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Understanding entomophagy : cultural diversity and consumer behavioural traits from Gabon to Belgium

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Abstract

Faced with global population growth and the expected rise in food demand, the search for alternative protein sources represents a major challenge for food security and the sustainability of food systems. In this context, edible insects appear as a promising option due to their nutritional, environmental and socio-economic benefits. However, their acceptance and integration into diets vary considerably across cultural contexts. This thesis aims to improve understanding of entomophagy in both traditional and non-traditional cultural settings through the study of two contrasting countries: Gabon and Belgium.

This thesis is structured around five scientific articles based on empirical surveys involving a total of 2,808 respondents from Belgian and Gabonese populations.

Firstly, the research provides an inventory of the diversity of edible insects available in Gabon and analyses current consumption patterns. The results highlight a high level of species richness, with 75 species recorded, but relatively limited consumption that is less widespread than in some neighbouring African countries. This situation can be explained by a combination of structural factors, including high levels of urbanisation, the continued availability of other animal protein sources, the limited integration of insects into formal distribution channels, as well as cultural and ethnic factors influencing dietary practices.

Secondly, the thesis analyses the behaviours, attitudes and levels of acceptance of Belgian consumers, including young people under 18 years of age, who are often underrepresented in the literature on this topic. The results indicate strong awareness of entomophagy in Belgium, alongside a moderate but highly variable level of acceptance across individuals. However, actual consumption remains limited and occasional, revealing a persistent gap between attitudes and dietary behaviour.

The comparative analysis highlights the central role of culture as a key determinant of knowledge, attitudes and practices related to insect consumption. Acceptance of entomophagy does not depend solely on individual or nutritional factors but is embedded within cultural systems that define what is considered edible. The differences observed between Gabon and Belgium, as well as within each country, illustrate the complexity of these dynamics.

The thesis also identifies several sociodemographic determinants of acceptance, particularly gender and field of study or occupation, although their effects vary across contexts. Individuals who are most open are generally men and those exposed to scientific environments or food innovation-related fields.

With regard to the promotion of entomophagy in Western contexts, two innovative strategies were examined among Belgian respondents: the preferred timing of consumption and the impact of preparing an insect-based food. The results show no clearly preferred consumption moment, but a marked avoidance of breakfast among Belgian respondents. Moreover, preparing an insect-based food significantly improves sensory evaluation, suggesting the existence of a “I cooked it myself” effect, observed for the first time in the Western literature on edible insects, and representing a promising avenue for enhancing acceptance.

More broadly, the effectiveness of promotion strategies depends strongly on context, consumer profiles and associated emotions, particularly disgust. No single approach appears universally effective, highlighting the need for combined strategies adapted to cultural contexts.

Finally, this thesis highlights the structural, regulatory and industrial challenges that hinder the development of the edible insect sector, particularly in Europe. Despite growing interest and certain regulatory advances, the sector continues to face economic uncertainty, production constraints and still limited demand. The integration of insects into Western food systems thus appears to be a long and complex process, driven more by cultural transformations than by technological or nutritional innovations.

In conclusion, this research shows that entomophagy cannot be regarded solely as a technical solution to global food challenges. It is deeply shaped by cultural representations, social norms and established dietary practices. While edible insects may contribute to diversifying protein sources and supporting the transition towards more sustainable food systems, their large-scale adoption will require long-term structural, cultural and behavioural changes.

Résumé

Face à la croissance démographique mondiale et à l'augmentation attendue de la demande alimentaire, la recherche de sources de protéines alternatives constitue un enjeu majeur pour la sécurité alimentaire et la durabilité des systèmes alimentaires. Dans ce contexte, les insectes comestibles apparaissent comme une option prometteuse en raison de leurs avantages nutritionnels, environnementaux et socio-économiques. Cependant, leur acceptation et leur intégration dans les régimes alimentaires varient fortement selon les contextes culturels. Cette thèse vise à améliorer la compréhension de l'entomophagie dans des contextes culturels traditionnels et non traditionnels, à travers l'étude de deux pays contrastés : le Gabon et la Belgique.

Cette thèse s'articule autour de cinq articles scientifiques, reposant sur des enquêtes empiriques ayant mobilisé un total de 2 808 répondants issus de populations belges et gabonaises.

Dans un premier temps, la recherche dresse un inventaire de la diversité des insectes comestibles disponibles au Gabon et analyse les caractéristiques de la consommation actuelle. Les résultats mettent en évidence une forte richesse spécifique, avec 75 espèces recensées, mais une consommation relativement limitée et moins répandue que dans certains pays africains voisins. Cette situation s'explique par une combinaison de facteurs structurels, notamment l'urbanisation élevée, la disponibilité continue d'autres sources de protéines animales, la faible intégration des insectes dans les circuits formels de distribution, ainsi que des facteurs culturels et ethniques influençant les pratiques alimentaires.

Dans un second temps, la thèse analyse les comportements, attitudes et niveaux d'acceptation des consommateurs belges, y compris les jeunes de moins de 18 ans, souvent peu représentés dans la littérature sur ce sujet. Les résultats indiquent une forte sensibilisation à l'entomophagie en Belgique, accompagnée d'un niveau d'acceptation modéré mais variable selon les individus. Toutefois, la consommation effective reste limitée et occasionnelle, révélant un écart persistant entre attitudes et comportements alimentaires.

L'analyse comparative met en évidence le rôle central de la culture comme déterminant majeur des connaissances, attitudes et pratiques liées à la consommation d'insectes. L'acceptation de l'entomophagie ne dépend pas uniquement de facteurs individuels ou nutritionnels, mais s'inscrit dans des systèmes culturels qui définissent ce qui est considéré comme comestible. Les différences observées entre le Gabon et la Belgique, ainsi qu'au sein même de ces pays, illustrent la complexité de ces dynamiques.

La thèse identifie également plusieurs déterminants sociodémographiques de l'acceptation, notamment le genre et le domaine d'études ou d'activité, bien que leurs effets varient selon les contextes. Les individus les plus ouverts sont généralement des hommes et des personnes exposées à des environnements scientifiques ou liés à l'innovation alimentaire.

En matière de promotion de l'entomophagie en Occident, deux stratégies innovantes ont été étudiées auprès de répondants belges : le moment de consommation privilégié et l'impact de la préparation d'un aliment à base d'insectes. Les résultats montrent l'absence de moment de consommation spécifiquement privilégié, mais une éviction nette du petit-déjeuner chez les répondants belges. Par ailleurs, la préparation d'un aliment à base d'insectes améliore significativement l'évaluation sensorielle, suggérant l'existence d'un effet de type « je l'ai cuisiné moi-même », observé pour la première fois dans la littérature occidentale sur les insectes comestibles, et constituant une piste prometteuse pour renforcer l'acceptation.

Plus largement, l'efficacité des stratégies de promotion dépend fortement du contexte, des profils de consommateurs et des émotions associées, en particulier le dégoût. Aucune approche unique ne s'avère universellement efficace, ce qui souligne la nécessité de stratégies combinées et adaptées aux contextes culturels.

Enfin, cette thèse met en lumière les défis structurels, réglementaires et industriels qui freinent le développement du secteur des insectes comestibles, notamment en Europe. Malgré un intérêt croissant et certaines avancées réglementaires, la filière reste confrontée à des incertitudes économiques, à des contraintes de production et à une demande encore limitée. L'intégration des insectes dans les systèmes alimentaires occidentaux apparaît ainsi comme un processus long et complexe, davantage conditionné par des transformations culturelles que par des innovations technologiques ou nutritionnelles.

En conclusion, cette recherche montre que l'entomophagie ne peut être considérée uniquement comme une solution technique aux défis alimentaires mondiaux. Elle dépend profondément des représentations culturelles, des normes sociales et des pratiques alimentaires établies. Si les insectes comestibles peuvent contribuer à la diversification des sources de protéines et à la transition vers des systèmes alimentaires plus durables, leur adoption à grande échelle nécessitera des changements structurels, culturels et comportementaux à long terme.

Foreword

As a child, I was fascinated by observing wildlife in my garden. In particular, I was intrigued by the organisational structure of ants and enjoyed feeding spiders with a variety of insects. However, my knowledge of insects was limited, and I could only name common insects such as flies, ants, and bees. My knowledge of these arthropods expanded during my scientific secondary education, but it remained relatively basic throughout my childhood.

In 2011, I joined Gembloux Agro-Bio Tech – University of Liège to study bioengineering as part of my scientific curriculum. During this period, I developed an interest in entomology and became aware of the diversity of insects in our gardens and other biotopes around the world. This awareness was gained through zoology courses and, more specifically, with the insect box (*i.e.* a box made by each student that had to contain 50 different insect families from at least 12 orders. Each insect had to be spread out and identified). Since then, I have seen *Bombylius sp.* L., 1758 (Bombyliidae: Diptera) and *Chrysis sp.* L., 1761 (Chrysididae: Hymenoptera) flying in my garden. In 2015, I completed a two-month internship at the Royal Belgian Institute of Natural Sciences (Brussels, Belgium). My work focused on the altitudinal variability of ants (and their competitors) from Papua New Guinea (**Figure 0-1**).

Figure 0-1. *Orectognathus sp*. Smith, 1853 (Hymenoptera: Formicidae).

At the same time, during one of his lectures, Professor Frédéric Francis presented Entofood, a spin-off company working in the field of entomophagy (*i.e.* eating insects). This was my first contact with this topic, which I promptly identified as promising. Edible insects represent a resource that is not currently used in many regions, and there is a need to identify alternative food sources to feed our growing population. Given my natural curiosity, I wanted to try this food, which was available in Belgian supermarkets. My first experience of consuming insects was with crunchy larvae of the greater wax moth seasoned with paprika (**Figure 0-2**). Following this tasting, I shared my opinion on Facebook: "The aspect and texture are a bit strange at first, but personally it was OK. And it tastes like nothing I have ever tasted before. But it is currently quite expensive (200€/kg)".

Figure 0-2. Crunchy larvae of the greater wax moth [*Galleria mellonella* (L., 1758) (Pyralidae: Lepidoptera)] seasoned with paprika.

Following this experience, I decided to pursue my academic career in the field of entomophagy. In 2016, I successfully completed my master's thesis on this topic, conducted under the supervision of Professor Frédéric Francis and Dr. Rudy Caparros Megido, among others. My work focused on the production and consumption of edible insects, and was conducted in part at Nong Lam University (Ho Chi Minh City, Vietnam; **Figure 0-3**; Detilleux, 2016). This master's thesis expanded my knowledge in the field of entomophagy and marked my first research experience in this area.

Figure 0-3. Overview of the master's thesis.
A: experimental breeding of *Gryllus bimaculatus* De Geer, 1773 (Orthoptera: Gryllidae);
B: insect-based foods for tasting session. Source: Detilleux (2016).

