | 1.64% | 22.95% | 27.87% | 44.26% |

Answers represent a scale from 1 for « disagree strongly » to 5 for « agree strongly ».

## 8.2 Evaluation of insect preparations

After applying generalized linear model, interactions between the countries where the tasting took place and type of product were discovered. Then, the willingness to discover strange food influenced taste and overall evaluation. Taste evaluation seemed also to differ with experience of insect tasting while texture evaluation had an interaction between sex and the willingness to discover strange food (Table 11).

Seeing interaction between country and product mentioned above, each evaluation will be discussed later by separating each country.

Table 11. Results of the generalized linear model test on different parameters measured during tasting session.

| Factor | DF | *F* | *p* | DF | *F* | *p* | DF | *F* | *p* |
|---|---|---|---|---|---|---|---|---|---|
| | Aspect | | | Smell | | | Texture | | |
| Country | 1 | 28.19 | **< 0.001** | 1 | 8.5 | **0.004** | 1 | 23.22 | **< 0.001** |
| Strange | 4 | 2.03 | 0.088 | 4 | 1.64 | 0.163 | 4 | 5.32 | **< 0.001** |
| Sex | 1 | 0.82 | 0.366 | 1 | 0.03 | 0.868 | 1 | 1.63 | 0.202 |
| Experience | 1 | 0 | 0.972 | 1 | 0.3 | 0.581 | 1 | 2.92 | 0.088 |
| Product | 5 | 29.16 | **< 0.001** | 5 | 29.34 | **< 0.001** | 5 | 14.75 | **< 0.001** |
| Country*Sex | 1 | 0.49 | 0.482 | 1 | 0.09 | 0.760 | 1 | 0.97 | 0.324 |
| Country*Experience | 1 | 1.83 | 0.177 | 1 | 0.04 | 0.837 | 1 | 0.99 | 0.32 |
| Country*Product | 5 | 10.66 | **< 0.001** | 5 | 8.44 | **< 0.001** | 5 | 15.55 | **< 0.001** |
| Strange*Sex | 4 | 1 | 0.406 | 4 | 1.47 | 0.209 | 4 | 3.36 | **0.010** |
| Strange*Product | 20 | 0.99 | 0.471 | 20 | 0.83 | 0.683 | 20 | 1.04 | 0.407 |
| Sex*Experience | 1 | 0.71 | 0.399 | 1 | 0.2 | 0.657 | 1 | 0.25 | 0.618 |
| Sex*Product | 5 | 1.55 | 0.171 | 5 | 1.09 | 0.365 | 5 | 0.73 | 0.600 |
| Experience*Product | 5 | 0.27 | 0.932 | 5 | 0.78 | 0.568 | 5 | 0.76 | 0.578 |

| Factor | DF | *F* | *p* | DF | *F* | *p* |
|---|---|---|---|---|---|---|
| | Taste | | | Overall | | |
| Country | 1 | 30.91 | **< 0.001** | 1 | 40.97 | **< 0.001** |
| Strange | 4 | 5.06 | **0.001** | 4 | 3.28 | **0.011** |
| Sex | 1 | 1.79 | 0.182 | 1 | 0.52 | 0.470 |
| Experience | 1 | 4.59 | **0.032** | 1 | 2.13 | 0.145 |
| Product | 5 | 33.34 | **< 0.001** | 5 | 38.66 | **< 0.001** |
| Country*Sex | 1 | 0.01 | 0.904 | 1 | 0.55 | 0.459 |
| Country*Experience | 1 | 0.41 | 0.521 | 1 | 0.61 | 0.435 |
| Country*Product | 5 | 19.98 | **< 0.001** | 5 | 20.72 | **< 0.001** |
| Strange*Sex | 4 | 1.36 | 0.248 | 4 | 1.65 | 0.161 |
| Strange*Product | 20 | 1.13 | 0.308 | 20 | 0.81 | 0.706 |
| Sex*Experience | 1 | 0.64 | 0.423 | 1 | 1.4 | 0.238 |
| Sex*Product | 5 | 0.97 | 0.438 | 5 | 1.52 | 0.182 |
| Experience*Product | 5 | 0.65 | 0.665 | 5 | 0.57 | 0.725 |

DF: degrees of freedom

### 8.2.1 Aspect

Aspect evaluation differed in relation to insect preparations in Vietnam ($H_{5,366} = 61.01$; $p < 0.001$) and in Belgium ($H_{5,354} = 96.30$; $p < 0.001$). Vietnamese people found that mealworm and silkworm were the most repugnant preparations while in Belgium, these insects had the best aspect evaluation when they were dough coated and fried (Table 12).

*Table 12. Mean evaluation of aspect of each insect preparation in each country (± standard deviation).*

| Insect preparation | Aspect evaluation | |
|---|---|---|
| | **Vietnam** | **Belgium** |
| Mealworm | $2.11 \pm 1.32^{c}$ | $2.35 \pm 1.04^{b}$ |
| Mealworm (f) | $3.05 \pm 1.08^{ab}$ | $3.33 \pm 1.22^{a}$ |
| Silkworm | $2.13 \pm 1.19^{c}$ | $1.46 \pm 1.32^{c}$ |
| Silkworm (f) | $3.29 \pm 1.19^{ab}$ | $3.11 \pm 1.38^{a}$ |
| Cricket | $2.79 \pm 1.32^{b}$ | $1.16 \pm 1.27^{c}$ |
| Cricket (f) | $3.61 \pm 1.19^{a}$ | $2.35 \pm 1.43^{b}$ |

This evaluation was based on a scale from 0 for repugnant to 5 for attractive.
(f) means "dough coated and fried". Different superscript letters indicate a significant difference between preparations in one country.

### 8.2.2 Smell

Answers for this evaluation were different in Vietnam ($H_{5,366} = 54.95$; $p < 0.001$) and also in Belgium ($H_{5,354} = 91.79$; $p < 0.001$). Silkworm had lower values for these assessments (Table 13).