Upon completion of my bioengineering degree, I was hired in 2017 as an assistant and PhD student in the Economy and Rural Development Laboratory at Gembloux Agro-Bio Tech – University of Liège. As a PhD student, I wished to extend my research into entomophagy as part of a larger project, which was beyond the scope of a master's thesis. Consequently, I developed a research project on entomophagy, identifying specific areas for further investigation within the scientific literature, with the support and guidance of my supervisors and thesis committee. From my perspective, entomophagy has consistently presented a challenge over the years. As you will see in this document, edible insects represent an ideal solution for enhancing the sustainability of our diet. Nevertheless, despite this potential, there is still a great deal of opposition to entomophagy. The main aims of my research were consequently to understand the underlying reasons for this reluctance and identify potential triggers for the development of entomophagy. I frequently focused my efforts on the consumer, rather than on the other actors in the chain, to achieve these aims. This document outlines the details of my PhD project and the related outcomes. It also provides a comprehensive overview of entomophagy, with the aim of disseminating knowledge about this food to interested audiences. Throughout these pages, however, it is important to bear in mind that entomophagy should not be considered as a universal solution to all food-related issues, but rather as one of several potential solutions.

References

Detilleux L., 2016. Comparative study of edible insect acceptance between Vietnam and Belgium and potentiality of cricket breeding in Southern Vietnam (Ho Chi Minh City).

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il ira loin ». Je ne sais pas s'il avait raison, mais j'espère que ce travail lui aurait fait plaisir et l'aurait rendu fier.

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List of acronyms

AD: Anno Domini (used for years after the birth of Christ)

ANOVA: Analysis of Variance

BC: Before Christ (used for years before the birth of Christ)

CENAREST: National Center for Scientific and Technological Research (Gabon)

CIA: Central Intelligence Agency

DIY: Do-It-Yourself

DRC: Democratic Republic of the Congo

EFSA: European Food Safety Authority

EU: European Union

FAO: Food and Agriculture Organization

FASFC: Federal Agency for the Safety of the Food Chain (Belgium)

FCFA: Franc of the Financial Community of Africa

GAIN: Global Alliance for Improved Nutrition

GDP: Gross Domestic Product

GLM: Generalised Linear Model

IBU: Item-By-Use

INSAB: National Higher Institute of Agronomy and Biotechnology (Gabon)

IPIFF: International Platform of Insects for Food and Feed

IRAF: Institute of Agricultural and Forestry Research (Gabon)

MUFA: Monounsaturated Fatty Acids

PA: Pennsylvania (USA)

PUFA: Polyunsaturated Fatty Acids

RTBF: Radio-Télévision Belge de la Fédération Wallonie-Bruxelles (Belgium)

SFA: Saturated Fatty Acids

SHC: Superior Health Council (Belgium)

ULiège: University of Liège (Belgium)

USA: United States of America

USD: United States Dollar

USTM: University of Sciences and Technologies of Masuku (Gabon)

WHO: World Health Organization

WTB: Willingness-To-Buy

WTP: Willingness-To-Pay

4Ps: Product, Price, Place, and Promotion

Chapter 1

Introduction

1. Contextual background

1.1. Global context

Producing enough food for a growing population has always been a challenge throughout history. The issue was already raised by Tertullian, a church leader, in the third century AD. Later, Thomas Malthus (18th century) or Paul Ehrlich (20th century) were also driven by the same concerns. Today, the debate is not over yet, as it is estimated that more than 9 billion people will need to be fed worldwide by 2050 (Alexandratos *et al.*, 2012). Food demand will therefore increase considerably, while current demand can already not be fully met as chronic hunger affects about 735 million people in the world (FAO *et al.*, 2023). Composition of food demand is also expected to change by 2050 with a shift towards foods derived from livestock: beef, sheep, goats, pork, poultry, dairy milks, and eggs (Komarek *et al.*, 2021). This trend will be mainly driven by rapid urbanization and rising incomes in developing countries, particularly in Asia (van Huis, 2013). In 2050, the urban model will be increasingly widespread, with almost 7 out of 10 people will live in cities (FAO *et al.*, 2023). The world will also become richer, and the economic gaps between the current developed and developing countries will be reduced (Alexandratos *et al.*, 2012). In this context, Komarek *et al.* (2021) estimate a 38% rise in the demand for food derived from livestock between 2020 and 2050.

However, diets rich in livestock-derived foods are often associated with chronic diseases (*e.g.*, colorectal cancer, cardiovascular disease, type 2 diabetes) and obesity, as these foods are high in energy and saturated fatty acids. Livestock production has also significant adverse impacts on the environment: use of fresh water, deforestation and loss of valuable habitats, pollution, *etc.* (Salter, 2019; Hawkey *et al.*, 2021). Finally, livestock triggers growing public concerns such as increasing prices, animal welfare and ethical issues, risk of zoonoses, and antibiotic resistance. To mitigate one part of these issues, the livestock sector is continually improving (*e.g.*, dietary control, manure management, design of housing system) but alternative foods with ecological, socio-economic, and health benefits are also required. Potential candidates with such features include plant-based meat analogues, in vitro meat, edible insects, and single-cell proteins (*i.e.* microalgae, bacteria, and fungi). All these candidates, excepting in vitro meat, have been part of many local diets around the world for a long time. But today, food sector intends to promote these foods worldwide so as to meet growing food demand in a sustainable way (van Huis, 2013; Popescu *et al.*, 2014; Loyon *et al.*, 2016; Kumar *et al.*, 2023).

In recent times, edible insects have particularly attracted the attention of industry and scholars who believe in their potential as a food source but also as a feed source (van Huis, 2022). However, the current work is exclusively concerned with insects as a food source.

1.2. Definition

“The practice of humans eating insects as food” is known as entomophagy (Cambridge Dictionnary, 2025). This word was built upon Greek terms “entomos” (*i.e.* insect) and "phagein" (*i.e.* eating), and it was mentioned in the literature for the first time in the eighteenth century. Today, the term entomophagy is common in scientific literature as related research is increasing (Gahukar, 2013; Evans *et al.*, 2015; van Huis, 2022). However, this term does not seem to be understood by the general population, who might prefer alternatives such as "eating insects" or "insects as food" (Caparros Megido *et al.*, 2016).

1.3. History

Cave paintings, engravings and coprolite[1] analyses revealed that edible insects were included in the diet of early man. Later in history, many authors in all ages (*e.g.*, Aristotle in 4th century BC, Charles Darwin in 19th century) described scenes of eating insects in their works and provided information on how to catch and cook them. Such evidences of entomophagy were highlighted worldwide (Van Itterbeeck *et al.*, 2012; Olivadese *et al.*, 2023). In this context, it can be stated that insects have been eaten by humans on every continent except Antarctica at some point in history (Schabel, 2010). However, in certain regions of the world (*e.g.*, Europe), their use has remained highly restricted throughout history, despite clear evidence of consumption (Pérez-Lloréns, 2024).

1.4. Entomophagy in 2026

Entomophagy has been documented in 128 countries, with at least two billion people worldwide regularly engaging in this eating practice. A recent inventory revealed that 2190 insect species are consumed across the globe. These species are distributed globally, occurring in a wide range of climatic conditions and in both aquatic and terrestrial ecosystems. Many of these insects can be found in multiple regions simultaneously, reflecting similar living conditions. However, the mere occurrence of these insects does not necessarily indicate their consumption, and entomophagy varies greatly between regions due to differences in culture and food preferences (van Huis *et al.*, 2013; Omuse *et al.*, 2024). Given the central role of culture in shaping food-related behaviours, it is important to clarify how this concept is understood in the present thesis.

In this thesis, the concept of culture is based on the definition proposed by Lo Monaco *et al.* (2019), who describe culture as a set of shared meanings (*i.e.*, collective interpretations and representations), norms and practices transmitted within a population and maintained over time. In this context, culture is understood as a collective framework that influences food-related behaviours through social transmission across generations. The expressions "cultures with entomophagy tradition" and "cultures without entomophagy tradition" are used in a contextual sense. They distinguish populations in which insect consumption has historically been integrated into dietary practices and transmitted across generations from those in which it has not. These categories are not absolute, as the prevalence and acceptance

[1]Coprolite : a piece of excrement that has become fossilized (Cambridge Dictionnary, 2025).

of entomophagy may vary within and between countries. Based on this conceptualization, the following sections provide an overview of the current state of entomophagy in cultures with and without an entomophagy tradition.

1.4.1. Cultures with entomophagy tradition

Eating insects is particularly common in tropical and subtropical communities. These populations typically inhabit areas characterized by a dense cover of shrubs, herbaceous vegetation, and mixed closed forests, which can provide a suitable habitat for a diverse range of edible insect species. Other specific conditions prevalent in the (sub)tropics also facilitate the harvesting of edible insects: (1) insects are generally larger in size, (2) many insect species are gregarious, (3) many non-seasonal insect species, (4) presence of many host plants (*e.g.*, bamboo for bamboo caterpillars), and (5) transfer of knowledge from one generation to another. Tropical and subtropical areas mainly correspond to African, Asian, and Latin American countries. Among them, five countries consume more than 200 insect species: Mexico (450), Thailand (272), India (262), the Democratic Republic of the Congo (DRC) (255), and China (235). Insects are frequently consumed entire, although they can also be processed (*e.g.*, granules, paste) (van Huis *et al.*, 2013; Raheem *et al.*, 2019a; Omuse *et al.*, 2024).

1.4.2. Cultures without entomophagy tradition

In Western countries, entomophagy is not a common practice and is sometimes regarded as an unacceptable dietary choice, despite the availability of some edible insects. To illustrate, Germany records 15 potentially edible insect species within its territory, but none is currently consumed. The Western rejection of this eating habit can be attributed to several factors: (1) disgust towards entomophagy, (2) high neophobia, (3) dearth of information about insect-based food, (4) dearth of prior experience of entomophagy, and (5) dearth of interest and indifference. Nevertheless, the aversion towards eating insects is gradually being supplanted by a more positive attitude in Western countries. There, edible insects are now frequently regarded as a sustainable novel food source (van Huis *et al.*, 2013; Raheem *et al.*, 2019a; Omuse *et al.*, 2024).

1.5. Main orders of edible insects eaten around the world

The 2190 species of edible insects are classified into 24 distinct orders, including Coleoptera, Hymenoptera, Lepidoptera, Orthoptera and Hemiptera. These 5 orders are the most common, accounting collectively for 88.7% of all edible insect species. It is also important to consider other orders, although their species diversity is lower. One example is Isoptera, which includes 66 termite species that are widely consumed throughout the world, particularly in Africa (Fombong *et al.*, 2018; Omuse *et al.*, 2024).