*Table 13. Mean evaluation of smell of each insect preparation in each country (± standard deviation).*

| Insect preparation | Smell evaluation | |
|---|---|---|
| | **Vietnam** | **Belgium** |
| Mealworm | $2.66 \pm 1.15^{cd}$ | $2.84 \pm 0.80^{ab}$ |
| Mealworm (f) | $2.91 \pm 0.99^{cd}$ | $3.35 \pm 1.05^{a}$ |
| Silkworm | $2.38 \pm 1.06^{d}$ | $1.50 \pm 1.03^{c}$ |
| Silkworm (f) | $3.03 \pm 1.10^{bc}$ | $3.18 \pm 1.42^{a}$ |
| Cricket | $3.50 \pm 0.99^{ab}$ | $2.48 \pm 0.75^{b}$ |
| Cricket (f) | $3.75 \pm 1.16^{a}$ | $3.37 \pm 1.12^{a}$ |

This evaluation was based on a scale from 0 for repugnant to 5 for attractive. (f) means "dough coated and fried". Different superscript letters indicate a significant difference between preparations in one country.

### 8.2.3 Texture

As mentioned earlier, tendency to try strange food interacted with the gender for this evaluation. Consequently, a separation by gender was performed to analyse these data. According to this analysis, the texture evaluation was influenced by participants' tendency to try strange food for both women ($H_{4,324}$ = 17.80; $p$ = 0.001) and men ($H_{4,396}$ = 10.19; $p$ = 0.037) (Table 14).

*Table 14. Mean score of texture evaluation by gender in relation to tendency to try strange food (± standard deviation).*

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Women | 3.96 ± 1.23$^{ab}$ | 2.71 ± 0.94$^{ab}$ | 2.59 ± 1.31$^{b}$ | 2.98 ± 1.45$^{ab}$ | 3.43 ± 1.31$^{a}$ |
| Men | 2.29 ± 0.51$^{ab}$ | 2.40 ± 2.23$^{ab}$ | 3.01 ± 1.45$^{ab}$ | 2.67 ± 1.32$^{b}$ | 3.14 ± 1.35$^{a}$ |

Evaluation of tendency to try strange food was based on a scale from 1 for « disagree strongly » to 5 for « agree strongly ».
Evaluation of texture was based on a scale from 0 for repugnant to 5 for attractive.
Different superscript letters indicate a significant difference for the texture evaluation for women or men.

Moreover, Vietnamese people ($H_{5,366}$ = 48.61; $p$ < 0.001) and Belgian people ($H_{5,354}$ = 77.78; $p$ < 0.001) differentiate insect preparations for texture (Table 15).

*Table 15. Mean evaluation of texture of each insect preparation in each country (± standard deviation).*

| **Insect preparation** | **Texture evaluation** | |
|---|---|---|
| | **Vietnam** | **Belgium** |
| Mealworm | 2.77 ± 1.21$^{c}$ | 3.43 ± 1.03$^{ab}$ |
| Mealworm (f) | 3.20 ± 1.13$^{bc}$ | 3.69 ± 1.05$^{a}$ |
| Silkworm | 2.58 ± 1.35$^{c}$ | 1.86 ± 1.36$^{d}$ |
| Silkworm (f) | 3.40 ± 1.39$^{ab}$ | 2.39 ± 1.34$^{cd}$ |
| Cricket | 3.65 ± 1.03$^{ab}$ | 1.93 ± 1.42$^{d}$ |
| Cricket (f) | 3.97 ± 1.17$^{a}$ | 2.88 ± 1.32$^{bc}$ |

This evaluation was based on a scale from 0 for repugnant to 5 for attractive. (f) means "dough coated and fried".
Different superscript letters indicate a significant difference between preparations in one country.

### 8.2.4 Taste

Generalized linear model mentioned above showed that this evaluation was influenced by a previous tasting (factor experience). However, after having studied this parameter with the Kruskal-Wallis method, this influence disappeared ($H_{1,720}$ = 2.68; $p$ = 0.101) because the generalized linear model used other factors in these calculations than the Kruskal-Wallis method.

Assessment of the taste was influenced by answer to the question related to strange food ($H_{4,720}$ = 19.37; $p$ = 0.001; Table 16).

*Table 16. Mean score of taste evaluation in relation to tendency to try strange food (± standard deviation).*

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Texture | 3.33 ± 1.23$^{ab}$ | 2.43 ± 1.84$^{ab}$ | 2.76 ± 1.51$^{ab}$ | 2.62 ± 1.40$^{b}$ | 3.15 ± 1.52$^{a}$ |
| N | 12 | 18 | 150 | 246 | 294 |

Evaluation of tendency to try strange food was based on a scale from 1 for « disagree strongly » to 5 for « agree strongly ».
Evaluation of taste was based on a scale from 0 for repugnant to 5 for attractive.
Different superscript letters indicate a significant difference for the taste evaluation. N is the number of replicates.

In Vietnam, this evaluation also differed in relations to insect preparations ($H_{5,366}$ = 56.16; $p < 0.001$) and the same observation was done for Belgian people ($H_{5,354}$ = 120.77; $p < 0.001$). Crickets (f)[17] had high taste values in the two countries (Table 17).

*Table 17. Mean evaluation of taste of each insect preparation in each country (± standard deviation).*

| Insect preparation | Taste evaluation | |
|---|---|---|
| | Vietnam | Belgium |
| Mealworm | $2.83 \pm 1.23^{cd}$ | $3.39 \pm 1.23^{a}$ |
| Mealworm (f) | $2.97 \pm 1.12^{cd}$ | $3.64 \pm 1.05^{a}$ |
| Silkworm | $2.44 \pm 1.30^{d}$ | $0.91 \pm 1.25^{c}$ |
| Silkworm (f) | $3.28 \pm 1.37^{bc}$ | $1.57 \pm 1.40^{c}$ |
| Cricket | $3.71 \pm 1.02^{ab}$ | $2.63 \pm 1.53^{b}$ |
| Cricket (f) | $4.02 \pm 1.07^{a}$ | $3.05 \pm 1.21^{ab}$ |

This evaluation was based on a scale from 0 for bad to 5 for good. (f) means "dough coated and fried".
Different superscript letters indicate a significant difference between preparations in one country.

### 8.2.5 Overall

Overall evaluation was influenced by participants' tendency to try strange food ($H_{4,720}$ = 12.12; $p = 0.017$; Table 18).

*Table 18. Mean score of texture evaluation in relation to tendency to try strange food (± standard deviation).*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Texture | $3.23 \pm 1.12^{ab}$ | $2.57 \pm 1.69^{ab}$ | $2.79 \pm 1.42^{ab}$ | $2.72 \pm 1.40^{b}$ | $3.13 \pm 1.40^{a}$ |
| N | 12 | 18 | 150 | 246 | 294 |

Evaluation of tendency to try strange food was based on a scale from 1 for « disagree strongly » to 5 for « agree strongly ».
Evaluation of texture was based on a scale from 0 for repugnant to 5 for attractive.
Different superscript letters indicate a significant difference for the texture evaluation. N is the number of replicates.

[17] (f) means "dough coated and fried".

Answers for this evaluation were different in Vietnam ($H_{5,366} = 66.55$; $p < 0.001$) and in Belgium ($H_{5,354} = 131.17$; $p < 0.001$). Overall assessment of silkworm had lower values for each country (Table 19).

*Table 19. Mean overall evaluation of each insect preparation in each country (± standard deviation).*

| Insect preparation | Overall evaluation | |
|---|---|---|
| | **Vietnam** | **Belgium** |
| Mealworm | 2.89 ± 1.06$^{cd}$ | 3.43 ± 1.08$^{ab}$ |
| Mealworm (f) | 3.09 ± 1.04$^{c}$ | 3.75 ± 0.90$^{a}$ |
| Silkworm | 2.44 ± 1.17$^{d}$ | 0.93 ± 1.15$^{d}$ |
| Silkworm (f) | 3.24 ± 1.26$^{bc}$ | 1.89 ± 1.36$^{c}$ |
| Cricket | 3.69 ± 0.95$^{ab}$ | 2.29 ± 1.41$^{c}$ |
| Cricket (f) | 4.10 ± 1.02$^{a}$ | 3.09 ± 1.17$^{b}$ |

This evaluation was based on a scale from 0 for good to 5 for bad. (f) means "dough coated and fried".
Different superscript letters indicate a significant difference between preparations in one country.

### 8.2.6 Experience of insect tasting

There was no statistical difference between respondent who had never eaten and people who had already eaten insects before tasting sessions (Table 20).

*Table 20. Mean evaluation of each parameter to the possible previous insect consumption (± standard deviation).*

| | Never eaten | Already eaten | Statistical parameter |
|---|---|---|---|
| Aspect | 2.59 ± 1.40$^{a}$ | 2.56 ± 1.46$^{a}$ | $H_{1,720} = 0.14$ <br> $p = 0.712$ |
| Smell | 2.90 ± 1.11$^{a}$ | 2.92 ± 1.26$^{a}$ | $H_{1,720} = 0.00$ <br> $p = 0.974$ |
| Texture | 3.10 ± 1.31$^{a}$ | 2.92 ± 1.44$^{a}$ | $H_{1,720} = 1.84$ <br> $p = 0.175$ |
| Taste | 3.01 ± 1.43$^{a}$ | 2.80 ± 1.53$^{a}$ | $H_{1,720} = 2.68$ <br> $p = 0.101$ |
| Overall | 3.02 ± 1.32$^{a}$ | 2.84 ± 1.46$^{a}$ | $H_{1,720} = 1.96$ <br> $p = 0.162$ |

Different superscript letters indicate a significant difference for each evaluation.
Each evaluation was based on a scale from 0 for bad or repugnant to 5 for good or attractive.

### 8.2.7 Are you ready to eat again?

Differences were observed in Belgium ($\chi^2 = 95.021$; $p < 0.001$) but not in Vietnam ($\chi^2 = 8.2627$; $p = 0.142$) in terms of willingness to eat these insect preparations in the future. In Belgium, mealworm ((f) or not) and cricket (f) were the most accepted for a future consumption (Table 21).

*Table 21. Percentage of participants who answered "yes" to the following question: "In the future, will you be ready to consume this product?"*

| Insect preparation | Vietnam | Belgium |
|---|---|---|
| Mealworm | 73.77%[a] | 86.44%[a] |
| Mealworm (f) | 85.25%[a] | 98.31%[a] |
| Silkworm | 65.57%[a] | 13.56%[d] |
| Silkworm (f) | 85.25%[a] | 28.81%[c] |
| Cricket | 90.16%[a] | 50.85%[b] |
| Cricket (f) | 98.36%[a] | 74.58%[a] |

(f) means "dough coated and fried". Different superscript letters indicate a significant difference between preparations in one country.

Each evaluation of insect preparations (aspect, smell,… ) was different whether it was done by participants who accepted to eat insects again or by someone who refused (Table 22).

*Table 22. Mean evaluation of each parameter in relation to the willingness to eat again insect preparation (± standard deviation).*

| | Not ready | Ready | Statistical parameter |
|---|---|---|---|
| Aspect | 1.77 ± 1.46[b] | 2.89 ± 1.29[a] | $H_{1,720} = 82.56$ $p < 0.001$ |
| Smell | 2.17 ± 1.22[b] | 3.21 ± 1.06[a] | $H_{1,720} = 92.90$ $p < 0.001$ |
| Texture | 1.80 ± 1.21[b] | 3.46 ± 1.16[a] | $H_{1,720} = 187.31$ $p < 0.001$ |
| Taste | 1.28 ± 1.06[b] | 3.52 ± 1.12[a] | $H_{1,720} = 296.04$ $p < 0.001$ |
| Overall | 1.28 ± 1.06[b] | 3.52 ± 1.12[a] | $H_{1,720} = 320.53$ $p < 0.001$ |

Different superscript letters indicate a significant difference for each evaluation.
Each evaluation was based on a scale from 0 for bad or repugnant to 5 for good or attractive.

### 8.2.8 What is your favourite?

Vietnamese people showed differences concerning their choice of preferred insect ($\chi^2$= 104.281; $p < 0.001$) and the same observation was done in Belgium ($\chi^2$= 61.869; $p < 0.001$). The cricket (f) was the most appreciated by Vietnamese people when it was the mealworm (f) in Belgium (Table 23).