1.5.1. Coleoptera

Coleoptera is the most diverse insect order in terms of edible species, with 705 identified species (Omuse *et al.*, 2024). The majority of these species are terrestrial, but over 10% are aquatic, principally among the family Dytiscidae (Ramos-Elorduy *et al.*, 2009). The palm weevil from genus *Rynchophorus* (Curculionidae) is the most popular edible beetle in the tropics, where it is a significant pest of palms. Three common species belonging to this genus are known to be consumed primarily in three different continents: *R. ferrugineus* (Olivier, 1790) in Asia, *R. palmarum* (L., 1758) in America, and *R. phoenicis* (Fabricius, 1801) in Africa (van Huis *et al.*, 2013). Such edible insects are mainly collected from the wild, with the harvesting process serving to decrease the pest pressure. However, in some areas, the growing demand for these species has led to the development of mass-producing systems. Once collected, these three species are consumed in a variety of ways including boiled, fried, grilled, processed into biscuit, cake, or snack bar, raw, stewed, *etc*. (Cartay *et al.*, 2020; Fernando *et al.*, 2023; Siddiqui *et al.*, 2024). In Europe, the mealworm [larva of *Tenebrio molitor* L., 1758 (Tenebrionidae)] is one of the most promising insect species for human consumption and was the first to receive marketing approval from the European Commission in 2021 (Skotnicka *et al.*, 2021; Vale-Hagan *et al.*, 2023). This species is a valuable source of nutrients and is particularly well accepted by Europeans consumers. The sensory profile of the larva exhibits a brittle texture, an intense flavour of cereals, nuts and umami, and a slight flavour of vegetables. Mealworms are already produced on a large scale in European countries (*e.g.*, France, the Netherlands) for use as fish and bird feed. To illustrate, Ynsect rears tons of *T. molitor* per week in France. In terms of research, there has been an eightfold increase in studies relating edible mealworms between 2015 and 2020 (Gkinali *et al.*, 2022).

1.5.2. Hymenoptera

In Hymenoptera insects, all developmental stages are commonly consumed, including eggs, larvae, pupae, and adults (van Huis *et al.*, 2013). This order is almost exclusively (97%) represented by edible species of ants (Formicidae), bees (Apidae), and wasps (Vespidae) (Omuse *et al.*, 2024).

The consumption of ants is a common practice in many countries, driven notably by their medicinal benefits. In China, traditional medicine uses ants to treat a range of ailments including cancer, depression, inflammation, insomnia, itching, rheumatoid arthritis, *etc*. Additionally, ants are also employed to enhance immunity, resist the effects of aging, and improve sexual dysfunction. The black ant [*Polyrhachis vicina* Roger, 1863 (Formicidae)] is particularly used for such applications in China and neighbouring countries, as it contains many compounds with pharmaceutical activities (*e.g.*, alkaloids, superoxide dismutase, unsaturated fatty acids) (Rastogi, 2011; Zhang *et al.*, 2023).

The rearing of the honey bee [*Apis mellifera* L., 1758 (Apidae)] has a long history, with evidence of their domestication dating back to the period of ancient Egypt. Historically, beekeeping was primarily focused on the production of honey (Al Naggar *et al.*, 2018). However, in the present era, the objective has expanded to encompass the production of other valuable products for use in the cosmetic (*e.g.*, beeswax, royal jelly) and pharmaceutical (*e.g.*, propolis, venom) industries, as well as the pollination of crops (van Huis *et al.*, 2013). Furthermore, honey bees are also considered as ideal nutritious food items, and they are already a popular food source in African and Asian countries. In addition to *A. mellifera*, other species of bees within the Apidae family are also consumed throughout the world, including *Apis dorsata* Fabricius, 1793; *Cephalotrigona capitata* (Smith, 1854); *Hypotrigona gribodoi* (Magretti, 1884); *Tetragonisca angustula* (Latreille, 1811); *Trigona clavipes* (Fabricius, 1804); and *Xylocopa* sp. Latreille, 1802 (Ghosh *et al.*, 2016; Omuse *et al.*, 2024).

The consumption of wasps has been particularly well documented in China, India and Japan, but such consumption is also recorded in other countries outside of Asia. The larvae, pupae and adults are consumed, although the former two stages are often preferred due to their palatability. A variety of dishes are prepared with wasps, including mochi, sushi and frying wasps with chicken eggs. Prior to the preparation of these dishes, the wasps are removed from their nest, as this is the medium used to maintain the insects' freshness when they are collected or purchased from the market. Given the considerable success of these insects, the local supply is sometimes insufficient to meet demand, necessitating the importation of wasps from neighbouring countries (Feng *et al.*, 2010; Nonaka, 2010; Thangjam *et al.*, 2020).

1.5.3. Lepidoptera

Lepidoptera, or the order of butterflies and moths, is a group of insects that are commonly consumed during their larval stage (*i.e.* caterpillars). However, the pupa (*i.e.* chrysalis) and adult stages are also eaten. Edible lepidopterans are found on every continent, except Antarctica. In Africa, they represent the most consumed insects, providing a significant source of nutrients and income for many households. There, Saturniidae is the most widespread edible family across the continent, including three major species: *Cirina butyrospermi* Vuillet, 1911; *Cirina forda* Westwood, 1849; and *Gonimbrasia belina* Westwood, 1849 (van Huis *et al.*, 2013; Siddiqui *et al.*, 2023). The shea caterpillar (*C. butyrospermi*) is consumed in many rural African zones, where it contributes seasonally to food security (Payne *et al.*, 2020a). These caterpillars are typically harvested just before their final pupation, allowing them to feed on the leaves of the shea tree (*Vitellaria paradoxa* C.F.Gaertn., 1807; Ericales: Sapotaceae). Despite the defoliation caused by *C. butyrospermi*, there is no negative impact on the yield of shea nuts, which are collected to make shea butter for food and cosmetic purposes. Such findings prompt the reconsideration of the pest status of the shea caterpillar in relation to the shea tree (Payne *et al.*, 2020b). Regarding the mopane worm (*G. belina*) and the pallid emperor moth (*C. forda*), they are the most popular edible species in Western African countries and in other African countries such as DRC and South Africa. They are mainly harvested as caterpillars on shrubs and trees, and their consumption, often limited to rural areas, is increasing in urban areas. These caterpillars are eaten for their taste, but also for their cultural significance and nutritional value (Nemadodzi *et al.*, 2023). In Mexico, more than 60 species of Lepidoptera are consumed, and most of them also belong to the Saturniidae family. On the Mexican plate, caterpillars are sometimes accompanied by different foods such as cheese, eggs, tortillas, tuna or rice (Ramos-Elorduy *et al.*, 2011).

1.5.4. Orthoptera

The order Orthoptera is comprised of crickets, grasshoppers, katydids, and locusts. The characteristic hind legs of these insects, which are developed for jumping, serve as a reliable identifier. Orthopterans are found in a variety of terrestrial habitats (*e.g.*, desert, forest, grassland) but they tend to thrive in tropical regions, where the warm climate allows for rapid development. A total of 310 species of orthopterans are consumed as food, including both the nymph and adult stages. It is relatively simple to obtain orthopterans, either by collecting them in the wild, which is often facilitated by the large size of the insects and their presence in swarms, or by rearing them, which is straightforward and has a high production rate (Ingrisch *et al.*, 2009; Meena *et al.*, 2021; Omuse *et al.*, 2024).

Within the order Orthoptera, the cricket is the most consumed insect, with consumption recorded in 49 countries. A total of 62 cricket species are consumed and the most common species include *Acheta domesticus* (L., 1758) (Gryllidae); *Brachytrupes membranaceus* (Drury, 1770) (Gryllidae); *Gryllotalpa orientalis* Burmeister, 1838 (Gryllotalpidae); *Gryllus assimilis* (Fabricius, 1775) (Gryllidae); and *Gryllus bimaculatus* De Geer, 1773 (Gryllidae). The sensory attributes of crickets exhibit variability, apart from texture, which is often constant. Crickets are relatively crunchy due to their chitinous exoskeleton, and the act of eating them produces a sound similar to that of eating crackers. However, the consumption of crickets with less chitin (*e.g.*, nymphs) reduces the crunchiness and facilitates the digestion of these insects (Magara *et al.*, 2021).

The consumption of orthopterans has been a traditional practice in Madagascar for centuries. A study conducted in 2019 recorded 37 edible orthopteran species, with most of these species endemic to Madagascar and belonging to the Acrididae family (*i.e.* family of grasshopper). These insects are primarily collected by Malagasy children during their leisure time, typically while playing in the rice fields or on the way home from school. Once collected, some part of the insect's body (*e.g.*, wings, legs, head, and intestines) may be removed before the insects are eaten grilled or fried, and as a snack or in a main meal (Van Itterbeeck *et al.*, 2019).

In the Mexican state of Oaxaca, the consumption of orthopterans also has a rich history, with a particular food item named chapulines. Chapulines are edible grasshoppers from different species, including *Sphenarium purpurascens* Charpentier, 1842 (Pyrgomorphidae) and *Melanoplus mexicanus* (Saussure, 1861) (Acrididae). In Oaxaca, chapulines are prepared in three distinct ways: (1) sautéed in oil and garlic, (2) substituting oil with lime juice in the first recipe and adding more garlic and salt, and (3) cooked in chiles. Chapulines are particularly popular in Oaxaca, where they can be found on restaurant menus. They are frequently served with a warm tortilla and guacamole, but they are also incorporated into familiar dishes such as omelettes, quesadillas and sorbets (Hurd *et al.*, 2019).

1.5.5. Hemiptera

Edible insects from the Hemiptera order, which include species of bugs and cicadas, are consumed at all developmental stages (*i.e.* egg, nymph, and adult). These insects can be both aquatic and terrestrial. In Mexico, approximately 150 species from the Hemiptera order are consumed, with most belonging to the Pentatomidae family (*e.g.*, *Edessa cordifera* Walker, 1868; and *Euschistus lineatus* Walker, 1867). However, a different family, Corixidae, constitutes ahuahutle, also known as Mexican caviar. This food consists of a mixture of eggs from different bug species, including *Corisella* sp. Lundblad, 1928; *Krizousacorixa* sp. Hungerford, 1930; and *Notonecta* sp. L., 1758. Renowned for its high protein content, ahuahutle is considered one of the most nutritious Mexican foods (van Huis *et al.*, 2013; Moreno *et al.*, 2022).

Hemipterans are also employed in the food industry, where they are used as a source of carminic acid, a red colourant derived from the dried bodies of female *Dactylopius coccus* Costa, 1835 (Dactylopiidae). Carminic acid is produced in the wild by this cochineal to protect itself from predators. In the food industry, once extracted, the colourant is known under the code name E120 and is used in the production of a variety of foods, including meats, candies, sodas (*e.g.*, Coca-Cola), yogurts, and others. Beyond food application, carminic acid is also employed in the cosmetics, pharmaceutical, textile, and plastics industries (Borges *et al.*, 2012; Caparros Megido *et al.*, 2015).

1.6. Overview of entomophagy

1.6.1. Nutritional value

Insects are regarded as a highly nutritious food source. However, their nutritional composition varies considerably from one species to another, as well as depending on intrinsic (*e.g.*, developmental stages, sex) and extrinsic (*e.g.*, diet, light, temperature) factors (Rumpold *et al.*, 2013; Oonincx *et al.*, 2021). Consequently, the nutritional generalities highlighted in this section do not apply to all edible insects.

Proteins are the main nutrient of insects, with contents ranging from 40 to 75% in their dry matter. The amino acid composition of hemimetabolous species is constant throughout their development, whereas holometabolous species exhibit variation between developmental stages, with immature and mature insects showing different morphological characteristics. Edible insects usually provide all the essential amino acids required by adult humans, although methionine may sometimes be deficient. Insect proteins are highly digestible, but this digestibility can be altered by the association of proteins with chitin or by processing methods such as drying (Rumpold *et al.*, 2013; Tang *et al.*, 2019; Oonincx *et al.*, 2021).