*Table 23. Percentage of people who preferred one insect preparation.*

| Insect preparation | Vietnam | Belgium |
|---|---|---|
| Mealworm | 3.28%$^c$ | 25.42%$^a$ |
| Mealworm (f) | 4.92%$^c$ | 37.29%$^a$ |
| Silkworm | 8.20%$^c$ | 0%$^c$ |
| Silkworm (f) | 9.84%$^c$ | 5.08%$^b$ |
| Cricket | 21.31%$^b$ | 8.47%$^b$ |
| Cricket (f) | 52.46%$^a$ | 23.73%$^a$ |

(f) means "dough coated and fried".
Different superscript letters indicate a significant difference between preparations in one country.

## 8.3 What is your opinion?

Participants' opinions between countries were not statistically different for questions about intention to eat and cook insects in the future (eat: $\chi^2$= 0.053; $p$ = 0.818 and cook: $\chi^2$ = 0.805; $p$ = 0.370). However, Vietnamese and Belgian participants did not show the same acceptance to consume insects fed with food waste ($\chi^2$= 26.554; $p < 0.001$; Table 24).

*Table 24. Percentage of participants who answered "yes" to questions after the tasting of 6 preparations.*

| Questions | Vietnam | Belgium |
|---|---|---|
| 1 | 88.52%$^a$ | 89.83%$^a$ |
| 2 | 90.16%$^a$ | 84.75%$^a$ |
| 3 | 50.82%$^b$ | 93.22%$^a$ |

Questions: 1. Will you be ready to eat insects more often? ; 2. Will you be ready to cook insects in the future? ; 3. Will you accept to consume insects fed with food waste?
Different superscript letters indicate a significant difference between countries.

Answers concerning the origin of edible insects were statistically different in Vietnam ($\chi^2$= 46.156; $p$ < 0.001) and in Belgium ($\chi^2$= 35.222; $p$ < 0.001) Indeed, Table 25 shows that Vietnamese people preferred that insects came from the wild while this origin was not mainly accepted in Belgium.

*Table 25. Percentage of the answer to the following question:*
*"From which origin do you prefer that edible insects come from?"*

| Origin | Vietnam | Belgium |
|---|---|---|
| Breeding | 26.23%$^{b}$ | 54.24%$^{a}$ |
| Unimportant | 9.84%$^{c}$ | 38.98%$^{a}$ |
| Wild | 63.93%$^{a}$ | 6.78%$^{b}$ |

Different superscript letters indicate a significant difference between answers in one country.

Figure 27 illustrates all answers to the following question: "What is (are) your feeling(s) concerning entomophagy". This question accepted several answers per respondent and was asked before and after the tasting in each country.

Before tasting, over half (55%) of the Vietnamese answers were "I am curious" while 27.5% of them were related to an interest for edible insects. In Belgium, these percentages reached respectively 43.92% and 32.98%. Moreover, 13.83% of the Belgian answers showed that some Belgian people were already convinced by entomophagy.

After eating six insect preparations, opinions of respondents were varied in both countries. The answer "I am convinced" increased from 5% to 11.76% in Vietnam and reached 18.81% in Belgium while answers related to curiosity decreased to 21.18% in Vietnam and 28.71% in Belgium. "I am interested" and "I am disgusted" were also more often mentioned after tasting (respectively from 27.5% to 50.59% and from 1.25% to 3.53% in Vietnam and from 32.98% to 41.58% and from 1.06% to 4.95% in Belgium).

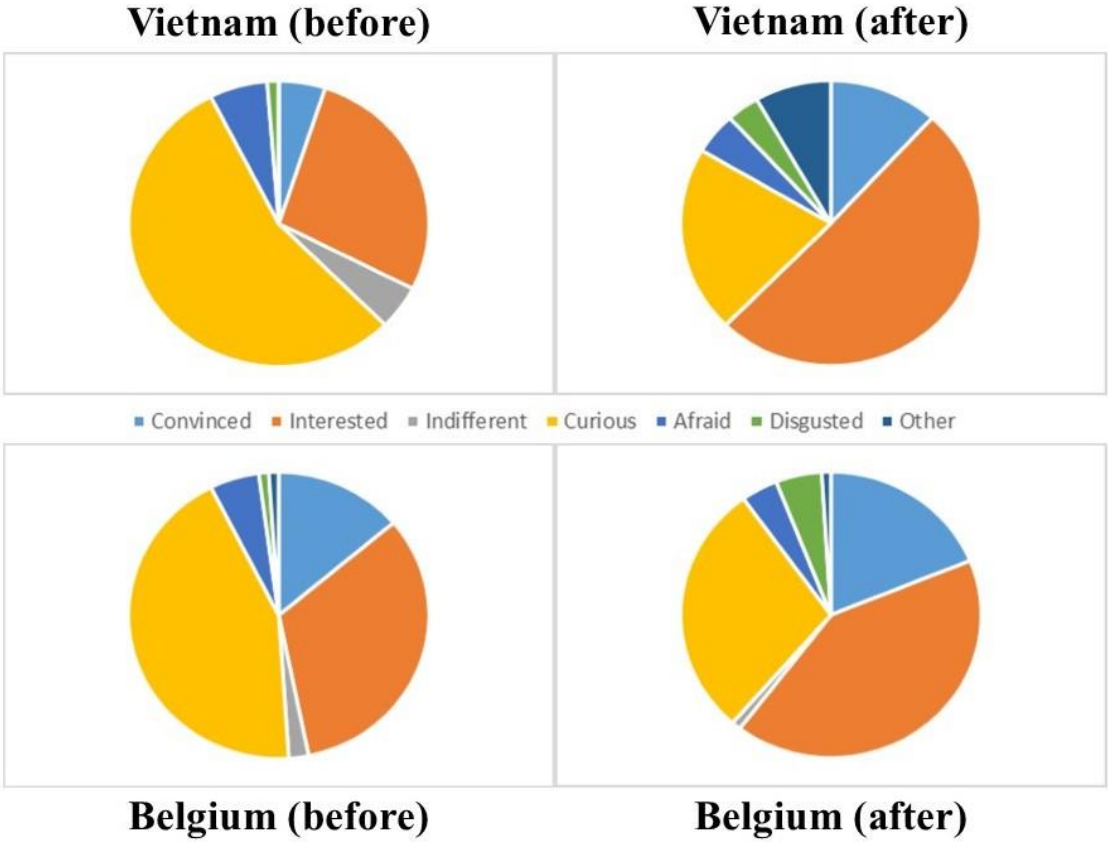


*Figure 27. Opinion of respondents concerning entomophagy (% of answers).*
Upper figures related to Vietnam and lower figures to Belgium. On the left, it concerns opinion before tasting session while opinion after this activity is on the right.