Lipids represent the second most important nutrient in edible insects, accounting for 10 to 70% of the dry matter. Commercially reared insects are typically fatter than their wild counterparts. This is due to the reduced energy expenditure in captivity, coupled with the fact that reared insects have greater access to diets with a higher energy content. Most insects are unable to synthesize linoleic acid and linolenic acid (*i.e.* two essential polyunsaturated fatty acids with major functions for humans) but they can obtain these nutrients from their diet. The diet also affects the production of cholesterol, as insects are unable to synthesize this sterol de novo. Consequently, the cholesterol is obtained directly from the diet or following a conversion of plant sterols provided by the diet to cholesterol (Rumpold *et al.*, 2013; Tang *et al.*, 2019; Oonincx *et al.*, 2021).

In addition to proteins and lipids, edible insects constitute also a valuable source of micronutrients, namely minerals and vitamins. Many minerals are abundant in insects, including copper, iron, magnesium, manganese, phosphorus, selenium, and zinc. Insects also contain calcium and potassium, although often in insufficient quantities to meet human needs. The low calcium levels observed in these animals are primarily due to their non-mineralised exoskeleton, which is mainly composed of proteins and chitin. Nevertheless, the minerals present in insects may be rendered unavailable by antinutritional factors (*e.g.*, oxalate, phytate, and tannin). Regarding vitamins, insects are a rich source of most B vitamins such as B2, B5, B6, B8, and B12 but they are not an efficient source of vitamins A and C. Previously, vitamin D was also assumed to be deficient in insects. However, recent research has highlighted considerable variability between species, with some insects capable of producing de novo vitamin D (Rumpold *et al.*, 2013; Tang *et al.*, 2019; Oonincx *et al.*, 2021).

In the insect body, carbohydrates other than fibre are almost absent, whereas fibre is abundant. The precise composition of the insect fibre remains uncertain, although it clearly includes chitin, a polymer that provides rigidity to the exoskeleton of insects (Oonincx *et al.*, 2021). The digestion of chitin by humans is possible due to the presence of chitinase in gastric juices. However, the success of this process is dependent on the enzymatic activity status (*i.e.* active or inactive) (Kouřimská *et al.*, 2016).

Finally, in terms of energy content, edible insects are typically more caloric than meat, as their major components are proteins and lipids (Rumpold *et al.*, 2013). A more detailed comparison of these two food categories reveals that both edible insects and meat are rich in nutrients, including those essential for human health (**Table 1-1**). Moreover, there is a significant variation in nutritional content within each food category, depending on comparable parameters (*e.g.*, diet, sex, species). It is therefore inaccurate to suggest that edible insects are more nutritious than meat, or vice versa, but they have quite similar nutritional profile, except for vitamin C and dietary fibre which are exclusively present in insects (Payne *et al.*, 2016; Orkusz, 2021).

Table 1-1. Energy and nutrient contents of some common edible insects and meat (/100 g of edible portion).

		A. domesticus (adult)	*T. molitor* (larva)	*T. molitor* (adult)	Beef sirloin	Chicken breast	Pork shoulder
Energy (kcal)		153	247	178	112	98	13.2
Protein (g)		20.5	25.0	24.13	20.1	21.5	16.89
Essential amino acid (mg)	Histidine	480	559	680	706	941	584
	Isoleucine	940	835	1030	997	1251	821
	Leucine	2050	1400	1960	1680	1579	1432
	Lysine	1100	1070	1050	1844	2022	1483
	Methionine	300	400	300	560	631	487
	Phenylalanine	650	654	620	911	772	699
	Threonine	740	770	810	951	911	966
	Tryptophane	130	216	260	232	360	235
	Valine	1070	1280	1500	1038	1345	927
Non-essential amino acid (mg)	Alanine	1800	1640	1810	1210	1441	1064
	Arginine	1250	1380	1020	1309	321	1085
	Aspartic acid	1720	1520	1660	1862	2157	1540
	Cystine	170	163	140	265	279	207
	Glutamic acid	2150	2130	2280	3165	3505	2542
	Glycine	1040	1040	2000	1007	1334	921
	Proline	1150	1300	1500	783	1028	659
	Serine	1020	960	980	835	886	620
	Tyrosine	1000	1370	790	746	735	622
Fat (g)		5.06	12.91	6.14	3.5	1.3	7.05
Fatty acids (g)	SFA	2.28	2.32	-	1.68	-	2.74
	MUFA	1.69	2.51	-	1.51	-	3.26
	PUFA	2.43	5.85	-	0.11	-	0.58
Cholesterol (mg)		98.5	51.3	-	59	58	50.02
Minerals (mg)	Calcium	99.6	42.9	24.2	4.0	5.0	4.1
	Copper	0.62	0.83	0.75	0.1	0.01	0.1
	Iodine	0.15	0.02	0.022	0.008	0	0.008
	Iron	5.46-8.83	2.47	2.87	3.1	0.4	0.9
	Magnesium	55.1	62-92	69	26.0	33.0	15.6
	Manganese	1.15	0.32	0.46	0.04	0.01	0.01
	Phosphorus	899.3	264-368	295.0	212.0	240.0	130.4
	Potassium	347-390	337.0	368.0	382.0	385.0	293.6
	Sodium	163-178	53.7	66.0	52.0	55.0	50.0
	Zinc	6.71-11.0	4.33-4.95	4.86	2.9	0.5	2.2
Vitamins (mg except where noted)	A (µg)	6.53	16.9-29.0	<30	11.00	6.00	0.00
	B1	0.04	0.18	0.1	0.12	0.09	0.49
	B2	3.41	0.81-1.21	0.85	0.26	0.15	0.23
	B3	3.84	4.07-4.65	5.64	5.54	12.44	4.86
	B6	0.23	0.81	0.81	0.25	0.55	0.25
	B12 (µg)	0.53	0.47	0.56	1.40	0.40	0.57
	C	3.0	1.8-9.9	5.4	0	0	0
	E	2.26	1.31-1.9	<0.34	0.20	0.30	0.33
Fibre (g)		4.6	3.52	7.4	0	0	0

SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids. Source: Orkusz (2021).

1.6.2. Human health

As mentioned above, edible insects are a nutritious food source, providing all the essential nutrients required for a healthy diet. In some cases, their nutritional profile may even meet some recommended nutrient intakes for humans (Gahukar, 2013;

Rumpold *et al.*, 2013). In these conditions, entomophagy is seen as a strategy to improve food security in several areas in the world (van Huis *et al.*, 2013). However, in regions where overnutrition problems are observed, eating insects would not be a good alternative to meat consumption, at least for insect species rich in energy, sodium and saturated fats, which could worsen the situation (Payne *et al.*, 2016).

In addition to being a rich source of essential nutrients, edible insects contain bioactive compounds that have beneficial effects on human health, such as antioxidant, antihypertensive, anti-inflammatory, antimicrobial, and immunomodulatory actions. Edible insects could also help in the fight against obesity, type 2 diabetes and Parkinson's disease. However, most of these positive effects of entomophagy on human health need to be confirmed in human clinical trials (Roos *et al.*, 2017; Aguilar-Toalá *et al.*, 2022). Despite this lack of evidence, edible insects are already used in traditional medicine of some countries with entomophagy tradition (*e.g.*, see 1.5.2 Hymenoptera).

As with other foodstuffs, the consumption of edible insects is not without inherent risks to human health. These risks are due to the presence of chemical compounds (*e.g.*, arsenic, heavy metals, pesticide residues, and toxins), microbiological agents (*e.g.*, bacteria, parasites, and viruses), prions[2], and allergens in insects. In general, the implementation of suitable rearing conditions (*e.g.*, a safe substrate) and/or appropriate processing steps after rearing (*e.g.*, heat treatment) can effectively mitigate most of food safety hazards (van der Fels-Klerx *et al.*, 2018). Regarding allergies, Ribeiro *et al.* (2019) advise individuals with a crustacean allergy to avoid consuming edible insects due to the potential for cross-reactivity, which is primarily mediated by two main allergens (*i.e.* arginine kinase, and tropomyosin). A similar recommendation could potentially be made for people allergic to house dust mite, although further research is required (Ribeiro *et al.*, 2019). This lack of study is also observed with other food safety hazards related to edible insects, despite some advancements being made in this field in recent years (van der Fels-Klerx *et al.*, 2018).

1.6.3. Production and environmental impact

The procurement of edible insects can be achieved through three methods, namely (1) wild harvesting, (2) semi-domestication (*i.e.* enhancing wild production through habitat manipulation), and (3) farming. The wild collection method is currently the most prevalent and can serve as an effective alternative to the use of pesticides for the management of pests (Yen, 2015). However, this practice is threatened by the decline of wild insect populations, which is caused by biological factors (*e.g.*, pathogens), habitat alteration (*e.g.*, deforestation), environmental contamination (*e.g.*, pesticide), and overexploitation. The implementation of sustainable harvesting practices, in combination with the conservation of insect habitats, is therefore necessary to mitigate this risk. Concurrently, the development of insect farming can also contribute to

[2]Prion : a small piece of protein that is thought to cause certain brain diseases (Cambridge Dictionnary, 2025).

alleviating the strain on wild insect populations (van Huis *et al.*, 2017; Piña-Domínguez *et al.*, 2022).

The practice of insect farming has a long history, dating back thousands of years. However, the first aim of this practice was not the consumption of the insects themselves, but rather the use of certain by-products such as honey (from *A. mellifera*) and silk [from *Bombyx mori* L., 1758 (Lepidoptera: Bombycidae)]. Subsequently, insect farming has also been employed for scientific [*e.g.*, *Drosophila melanogaster* Meigen, 1830 (Diptera: Drosophilidae)], pest management [*e.g.*, *Adalia bipunctata* (L., 1758) (Coleoptera: Coccinellidae)], and service [*e.g.*, pollination of greenhouse crops with *Bombus terrestris* (L., 1758) (Hymenoptera: Apidae)] purposes (Caparros Megido *et al.*, 2015). It is only recently that insect farming has begun to produce edible insects for human and, above all, animal consumption. Today, the edible insect production units vary considerably around the world, ranging from small-scale domestic farms to large-scale industrial vertical farms which reach heights of nearly 40 metres. A variety of insects are reared on these farms, with the selection of species dependent on several factors, including the characteristics of the insect species themselves (*i.e.* behaviour and biology) as well as local preferences and customs. The most commonly reared insect species for human consumption are species of mealworm (*e.g.*, *T. molitor*), cricket (*e.g.*, *A. domesticus*), and locust [*e.g.*, *Locusta migratoria* (L., 1758) (Orthoptera: Acrididae)] (Caparros Megido *et al.*, 2024).

The production of edible insects has an impact on the environment; however, this is less significant than that associated with the conventional livestock production. As with the nutritional aspect, the environmental parameters differ between insect species. The remainder of this section will therefore detail the environmental benefits of insects, using the mealworm (*T. molitor*) as a reference. The environmental impact of this species has been studied more extensively than that of other species used for food purposes (Smetana *et al.*, 2016; van Huis *et al.*, 2017).

The practice of insect farming has a lesser impact on the global warming than the production of conventional livestock, as the emissions of greenhouse gases (*i.e.* CO_2, CH_4, and N_2O) and NH_3 are lower. In the production of edible insects, almost all emitted greenhouse gases can be attributed to the production and transportation of the feed and the energy used for equipment that controls the rearing climate. Consequently, the direct contribution of insects to global warming is relatively insignificant. Furthermore, some species, such as *T. molitor*, *A. domesticus*, and *L. migratoria*, do not produce methane (CH_4) (Oonincx *et al.*, 2010, 2012; Halloran *et al.*, 2017).

Oonincx *et al.* (2012) also highlighted that the production of mealworms in the Netherlands requires a comparable amount of energy as the production of pork. This energy requirement is particularly necessary for the purpose of heating insect rearing rooms, as insects are poikilothermic[3] and depend on the ambient temperature for their

[3] Poikilothermic : animals that are poikilothermic have body temperatures that changes with the temperature around them (Cambridge Dictionnary, 2025).

growth and development (Oonincx *et al.*, 2012). The growth of *T. molitor* is optimal between 25 and 28°C, while temperatures below 17°C inhibit embryonic development (Ribeiro *et al.*, 2018). For other species, such as *A. domesticus*, the optimum temperature for growth is even higher (30°C). In Europe and North America, this range of optimal temperatures is not reached throughout the year, whereas in tropical countries it is reached more easily and consistently. The energy required for temperature regulation therefore varies according to the geographical location of the insect farm (Halloran *et al.*, 2016). To illustrate, Halloran *et al.* (2017) conducted research on a Thai cricket farm that did not use temperature control equipment. The implementation of improvements can assist in the reduction of energy consumption (*e.g.*, using the metabolic heat of larger larvae to heat the smaller larvae) and the mitigation of the detrimental environmental impact of energy (*e.g.*, using renewable energy) (Oonincx *et al.*, 2012; Ros-Baró *et al.*, 2022).

Being poikilothermic, insects do not need to use energy from their feed to maintain their body temperature and can therefore use it efficiently for growth. Edible insects are more efficient at converting their feed into animal tissue than conventional livestock (Oonincx *et al.*, 2012; van Huis *et al.*, 2017). Furthermore, edible insects can valorise the food and feed waste from animals and humans, contributing to a circular economy (Ros-Baró *et al.*, 2022). For example, mealworms can be reared on dried by-products from the beer, bread, cookie, and potato industries. Some edible insects can also be successfully grown on chicken, cattle and pig manure. However, not all rearing substrates are legally approved for insect production [*e.g.*, the use of manure is banned in the European Union (EU)] (van Huis *et al.*, 2017).

Finally, the production of edible insects requires much less land and water than the livestock production. As with energy use, most of the land and water requirements are associated with feed production (van Huis *et al.*, 2017). Feed optimisation will therefore help to further reduce the environmental impact of insect farming, as well genetic selection and automation of rearing processes (Oonincx *et al.*, 2012). **Figure 1-1** summarises the environmental benefits of insect farming, and more specifically mealworm farming, compared to traditional livestock farming, as detailed above. Beyond this comparison, Smetana *et al.* (2015) argue that edible insects are a more environmentally friendly option than the majority of other meat alternatives, such as in vitro meat and mycoprotein-based products.

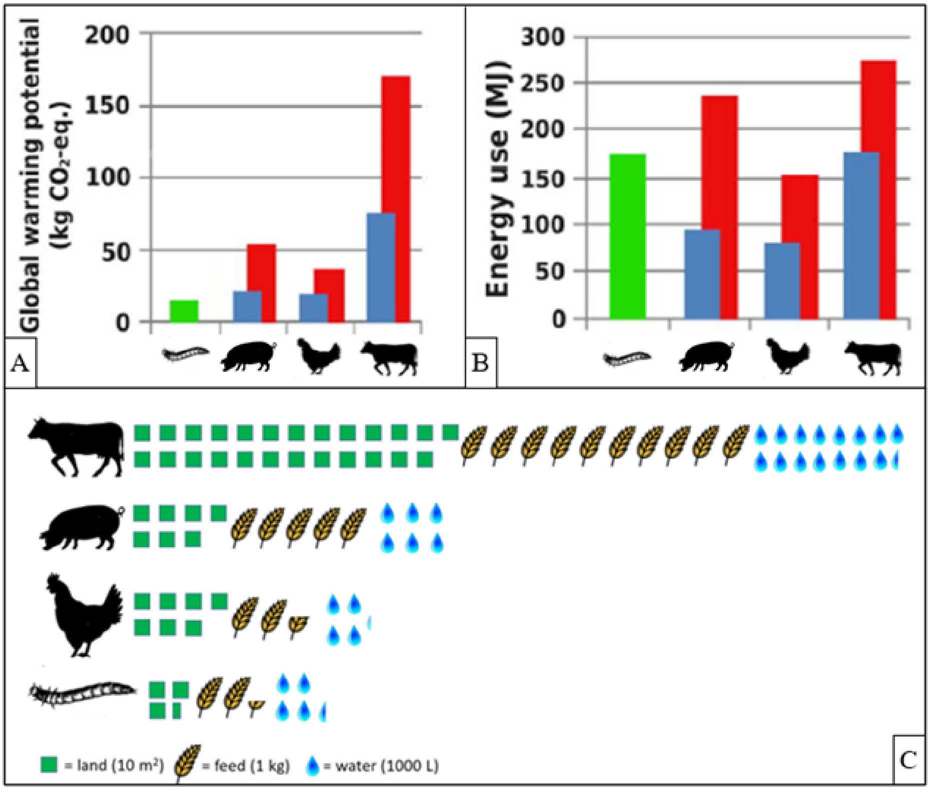

Figure 1-1. Environmental parameters for the production of mealworms (*T. molitor*) and common meat (beef, chicken, and pork).

A: global warming potential (kg of CO_2 eq./kg of edible protein). Green bars represent the reported values, while blue and red bars indicate the minimum and maximum values reported in the literature, respectively.; B: energy use (mega joules/kg of edible protein). Color coding as in A; C: amount of land, feed, and water required to produce 1 kg of live animal weight. Sources: Oonincx *et al.* (2012); Dobermann *et al.* (2017).

While insect farming offers several environmental advantages, it could also prove to be a significant contributor to the spread of new biological invasions. However, the potential for such invasions to occur can be mitigated through the implementation of legislative measures (*e.g.*, list of quarantine pests), the conduct of risk assessments, and the use of appropriate equipment (*e.g.*, sealed or filtered openings) (van Huis *et al.*, 2017; Bang *et al.*, 2021).

1.6.4. Market and economics

In cultures with entomophagy tradition, insects are also consumed as food due to their relatively low cost. The practice of wild harvesting is almost cost-free, whereas small-scale farming does not necessitate significant initial capital outlay, given that insect breeding does not require the use of sophisticated technologies. Most edible insects are then consumed by the household, with any surplus being sold at local markets. This provides revenue opportunities for an entire value chain, including several actors such as collectors/farmers, wholesalers and retailers. The price of edible insects at these markets is generally higher than that of conventional food (Tang *et al.*, 2019; Baiano, 2020; Boukid *et al.*, 2023). To illustrate, the price of a kilogram of edible insects in markets of the Indian state of Nagaland ranges from 1.5 to 10 times that of a kilo of beef or pork (Mozhui *et al.*, 2023).

The growing global interest in edible insects has prompted a surge in investment and the establishment of large-scale industrial farms in countries with and without entomophagy traditions. For example, at least 13 companies in the United States were engaged in the production of mealworms in February 2024 (Boukid *et al.*, 2023; Caparros Megido *et al.*, 2024). The activities of such companies provide opportunities for employment across the entire value chain, from production to sales (Tang *et al.*, 2019). Furthermore, they can ensure more stable production, thereby facilitating the commercialisation of food products in the global market. A total of 220 insect-based foods (*e.g.*, energy bars, ice cream, and pasta) and 16 insect-based drinks (*e.g.*, energy drinks, and nutritional drinks) were launched globally between 1996 and 2021. Of these, the largest proportion (36%) were marketed in Europe, which reflects the growing European interest in entomophagy in recent years. Conversely, no insect-based product launches were recorded in Africa during the same period. This finding may be attributed to the fact that entomophagy remains a traditional practice in Africa and the sector is not yet sufficiently organised (Boukid *et al.*, 2023). In Europe, the price of insect-based foods is also high, particularly for products with a high insect content. A study conducted in 2020 documented a price range of 2€ to 22€ per 100 grams for *T. molitor*-based food products (Pippinato *et al.*, 2020). A more recent Polish study recorded comparable data, with prices per 100 grams of insect-based protein bars at 5€ and whole insects at 26€ (Szulc, 2023). These examples highlight that consumer prices of insect-based products vary considerably depending on the type of product and the proportion of insect-derived ingredients incorporated. Products containing a limited amount of insect ingredients may therefore be less sensitive to variations in insect-related costs, as these costs represent a smaller share of the total production cost, compared with products consisting of whole insects or containing a high insect content.

Such prices represent the final amount paid by consumers for insect-based foods. They result from the accumulation of costs along the entire value chain, including insect production, processing, packaging, distribution and marketing (Chen *et al.*, 2025). Therefore, reducing the price gap between insect-based foods and conventional protein sources will require improvements throughout the entire value chain. The limited number of studies investigating the economic aspects of the insect value chain has mainly focused on the production stage of edible insects. According to Dossey *et al.* (2016), insect farming costs need to be reduced by at least 25%, while production scale must increase substantially to improve the competitiveness of insect-based proteins compared with conventional animal protein sources. Currently, the main drivers of insect production costs are feed costs, which influence insect growth and quality, and labour costs, as many insect production processes remain insufficiently mechanised. The use of low-value feed and the automation of key processes (*e.g.*, cleaning, feeding, and harvesting) could contribute to reducing these production costs (Niyonsaba *et al.*, 2021).

In terms of the global market for edible insects (for food and feed), it is anticipated that the value will increase at an annual rate of 33.72% between 2021 and 2026, reaching a total value of over 5.5 billion USD. It is projected that this growth will continue later, with the market reaching 8 billion USD by 2030. In Europe, the value of the edible insect sector is expected to grow by 1,668% between 2021 and 2029 (Boukid *et al.*, 2023; Caparros Megido *et al.*, 2024). Nevertheless, these projections should be interpreted with caution. Recent developments in the sector suggest that the industrialisation of edible insects in Western countries has been more challenging than initially anticipated, with several companies facing major economic difficulties. These challenges raise questions regarding the scalability, economic viability and long-term sustainability of industrial insect production.