# 9 Survey

After deleting incomplete surveys, a total of 112 questionnaires were analysed, including 44 from market and 68 from supermarket. As for the tasting session, gender parity was almost reached (53.57% of women and 46.43% of men) but there was a higher age variability than tasting session: 4.46% was under 18 years old, 28.57% belonged to the second age class (18-25 years old), 39.29% to the third (26-35 years old), 25% to the fourth (36-65 years old) and 2.68% to the last (more than 65 years old). Higher variability than previous activity was also observed for level study: 1.79% had a primary level, 34.82% a secondary level, 12.50% a graduate level and 50.89% a university degree. Participants' tendency to try strange food was different between the survey and the Vietnamese tasting session ($H_{1,173} = 7.57$; $p = 0.006$; Table 26).

*Table 26. Percentage of each answer for following question: "I like to try strange food". Do you agree with this proposal?*

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Survey | 25% | 8.93% | 14.29% | 16.96% | 34.82% |
| Tasting | 3.28% | 1.64% | 22.95% | 27.87% | 44.26% |

Answers represent a scale from 1 for « disagree strongly » to 5 for « agree strongly ».

Moreover, during the survey, this tendency depended on the study level ($H_{3,112}$ = 12.60; $p$ = 0.006 ; Table 27) but not on the age ($H_{4,112}$ = 0.103; $p$ = 0.103).

*Table 27. Mean score to the following question: "I like to try strange food". Do you agree with this proposal? In relation to study level (± standard deviation).*

| | None | Primary | Secondary | Graduate | University |
|---|---|---|---|---|---|
| Strange | / | 1.50 ± 0.71$^{b}$ | 2.59 ± 1.68$^{ab}$ | 3.79 ± 1.48$^{a}$ | 3.68 ± 1.43$^{a}$ |
| N | 0 | 2 | 39 | 14 | 57 |

Answers represent a scale from 1 for « disagree strongly » to 5 for « agree strongly ».
Different superscript letters indicate a significant difference between study level. N is the number of replicates.

A second comparison between the Vietnamese tasting session and survey was done about feeling about entomophagy. Results presented here for tasting session concern answers before the tasting. As seen on Figure 28, there were more answers related to fear in the survey (40%) than before the tasting session (6.25%). The same observation was done for the answers ‘I am indifferent” (18% for the survey and 5% for the tasting session) and “I am disgusted (9% for the survey and 1.25% for the tasting session). Concerning answers related to interest and curiosity, the reverse trend was noticed with the highest percentage for the tasting session.

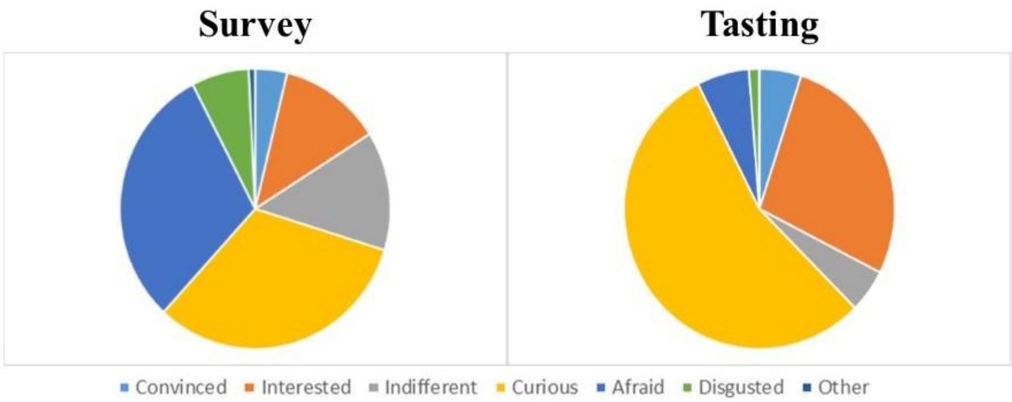


*Figure 28. Opinion of respondents concerning entomophagy (% of answers).*
On the left, figure concerns opinion of the survey while opinion before the tasting session is on the right.

Finally, questionnaires of participants who had never eaten insects before the survey or the tasting session were isolated in order to study their willingness to eat and to cook insects in the future. As a reminder, questions about this future willingness were asked after the tasting of six preparations. This analysis showed a difference between the survey and the tasting session (eat: $\chi^2$= 45.935; $p$ < 0.001 and cook: $\chi^2$= 19.520; $p$ < 0.001; Table 28).

*Table 28. Comparison of answers between people who had never eaten insects before the survey or the tasting session.*

| Questions | Survey | Tasting |
|---|---|---|
| 1 | 12.90%$^{b}$ | 86.21%$^{a}$ |
| 2 | 40.32%$^{b}$ | 89.66%$^{a}$ |

These percentages are related to people who said “Yes” to the following questions: 1. Will you be ready to eat insects more often? ; 2. Will you be ready to cook insects in the future?
Different superscript letters indicate a significant difference between activities.

# Discussion

# 10 Cricket breeding

## 10.1 Materials

In order to avoid that future breeding of *G. bimaculatus* have the same problems than met during these activities, this first part focus on the choice of materials for such breeding.

Firstly, as mentioned in the bibliography, it is important that breeding boxes have openings to ventilate. However, in order to prevent entrance of predators and exit of crickets, these openings have to be covered with a net (Guyot, 1990; Durst et al., 2015). It is advised to use a metallic net for all openings rather than a plastic net. Indeed, as observed during the preliminary experimental breeding and the experimental breeding, plastic net can be easily perforated and represented an entrance for predators or an exit for crickets. Moreover, meshes of net have to be sufficiently small to avoid escape of the first instar larval which measured 2 mm (Guyot, 1990).