1.6.5. Ethics

In recent times, consumers, particularly in the West, have become increasingly concerned about the issue of animal welfare, and more specifically the welfare of animals during the farming process. This has led to a shift in consumer behaviour, with animal welfare becoming an important factor in purchasing decisions. The concept of animal welfare is frequently referenced in legislation pertaining to conventional livestock. Some of these legal texts, including those of the European Commission, were drafted on the basis of Brambell's five freedoms: (1) freedom from hunger and thirst, (2) freedom from discomfort, (3) freedom from pain, injury or disease, (4) freedom to express normal behaviour, and (5) freedom from fear and distress (Delvendahl *et al.*, 2022).

Regarding edible insects, the issues pertaining to their welfare are frequently overlooked and not addressed in legal texts or official guidelines, with a few exceptions (*e.g.*, regulations for insect welfare in Finland, and guidelines for cricket farming in Thailand). Consequently, edible insects are farmed in a "legislative grey zone", and the search for optimal breeding practices is primarily based on empirical trial and error. Among these, the replication of the natural environment of the species in the rearing facilities is currently regarded as one of the most effective methods for ensuring the welfare of insects (Gjerris *et al.*, 2016; Delvendahl *et al.*, 2022). The application of the Brambell's five freedoms for farmed animals is also receiving increasing attention in the context of insect welfare, given that they represent a set of well-established principles. As with conventional animals, the standards for the welfare of insects must be species- and developmental stage-specific. However, the criteria for ensuring insect welfare are likely to differ from those for livestock welfare, due to the significant biological differences between the two. For instance, the welfare of livestock frequently necessitates a low stocking density, whereas a high density can typically be applied to insects, as many species are gregarious. Beyond recommendations, research on welfare is required for the edible insect sector, given the current lack of certainty on this issue (*e.g.*, the ability of insects to experience pain). Until further research is conducted, insect farmers should adhere to the precautionary principle in mass rearing conditions and euthanasia procedures (Delvendahl *et al.*, 2022).

1.6.6. Legislation

Regulations governing the production and use of insects as food vary greatly from country to country, both in cultures with and without a tradition of entomophagy. In Thailand, regulations, standards, and guidelines have been established to frame the insect sector (*e.g.*, food safety, food quality, labelling, and packaging), while in China the production and sale of edible insects are regulated by law. In most other countries, the regulatory framework for edible insects is underdeveloped (*e.g.*, India, and Vietnam) or non-existent (*e.g.*, African countries). However, in the event of an agreement to export insects to the EU, insect farmers from non-EU countries must comply with the specifications recommended by the EU (Grabowski *et al.*, 2020; Caparros Megido *et al.*, 2024).

In the EU, the legislative framework did not include the concept of edible insects as food until 2018. However, rather than prohibiting the consumption of insects at the EU level, member states were permitted to make their own determinations on the matter (Skotnicka *et al.*, 2021). To illustrate, in Belgium, 10 insect species were approved for human consumption in 2014 (FASFC *et al.*, 2014). Since 1st January 2018, the EU has reasserted its regulatory authority over edible insects by incorporating them into the legislation on "Novel Foods" [Regulation (EU) No 2015/2283]. In practice, insect-based food products may only be marketed if the requisite authorisation has been granted by the European Commission, following the completion of a procedure delineated in another European regulation [Regulation (EU) 2018/456]. In summary, the initial stage of the procedure entails the submission of a dossier by an applicant to the "Novel food application". The European Food Safety Authority (EFSA) then assesses this dossier and provides an opinion on the potential safety risks associated with the consumption of the product in question. This opinion is subsequently examined by the European Commission, which ultimately determines whether to grant authorisation for the product to be marketed throughout the EU. The entire procedure is lengthy (at least 17 months) and requires the submission of a significant amount of data by the applicant, which may act as a deterrent for a new application. The authorisations are highly specific, and any change affecting the food product, the production process (*e.g.*, feed for edible insects) and/or the conditions of use requires the submission of a new application (Lotta, 2019; Caparros Megido *et al.*, 2024). It is also relevant to mention that if the applicant's dossier contains newly established data, the applicant is entitled to five years of market exclusivity for the authorised product, and the aforementioned data is afforded protection for the same period (European Commission, 2015; IPIFF, 2024b). As of February 2025, 7 novel food authorisations have been implemented for edible insects, encompassing 4 distinct insect species; 3 dossier received positive opinion from the EFSA (**Table 1-2**); and new dossiers are currently under assessment by the EFSA, some of which include additional insect species (*e.g.*, *A. mellifera* male pupae) (IPIFF, 2024b).

Table 1-2. Authorised edible insects' food products for human consumption in European Union.

Insect species	Form(s)	Applicant	EFSA's opinion	European Commission's decision	Regulation (EU) No
A. diaperinus (larva)	Frozen, paste, dried, and powder	Ynsect NL B.V. (The Netherlands)	✓ (04/07/2022)	✓ (05/01/2023)	2023/58
A. domesticus	Frozen, dried, and powder	Fair Insects B.V. (The Netherlands)	✓ (17/08/2021)	✓ (10/02/2022)	2022/188
		Belgian Insect Industry Federation (Belgium)	✓ (16/12/2024)	-	-
	Partially defatted powder	Cricket One Co. Ltd (Vietnam)	✓ (13/05/2022)	✓ (03/01/2023)	2023/5
	Powder	Società Agricola Italian Cricket Farm S.r.l. (Italy)	✓ (29/07/2024)	-	-
L. migratoria	Frozen, dried, and powder	Fair Insects B.V. (The Netherlands)	✓ (02/07/2021)	✓ (12/11/2021)	2021/1975
T. molitor (larva)	Dried	SAS EAP Group (France)	✓ (13/01/2021)	✓ (01/06/2021)	2021/882
	Frozen, dried, and powder	Fair Insects B.V. (The Netherlands)	✓ (25/08/2021)	✓ (08/02/2022)	2022/169
	Frozen and dried	Belgian Insect Industry Federation (Belgium)	✓ (16/01/2025)	-	-
	UV-treated powder	Nutri'Earth (France)	✓ (01/06/2023)	✓ (20/01/2025)	2025/89

A. diaparinus: *Alphitobius diaperinus* (Panzer, 1797) (Coleoptera: Tenebrionidae). ✓: positive opinion/decision; - : pending decision/regulation. Date format for opinion/decision: day/month/year. Sources: EFSA (2024); IPIFF (2024b); EUR-Lex (2025). Updated in September 2025.

Despite the advancements in EU regulations, Zuk-Gołaszewska *et al.* (2022) identified several gaps associated with policy making, legislative solutions, standardization, and certification of mass-produced edible insects (*e.g.*, "legal regulations, introduction of universal standards and certification requirements for edible insect farming").

1.6.7. Consumer acceptance

Despite the benefits of eating edible insects, entomophagy remains an unusual food practice in Western countries (Omuse *et al.*, 2024). In cultures with entomophagy tradition, the modernisation of diets is threatening the traditional practices, including insect consumption (Müller, 2019). The objective of the entomophagy sector is therefore twofold: on the one hand, to facilitate its introduction in cultures without such a tradition, and on the other, to preserve it in cultures where it has historically been practiced. To achieve this dual objective, it is therefore necessary to identify the underlying reasons for consumer acceptance or rejection of entomophagy. For this purpose, Alhujaili *et al.* (2023) proposed a framework of factors affecting consumer acceptance of entomophagy (**Figure 1-2**). This framework was based on a comprehensive review of the relevant literature, which was primarily Western-centric. The factors were classified into two categories: (1) personal factors, and (2) elements of the marketing mix. A concise overview of these factors is provided below. However, it should be noted again that the description of the factors is based on trends that are not consistently identified across all studies, and that such trends mainly reflect Western populations and may differ in other cultural contexts (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023; Syartiwidya *et al.*, 2025).

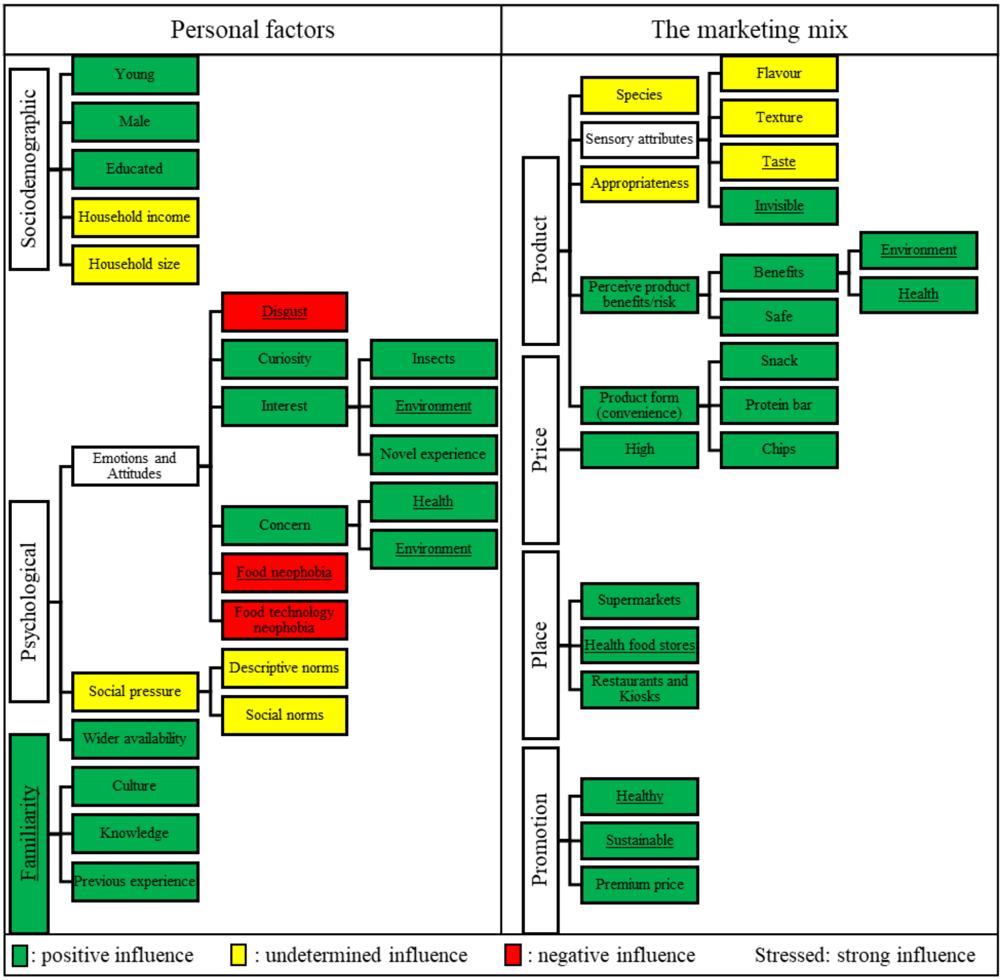

Figure 1-2. Factors influencing consumer acceptance of entomophagy.
Source : Alhujaili *et al.* (2023).

Personnal factors

Consumers who are more inclined to accept the consumption of edible insects tend to be young men with a high level of education (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023). However, Brunner *et al.* (2019) noted in their study that educational influence varies according to the cultural context. In Switzerland, early adopters of entomophagy were highly educated, whereas in Thailand, they exhibited a relatively low level of education. The scholars explained this difference by the tendency of educated people to avoid traditional practices, perceived as primitive, in cultures with entomophagy tradition. Conversely, in cultures without entomophagy tradition such as Switzerland, educated people perceive edible insects as sustainable and healthy and are inclined to consumed them (Brunner *et al.*, 2019).

Beyond these determinants, other contributions in the literature have identified the place of residence as an additional parameter. Although this factor has not been systematically investigated, several studies indicate that consumers living in urban areas tend to show a greater acceptance of edible insects. Urban people are generally more exposed to diverse food environments and tend to be more open to tasting novel products compared to those in rural areas. Nevertheless, other research reports no significant effect of residence, suggesting that this variable exerts an influence only under certain conditions or cultural contexts (Ozgen, 2014; Kröger *et al.*, 2022).

Consumer acceptance of entomophagy is also positively influenced by other personal characteristics, including curiosity about entomophagy; interest in edible insects and their environmental benefits, and in novel food experiences; concerns about the health and environmental impact of food, and the perception that edible insects are readily available. Furthermore, familiarity with entomophagy, whether through cultural exposure, previous experience, or knowledge, has a positive impact on consumer acceptance (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023). This last finding explains why many scholars are favourable to insect-based tasting and diffusion of information related to entomophagy to promote edible insects in cultures without entomophagy tradition (Caparros Megido *et al.*, 2014, 2016, 2025; Lensvelt *et al.*, 2014; Barsics *et al.*, 2017; Mancini *et al.*, 2019; Woolf *et al.*, 2019; Barton *et al.*, 2020; Sogari *et al.*, 2023).

Conversely, other factors exert a negative impact on consumer acceptance. One of these factors is disgust, which is exhibited by some consumers in response to both processed and unprocessed edible insects. Disgust towards entomophagy is particularly prevalent in cultures without entomophagy tradition as edible insects are often associated with a negative image, including that of being dirty, a source of contamination and disease, and associated with death. Furthermore, an aversion to novelties can also be a rationale for rejecting entomophagy. This may manifest as an aversion to eating novel foods (*i.e.* food neophobia) or a fear of new technologies in food (*i.e.* food technology neophobia). In the field of entomophagy, studies examining food neophobia are prevalent. Many of these studies have documented a negative influence on the consumer acceptance, and a positive correlation with the disgust towards edible insects. Conversely, food technology neophobia has been less studied, but it is often identified as a significant barrier to the acceptance of entomophagy (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023; Sogari *et al.*, 2023).

The marketing mix[4]

Consumer acceptance of entomophagy may be enhanced by adjusting in the right way the 4Ps of the marketing mix, namely product, price, promotion, and place (Alhujaili *et al.*, 2023).

The consumer acceptance of entomophagy is influenced by several characteristics of insect-based products. Among these, sensory attributes (*e.g.*, appearance, taste, and texture) are deeply studied in the literature on entomophagy (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023). Such studies have demonstrated, for example, that the use of processed and invisible insects in the food products can enhance acceptance among Western consumers, suggesting that powdered insects may be a more promising option than whole insects in Western culture. Conversely, consumers from cultures with entomophagy tradition have demonstrated a willingness to consume both processed and unprocessed insects (Hartmann *et al.*, 2015; Tan *et al.*, 2015; Caparros Megido *et al.*, 2016, 2025; Boukid *et al.*, 2023). Nevertheless, the species employed, the developmental stage and the quantity of insects in the food must also be considered, as these factors influence both acceptability and sensory parameters (Ardoin *et al.*, 2020b; Mishyna *et al.*, 2020; Kröger *et al.*, 2022; Alhujaili *et al.*, 2023). The association between edible insects and familiar flavours (*e.g.*, paprika) and the incorporation of insects in traditional food preparation (*e.g.*, burger) are also perceived as strategies to facilitate the acceptance of insects by Western consumers (Caparros Megido *et al.*, 2014, 2016; Lensvelt *et al.*, 2014; Hartmann *et al.*, 2015). Such strategies should be particularly more successful with savoury flavours/food preparations as edible insects are mainly regarded as meat alternatives in Western countries (Tan *et al.*, 2015, 2017; Caparros Megido *et al.*, 2016). However, all associations between insects and familiar flavours/food preparations are not necessarily evaluated in the same way, depending on product appropriateness (*i.e.* perceived suitability of product preparation). For instance, Dutch respondents considered insect-based meatballs as more appropriate than insect-based dairy drinks, whereas American respondents identified protein/energy bars and chips/snack crackers as the most appropriate insect-based foods among a list of 30 foods and drinks. Such judgments exert an influence on both the willingness to consume and the willingness to purchase the food in question (Tan *et al.*, 2017; Ardoin *et al.*, 2020a).

As previously suggested by American respondents, insect-based snacks (*e.g.*, chips, and protein bars) are the most acceptable forms among Western consumers, as they are the most suitable to meet their expectations (*i.e.* convenient to access and prepare). Consumer acceptance of entomophagy is also influenced by the perception of certain traits of insect-based foods, such as their perceived benefits for human health and the

[4] Marketing mix : the combination of actions a company uses when selling a product or service. These are often described as the four Ps (= product, price, place, and promotion ; Cambridge Dictionnary, 2025).

environment, and the absence of any perceived safety risks associated with their consumption. Communicating with consumers about such aspects would therefore increase the acceptability of entomophagy (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023).

Finally, availability and price of insect-based foods are also regarded as key factors in consumer acceptance of entomophagy, as well as its long-term consumption. Such elements of the marketing mix are mainly examined in Western studies. In these studies, many participants express a preference for locating insect-based foods predominantly within supermarkets. Regarding price, despite the association between high price and quality, most people are reluctant to pay extra for insect-based foods over familiar alternatives (House, 2016; Collins *et al.*, 2019; Giotis *et al.*, 2021; Kröger *et al.*, 2022; Alhujaili *et al.*, 2023). However, their willingness-to-pay for insect-based food depends on the carrier (*i.e.* the familiar food used to incorporate insects) (Lombardi *et al.*, 2019).

2. Research gaps

While the framework developed by Alhujaili *et al.* (2023) provides a solid baseline for analysing the determinants of consumer acceptance of entomophagy, several dimensions remain insufficiently explored in the literature.

2.1. Cultural influence

Throughout the beginning of this manuscript, culture is presented as a major factor in the practice of entomophagy, but this also applies to other types of food. Indeed, culture fundamentally shapes consumers' food choices, attitudes, and acceptance. It influences sensory perceptions, modulates taste preferences, and frames both individual and collective representations of food. Understanding cultural differences in perception, knowledge, and attitudes is therefore essential for explaining consumer behaviour and predicting consumer acceptance (Jeong *et al.*, 2021). In the case of entomophagy, where food traditions, beliefs, and familiarity vary greatly across cultures, examining the role of culture becomes particularly relevant. A deeper understanding of these cultural dynamics is necessary to anticipate consumer responses and to identify the factors that either facilitate or hinder the acceptance of insect-based foods. Cross-cultural studies are especially useful for highlighting similarities and differences between cultures in terms of their perception and acceptance of food, including edible insects (Tan *et al.*, 2015). However, as shown in **Table 1-3**, less than 10% of the cross-cultural studies conducted in this field include African countries.

Table 1-3. Overview of cross-cultural studies relative to entomophagy.

Continent.s	Countries	Author.s (year)
Africa – Asia	Ethiopia – South Korea	Ghosh *et al.* (2020)
Asia	China and South Korea	Yaxin *et al.* (2020)*
	China and Thailand	Phonthanukitithaworn *et al.* (2023)
	Japan and Malaysia	Lim *et al.* (2024)
	Japan and Singapore	Matsuoka *et al.* (2023)*
Asia – Europe	China – Germany	Hartmann *et al.* (2015)
	China – France	Yan *et al.* (2024)
	Thailand – Netherlands	Tan *et al.* (2015)
	Thailand – Switzerland	Brunner *et al.* (2019)
Asia – North America	India – USA	Ruby *et al.* (2015, 2019)
Asia – Oceania	India – Australia and Papua New Guinea	Meyer-Rochow *et al.* (1997)
Europe	Albania and Romania	Mara *et al.* (2025)
	Belgium, France, Germany, Italy, Poland, and Sweden	IPIFF (2024a)
	Czech Republic, Finland, Germany, and Sweden	Piha *et al.* (2016)
	Denmark, Germany, and Spain	Faber *et al.* (2022)*
	Denmark and Italy	Verneau *et al.* (2016)
	Finland, Netherlands, Poland, Spain, and United Kingdom	Grasso *et al.* (2019)*
	France and Ireland	Ranga *et al.* (2024)
	Germany and Netherlands	Naranjo-Guevara *et al.* (2020)
	Greece and Ireland	Ranga *et al.* (2025)
	Italy and Netherlands	Menozzi *et al.* (2017)
	Norway and Portugal	Ribeiro *et al.* (2022)
	Slovenia and United Kingdom	Rehman *et al.* (2024)*
Europe – North America	Croatia, Lithuania, Portugal, and Romania – Mexico	Mariscal-Moreno *et al.* (2025)
	France – Canada and USA	Hénault-Ethier *et al.* (2020)
	Spain – Mexico and USA	Castro *et al.* (2020)
Europe – Oceania	Netherlands – Australia	Lensvelt *et al.* (2014)
	United Kingdom – New Zealand	Wang *et al.* (2024)*
Europe – South America	France – Colombia	Marquis *et al.* (2023)
World (3 continents or more)	Belgium and Italy – Mexico and USA – China	Mancini *et al.* (2024); Sogari *et al.* (2023); Tzompa-Sosa *et al.* (2023a,b)
	Croatia, Greece, Latvia, Lithuania, Poland, Portugal, Romania, Serbia, Slovenia, and Spain – Mexico – Lebanon and Turkey	Guiné *et al.* (2023b)

Continent.s	Countries	Author.s (year)
	Croatia, Greece, Latvia, Lithuania, Poland, Portugal, Romania, Serbia, Slovenia, and Spain – Mexico – Brazil – Lebanon and Turkey	Guiné *et al.* (2022, 2023a, 2024a,b,c)
	France, Netherlands, Spain, and United Kingdom – Dominican Republic and USA – China – New Zealand	de Koning *et al.* (2020)*
	Germany, Norway, Portugal, and United Kingdom – Brazil – Mozambique	Cunha *et al.* (2015)
	Russia, Spain, and United Kingdom – Mexico and USA – Brazil and Peru – China, India, Japan, and Thailand – Australia – South Africa	Castro *et al.* (2019a,b); Cho *et al.* (2025); Park *et al.* (2025)
	Spain and United Kingdom – Dominican Republic – Brazil	Gómez-Luciano *et al.* (2019)*
	United Kingdom – China – Australia	Ford *et al.* (2023, 2024)*
	USA – India and Singapore – Australia	Giacalone *et al.* (2023)*

*: study relative to alternative protein source or novel food, not specifically to edible insects. Updated in September 2025.