Concerning water supply, mass rearing showed the importance of using a sponge during the larval stage of cricket because a container, even filled with gravels, causes a high mortality rate. However, this drinking trough with gravels can be used later, when crickets become bigger.

Finally, Mr Alabi and Mr Lê Thanh Tùng recommended also giving some hiding places as egg cardboards or bamboo baskets for crickets. However, choice concerning this material cannot be assessed with the three breeding done in Vietnam but importance of these hiding places was confirmed by Guyot (1990).

## 10.2 Diet evaluation

In this study, crickets fed with fish feed and elephant grass were heavier than those receiving chicken feed and sweet potatoes. This finding is the only difference of this breeding concerning final weight because crickets fed with other diets cannot be differentiated.

In terms of mortality and fertility, there was no difference between each diet because similar mortality rate and mean number of eggs per couple and per day were recorded. Mortality reached on average more than 50% for each diet and a such high rate was also observed by Oonincx et al. (2015) who studied mortality during a rearing of *A. domesticus*. In our study, this high percentage could be explained by two main reasons: cannibalism of *G. bimaculatus* as well as stress and injuries associated with handling of crickets and rearing materials (Guyot, 1990). However, it should be noted that cricket breeding can have lower mortality than presented above. Indeed, Caparros Megido et al. (2015) achieved a breeding of *Teleogryllus testaceus* Walker 1869 (Orthoptera: Gryllidae) with a cricket mortality with less than 15% for most crickets. Nutritionally, diet without extra feed (chicken or fish feed alone) and diet containing chicken feed and carrots produced crickets with the highest level of proteins. Then, concerning lipid, crickets fed with chicken feed and sweet potatoes were the fattest. This finding can be explained by the highest level of carbohydrates simultaneously for feed and extra feed because carbohydrates take part in the synthesis of triglyceride, a lipid compound (Arrese et al., 2010).

Despite this last observation, no diet seemed to be more interesting than the others when all measurements recorded during this experiment were taken into account. Moreover, extra feed was not required to improve these parameters because crickets fed with only feed showed similar or superior (for protein content) results than crickets that received an extra feed. However, before saying that an extra feed was not advantageous, it would be interesting to measure other parameters. For example, carrots are known as β-carotene suppliers and it would be interesting to know if crickets fed with this extra feed have higher vitamin A content (Singh et al., 2001). Taste evaluation of reared cricket could be also measured if this insect was used for human consumption. Effectively, according to Hanboonsong et al. (2013) and Durst et al. (2015), insects might become tastier when they receive extra feed as vegetables.

While no nutritional advantage was reported for use of extra feed, this component could have an economic interest. Indeed, when extra feed is cheaper than feed, it can partly replace feed in order to decrease the price of diet (Durst et al., 2015). In Vietnam, this lower price was observed for elephant grass because this resource is abundant in this country and is even mainly collected in wild for free. Concerning carrots and sweet potatoes, it is more difficult to compare their prices with those of chicken/fish feed because a price variation was observed throughout the year with factors as weather condition for carrots and sweet potatoes or protein content for chicken/fish feed. But all Vietnamese sellers interviewed seemed to be ready to sell unsold carrots or sweet potatoes for a cheaper price and a large proportion of them even accepted to give them for free. If this opportunity is confirmed, carrots and sweet potatoes could also be used for a cheaper diet. However, this partial substitution of feed by extra feed require to know the amount of each component in order to keep the same insect performance. Another possibility is to merge feed and extra feed, as done with the breeding of Caparros Megido et al. (2015), to develop an experimental diet. This solution also requires to determine the percentage of each component in the diet in order to have the cheaper price with the same insect performance. Finally, concerning the choice between chicken and fish feed, this study showed that measured parameters (mortality, protein content,…) were similar while price was low for chicken feed. For these reasons, chicken feed seems to be more interesting than fish feed.

# 11 Tasting session and survey

In each tasting session, more than 50% of respondents had already eaten insects before this activity but this percentage was higher in Belgium than in Vietnam. This difference between countries was unexpected because Southeast Asia is an area known for insect consumption by humans (Meyer-Rochow, 2010). For example, a study led by Barennes et al. (2015) in Laos, a neighbouring country of Vietnam, showed that only 2% of Laotian respondents have never consumed insects. Moreover, concerning Belgium, edible insects are considered as novel food and are not consumed traditionally (Caparros Megido et al., 2014; Lensvelt et al., 2014; Hartmann et al., 2015). To do the same comparison for Belgium than Vietnam with a neighbouring country, a study led by Hartmann et al. (2015) recorded than a little more than 13% of German respondents have already eaten insect. However, the observation recorded in our study can be explained by several reasons in each country. In Vietnam, entomophagy is uncommon in big towns, as HCMC, and Vietnamese tradition maybe follows the same trend than in Laos where edible insects gradually disappear from the menu because of changes in food habits, decrease in insect availability and increase in insect price (Clark, 2014; Barennes et al., 2015). Concerning the tasting session in Belgium, it took place in the sensory analysis room of the food science and formulation unit of Gembloux Agro-Bio Tech. This university, mainly with its entomology unit, educates students about entomophagy and has organized several events (ex: Insectopolis[18]) where it was possible to taste insects. Consequently, students, which represented the major part of respondents of our study, have more often the opportunity to try this food.

Previous insect consumption did not affect evaluation of insect preparations because no parameter has differently been assessed according to whether evaluation was done by someone who had never eaten insect or not. This result contrasts with the study of Caparros Megido et al. (2016) which showed that the best assessments of taste and aspect were associated with a previous insect consumption. During our tasting sessions, evaluation of insects also depended on countries and within a country, it differed with insect preparations. This double influence was also recorded for the willingness to consume insects in a similar study which took place in China and in Germany (Hartmann et al., 2015). Focusing only on differences of evaluations between the six insect preparations, this finding is consistent with other insect tasting sessions and studies related to entomophagy (Caparros Megido et al., 2014, 2016; Hartmann et al., 2015; Gmuer et al., 2016). Moreover, evaluation of insect preparations varied when it was done by people who were ready to eat insects again or by respondents who refused.

During our hedonic evaluation, Vietnamese respondents preferred crickets and more particularly crickets which were dough coated and fried. These two insect preparations had the best notations for assessments of smell, texture, taste and overall evaluation. In Belgium, crickets dough coated and fried were also chosen as favourite preparations with the two mealworm preparations. These Belgian preferences were related to high scoring of texture, taste and overall assessment. Consequently, these parameters seemed to have an impact on the choice of preferred insect preparations and therefore on consumer acceptance. Effectively, taste and even expected taste are seen as factors which mainly influence consumer acceptance and a bad taste (or expected taste) can be a reason to reject a type of food (Barrena et al., 2012; Hartmann et al., 2015; Balzan et al., 2016; Caparros Megido et al., 2016). The association between food preference and taste assessment was also highlighted by Caparros Megido et al. (2016). Indeed, in their study, food preparation with the best taste evaluation was also the most appreciated food. Concerning our study, the comparison between insects of the same species but cooked differently showed that dough coated and fried insects had a better evaluation of taste. The reason of this difference was the fritter dough surrounding insects because it added known flavour and people prefer generally to eat meal whose taste is familiar (Wansink, 2002; van Huis, 2013; Caparros Megido et al., 2014; Hartmann et al., 2015). Concerning texture and smell, tasting sessions of our study showed that scoring of these parameter were generally higher for preferred insects than other. These observations were consistent with works of Szczesniak (2002) and of Demattè et al. (2014). The first author showed that food acceptance depended on texture but influence of this parameter was hardly studied because it involved several factors (Szczesniak, 2002). Demattè et al. (2014) stated that smell evaluation of neophobic people was more negative for almost all odours and these smells played a role in

[18] Insectopolis is an insect festival which took place on 2001, 2007 and 2014 and organised by Gembloux-Agro Bio Tech. During this event, several activities about insects were proposed as conference, exhibition, visit of the entomological conservatory, tasting session, photo competition,… (Gembloux Agro-Bio Tech, 2014).

food preference. In our study, texture and smell of dough coated and fried insects seemed also to be more appreciated than similar insects which were sautéed with oil. Once again, this kind of insect preparation allowed to bring familiar characteristics such as crispy texture which was more appreciated, as also seen by Caparros Megido et al. (2014). The last parameter is aspect but it did not show a clear difference in the notations between preferred insect preparations and others. However, as for other parameters discussed above, scoring of aspect was higher when insects were dough coated and fried. Effectively, the fritter dough surrounding insects allowed to look like familiar food and it hid the insects. Consequently, fear and other negative perceptions which can exist on seeing these insects decreased (Lensvelt et al., 2014).

Vietnamese people were mainly ready to eat again the six insect preparations while in Belgium, respondents were reluctant for the two preparations with the silkworm and for cricket which was just sautéed in the oil. A possible explanation of this difference is that silkworm is more familiar for Vietnamese people because this insect is sold in market and in supermarket. Concerning cricket, it were not hid by a fritter dough and its entire body (head, legs,…) was consequently visible. A study led by Balzan et al. (2016) in an European country (Italy) showed that legs and eyes had a negative sense and this trend could be similar for Belgian people. Fear or disgust about this vision could be consequently more important for Belgian people than Vietnamese and would thus explain the difference between the scoring of the two countries for aspect of cricket.

After the tasting session, several questions showed again differences between the two countries. The first concerned the answer to the following question: "From which origin do you prefer that edible insects come from?". In Vietnam, wild was the most often chosen while Belgian people preferred that edible insect came from breeding. An explanation could be that Belgian people have a greater sensitivity to hygiene and security of food while Vietnamese participants downplay these aspects. Moreover, Western people see insect breeding as a safe supplier which can be compared with conventional livestock farming (Balzan et al., 2016). Belgium and Vietnam also showed difference related to the acceptance of food waste as cricket feed. More than 90% of Belgian people accepted this while only 50% in Vietnam. This contrast is probably related to a greater sensitivity to waste recycling for Belgian people.

As mentioned before, several studies highlight the importance of events with possibility of insect tasting because general opinion about entomophagy seems to be more positive after the first tasting (Looy et al., 2006; Caparros Megido et al., 2014; Lensvelt et al., 2014). These tasting sessions globally followed the same trend with an increase in confident and interested people, but disgust also increased. Consequently, this event allowed people to make their own opinion and concerning our study, this opinion was generally positive. After the tasting session, more than 80% of respondents in each country were also ready to eat and cook insects in the future. A comparison between two groups of people who had never eaten insects was done. The first group, from the tasting session, tasted insects while the second, from the survey, did not consumed insects. Willingness to consume and cook insects in the future was after compared and this willingness was higher for the group who took part in the tasting session. Consequently, this first experience had a positive impact on the willingness to consume and cook insects in the future. Moreover, this greater willingness, which is positively correlated with liking a novel food for the first time, means that the insect preparations were generally appreciated during the tasting session (Tuorila et al., 1994; Caparros Megido et al., 2014).

Finally, it should be noted that a selection was operated before tasting sessions because these events were announced as events where insects were going to be eaten. Consequently, this advertisement may have attracted curious people or discouraged people who had a disgust against insects for example. Comparison of opinions between people of the survey and people of the tasting confirmed this assumption. Indeed, respondents of the survey were more afraid and disgusted, less interested and curious and their tendency to try strange food was lower than people who took part in the tasting session and who knew that they were going to eat insects. This selection was operated by several tasting sessions as for the study of Sogari (2015) but it would be interesting to avoid this. To do so, invitations and announcements of the insect tasting sessions have not to mention that it is about edible insects.

# CONCLUSION

During the breeding of *G. bimaculatus*, several diets differentiated from others in terms of nutritional parameters. Indeed, the highest protein contents were associated with crickets fed without extra feed (chicken or fish feed alone) or with diet containing chicken feed and carrots. Diet made of chicken feed and sweets potatoes produced the fattest crickets.

However, none of the 8 experimental diets showed a real advantage regarding all parameters tested. Extra feed was consequently not required to improve these factors but it could have an impact on other parameters, as taste of insect or vitamin content, and it could offer an economic advantage. The latter would be possible when extra feed is cheaper because it could decrease the cost of cricket diet by partly replacing feed by extra feed. Nevertheless, additional studies are required to set up this replacement. Chicken and fish feeds showed similar performances during this work but the lower price of chicken feed offered an advantage.

During tasting sessions, evaluation of parameters differed with countries and between preparations. These preparations were differently appreciated in Vietnam and in Belgium but a preference for dough coated and fried preparations was observed in the two countries. This fritter dough allowed to improve evaluation of all parameters because it hid insects, it brought crispy texture and it allowed to create a familiar food. This kind of preparation seems to be interesting to increase consumer acceptance.

The tasting sessions allow people to make their own opinion, good or bad, and increase their willingness to consume insects in the future. In our study, this general opinion was positive even if some additional cases of disgust were observed. This general positive opinion was accompanied with a large number of respondents who were ready to eat insects again. Consequently, entomophagy seems to have the opportunity to spread both in Vietnam and in Belgium.

However, in order to confirm the possibilities for entomophagy to develop, future surveys are required to test the acceptance of other age groups, other study levels in different areas of these countries. It also seems important that future tasting sessions try to avoid announcing that insects are on the menu of these events. This announcement selects people who are curious or ready to taste novel food and consequently, their opinion does not reflect the general perception.

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# ANNEXES

## 12 Questionnaire related to feed and extra feed (Annex 1)

**Do you sell:**

☐ Carrots ☐ Sweet potatoes ☐ Elephant grass

☐ Fish mash ☐ Chicken mash

**What is the price per kg?**

.....................................................................................................................................

.....................................................................................................................................

**Is the price constant during all of the year?** ....................................................................

**If no, can you give me the variation? And why is there this variation?**

.....................................................................................................................................

.....................................................................................................................................

**Do you offer this product all of the year?** .........................................................................

**If no, when? And why?** ..........................................................................................

.....................................................................................................................................

**What do you do with the product that you don't sell?**

.....................................................................................................................................

.....................................................................................................................................

**Are you ready to give these old and unmarketable product for free to a farm which rears insects?**

.....................................................................................................................................

.....................................................................................................................................

.....................................................................................................................................

**If no, are you ready to sell these old and unmarketable product for a cheaper price to the same farm?**

.....................................................................................................................................

.....................................................................................................................................

# 13 Questionnaire related to tasting session (Annex 2)

***Before tasting session***

**Gender:**

☐ Male ☐ Female

**Age:** .........................................................................................................................

**Nationality:** ...............................................................................................................

**Level of study:**

☐ None
☐ Primary
☐ Lower secondary
☐ Upper secondary
☐ Superior (non-university)
☐ Superior (university)

**« I like to try strange food ». Do you agree with this proposal?**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Disagree strongly) | | | | (Agree strongly) |

**What is (are) your feeling(s) concerning entomophagy (several answers are possible):**

☐ Confident
☐ Interest
☐ Indifferent
☐ Other
☐ Curiosity
☐ Fear
☐ Disgust

**Have you already eaten insects?**

☐ Yes ☐ No

**<u>If yes</u>, how often do you eat insects?**

☐ Once per year or less frequently
☐ Once per month
☐ Once per week
☐ Once per day

**<u>If yes</u>, where do you often eat insects (several answers are possible)?**

☐ At home
☐ In restaurant
☐ Other
☐ In the market
☐ In the street

## ***One page for each insect preparations***

**Note the product:**

**Aspect**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Repugnant) | | (Neutral) | | (Attractive) |

**Smell**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Repugnant) | | (Neutral) | | (Attractive) |

**Texture**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Repugnant) | | (Neutral) | | (Attractive) |

**Taste**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Bad) | | (Neutral) | | (Good) |

**Overall assessment**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Bad) | | (Neutral) | | (Good) |

**In the future, will you be ready to consume this product ?**

☐ Yes ☐ No

## After tasting session

**Which food do you prefer to eat?**

☐ 649 ☐ 972 ☐ 215 ☐ 420 ☐ 842 ☐ 908

**After this tasting, what is (are) your feeling(s) concerning entomophagy (several answers are possible):**

☐ Confident ☐ Curiosity
☐ Interest ☐ Fear
☐ Indifferent ☐ Disgust
☐ Other

**Will you be ready to eat insects more often?**

☐ Yes ☐ No

**From which origin do you prefer that edible insects come from?**

☐ Breeding ☐ Unimportant ☐ Nature

**Will you accept to consume insects which have been fed with food waste?**

☐ Yes ☐ No

**Will you be ready to cook insects in the future?**

☐ Yes ☐ No

# 14 Questionnaire related to survey on market and supermarket (Annex 3)

**Gender:**

☐ Male ☐ Female

**Age:** ..........................................................................................................................

**Nationality:** ...............................................................................................................

**Level of study:**

☐ None ☐ Upper secondary
☐ Primary ☐ Superior (non-university)
☐ Lower secondary ☐ Superior (university)

**Profession**: ..............................................................................................................................

**« I like to try strange food ». Do you agree with this proposal?**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |
| (Disagree strongly) | | | | (Agree strongly) |

**What is (are) your feeling(s) concerning entomophagy (several answers are possible):**

☐ Confident ☐ Curiosity
☐ Interest ☐ Fear
☐ Indifferent ☐ Disgust
☐ Other

**Have you already eaten insects?**

☐ Yes ☐ No

**<u>If yes</u>, how often do you eat insects?**

☐ Once per year or less frequently ☐ Once per week
☐ Once per month ☐ Once per day

**<u>If yes</u>, where do you often eat insects (several answers are possible)?**

☐ At home ☐ In the market
☐ In restaurant ☐ In the street
☐ Other

**Will you be ready to eat insects more often?**

☐ Yes ☐ No

**From which origin do you prefer that edible insects come from?**

☐ Breeding ☐ Unimportant ☐ Nature

**Will you accept to consume insects which have been fed with food waste?**

☐ Yes ☐ No

**Will you be ready to cook insects in the future?**

☐ Yes ☐ No