2.2. Sociodemographic determinants

While understanding the cultural context is essential, consumer acceptance also depends on other sociodemographic factors. As previously discussed, the review of Alhujaili *et al.* (2023) provided the sociodemographic profile of Western consumers who accept entomophagy, encompassing gender (male > female), age (young > old) and education (high education > low education). Other contributions in the literature have also identified place of residence as a determining factor (urban > rural), although further investigation is needed given the divergent conclusions reported (Kröger *et al.*, 2022).

Within Western literature, additional determinants such as religion, household income and occupation have been examined, albeit to a limited extent. The limited trends that have emerged generally indicate an insignificant effect on the acceptance of entomophagy in these contexts. However, the scarcity of evidence does not permit the drawing of robust conclusions, thus highlighting the necessity for further investigation into these parameters (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023).

Conducting such investigations would contribute to refining the profile of willing consumers, or consumers who accept entomophagy (**Figure 1-3**). These individuals are widely regarded as the most suitable candidates for establishing an initial market base. As indicated by the literature, the identification and targeting of these consumers can offer significant insights into the development and positioning of insect-based foods, ensuring that these foods are developed in a manner that aligns with the preferences and expectations of the target (Verbeke, 2015; House, 2016; Rovai *et al.*, 2021).

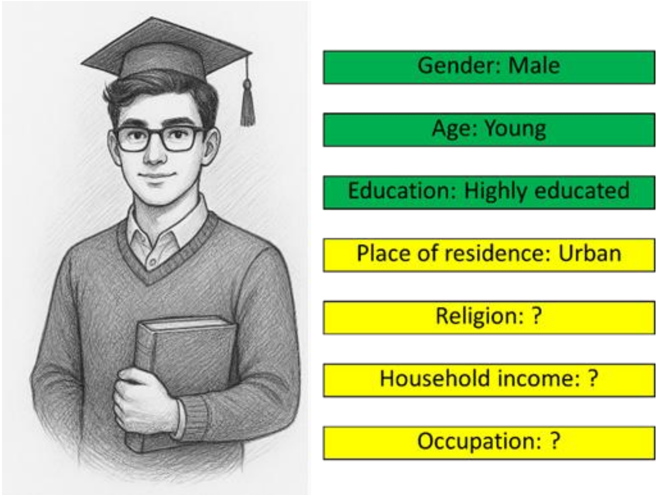

Figure 1-3. Sociodemographic profile of willing consumers in Western countries. Green factors indicate established factors, yellow factors indicate undetermined factors.

2.3. Opinion of Western youngsters

In the characterization of willing consumers' profile, age is identified as a major determinant, ranking among the most extensively studied factors in Western literature (Alhujaili *et al.*, 2023). Age is also employed as a discriminating variable, with researchers frequently examining specific age groups within a population to assess the acceptance of entomophagy. However, consumers under the age of 18 are often disregarded in Western literature (Tan *et al.*, 2015, 2016, 2017; Verbeke, 2015; Hartmann *et al.*, 2015; Caparros Megido *et al.*, 2016; Sogari *et al.*, 2017, 2019; Kostecka *et al.*, 2017; Clarkson *et al.*, 2018; Myers *et al.*, 2018; Brynning *et al.*, 2020; Videbæk *et al.*, 2020; Cicatiello *et al.*, 2020; Ribeiro *et al.*, 2022; Castro-Alija *et al.*, 2024; Peksever *et al.*, 2024). Consequently, their perceptions of entomophagy remain largely unknown, and it is unclear whether the main strategies identified to promote edible insects among adult consumers (see below) are equally effective with younger audiences.

2.4. Promotion strategies

Evaluating consumer acceptance, as well as examining the factors that influence it, is crucial. Nevertheless, in order to enhance consumer acceptance of edible insects, it is also essential to develop strategies for promoting entomophagy. Such strategies should be based on the target market segment and the specific characteristics of the consumers concerned (Syartiwidya *et al.*, 2025).

In the literature, several studies have examined strategies to promote edible insects among Western consumers. Section 1.6.7 (Consumer acceptance) provides a non-exhaustive overview of the effective strategies discussed in the literature by Western scholars, which are summarised in **Table 1-4**.

Table 1-4. Overview of strategies for promoting edible insects to Western consumers.

Target	Strategies
Consumer	Participate in insect-based tastings
	Receive information on entomophagy and its benefits
Insect-based food	Use of powdered/processed insects
	Combine insects with familiar flavours
	Focus on savoury flavours
	Incorporate insects into traditional food preparations
	Ensure appropriate pairing of insects with other ingredients
	Offer insect-based snacks
Marketing	Facilitate product availability in familiar retail settings
	Maintain competitive pricing, comparable to traditional alternatives

References and further details are provided in section 1.6.7 (Consumer acceptance).

Additional aspects could also be investigated and could be potentially incorporated into this list in the future. In this section, two specific aspects will be addressed: the appropriate context and the individual preparation of insect-based foods.

2.4.1. Appropriate context

Beside the notion of product appropriateness discussed in section 1.6.7 (Consumer acceptance; the Marketing mix), the general concept of appropriateness is also used to characterise the context of the eating situation (*i.e.* food appropriateness) or the combination of foods within a meal (Tan *et al.*, 2017; Ardoin *et al.*, 2020a). This concept helps explain why providing a food with the recommended sensory attributes does not necessarily ensure consumer satisfaction. For instance, a dish generally regarded as highly palatable, such as a stew, may nevertheless be rejected if served in an inappropriate context, such as at breakfast (Tan *et al.*, 2017). Food is embedded within a broad context encompassing various dimensions including audience, place, timing, and social environment (Jaeger *et al.*, 2017). Despite their importance, these contextual factors are often overlooked in the literature relative to entomophagy (Elzerman *et al.*, 2011; House, 2016; Tan *et al.*, 2016). A more systematic consideration of such parameters would be valuable, as identifying the most appropriate contexts for insect consumption could provide critical insights for the insect industry and inform strategies for the development and positioning of insect-based foods (Cardello *et al.*, 1996).

2.4.2. Individual preparation of insect-based food

As highlighted in **Table 1.4**, tasting sessions are seen as a strategy to promote edible insects among Western consumers. Consequently, such activities are frequently included in studies on entomophagy. A recurrent limitation, however, is that insect-based foods are often prepared by the study's stakeholders rather than by the participants themselves (Looy *et al.*, 2006; Caparros Megido *et al.*, 2014, 2016; Lensvelt *et al.*, 2014; Sogari *et al.*, 2017; Tan *et al.*, 2017; Barton *et al.*, 2020; Castro *et al.*, 2020; Cicatiello *et al.*, 2020; Delicato *et al.*, 2020; Petersen *et al.*, 2020; Skotnicka *et al.*, 2023; Rocha *et al.*, 2025; Khalil *et al.*, 2025). Yet, personal involvement in food preparation has a strong influence on individual perception and appreciation of the food (Boutrolle *et al.*, 2009). Simply suggesting that participants cook insects themselves increases their willingness to take part in tasting events, while personal preparation reduces the disgust associated with entomophagy (Loo *et al.*, 2013; Deroy *et al.*, 2015; Hamerman, 2016). Furthermore, self-prepared dishes are generally better appreciated and consumed in larger quantities than foods prepared by others (Dohle *et al.*, 2014). In this context, examining the role of cooking activities in the consumption of edible insects appears particularly relevant, as such practices could be potentially incorporated into Western strategies to promote entomophagy.

3. Study areas

Given the central role of culture in shaping food practices and consumer acceptance, it is essential to investigate entomophagy within distinct cultural contexts. To this end, the present thesis focuses on two study areas: Belgium and Gabon. This section provides a brief overview of each country and outline the rationale behind their selection. In the case of Belgium, a short analysis of the market offer is also presented, as this aspect is less deeply explored in the following chapters than in Gabon. This analysis draws primarily on company websites and press sources, rather than scientific literature.

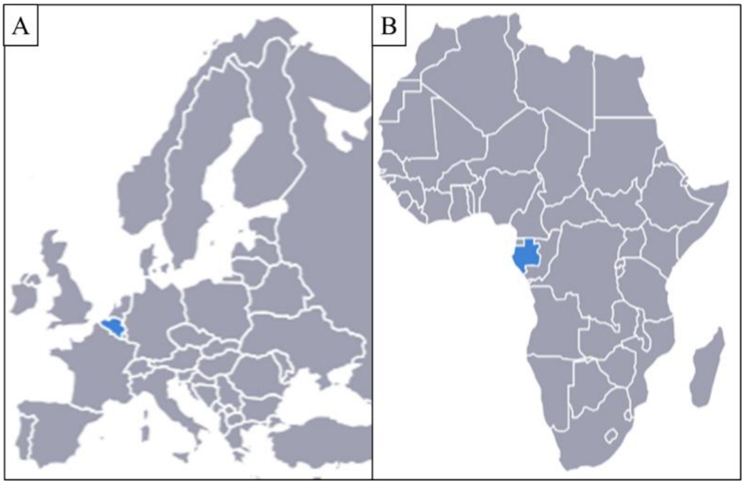

Figure 1-4. Study area of the current thesis.
A: Belgium's position in Europe; B: Gabon's position in Africa. Maps was designed with Visme (https://www.visme.co/).

3.1. Belgium

Belgium is a country in Western Europe with a temperate climate (**Figure 1-4A**). The population of the country is approximately 12 million, with the majority (98.2% in 2023) is concentrated in urban areas, including Brussels (*i.e.* the capital) and Antwerp. Belgium is regarded as a country with a high income (Central Intelligence Agency (CIA), 2024a).

Regarding entomophagy, the Belgian context is broadly comparable to that of the other Western countries. There is no entomophagy tradition in Belgian food habits; however, there has been a recent increase in interest in this novel food source (Van Thielen *et al.*, 2018). Belgium has also emerged as a notable contributor to research and innovation in this field. This growing involvement can be attributed to well-established institutional frameworks, substantial funding initiatives, and a strong policy focus on sustainability (Wardiman *et al.*, 2025). Several studies conducted in Belgium have specifically aimed to identify the factors that may foster the adoption of entomophagy, both nationally and across Western societies (Caparros Megido *et al.*, 2014, 2016; Verbeke, 2015; Schouteten *et al.*, 2016; Barsics *et al.*, 2017; Van Thielen *et al.*, 2018; Delicato *et al.*, 2020). Five of these studies include cross-cultural studies (IPIFF, 2024a; Mancini *et al.*, 2024; Sogari *et al.*, 2023; Tzompa-Sosa *et al.*, 2023a,b). In Western countries such as Belgium, the growing interest in entomophagy is primarily driven by the need to transition towards a more sustainable food source (Raheem *et al.*, 2019b).

In this country, the marketing of insect-based foods has been permitted since 2014, when a list of 10 insect species approved by the relevant Belgian authorities was published (**Table 1-5**). The list was implemented in accordance with the recommendations of the Belgian Federal Agency for the Safety of the Food Chain (FASFC) and the Superior Health Council (SHC), following an evaluation of the potential microbiological, chemical (including allergens), and physical hazards associated with the consumption of the ten species by humans (FASFC *et al.*, 2014).

Table 1-5. List of species and their development stages approved for human consumption by Belgian legislation in 2014.

Order	Family	Species	Development stage.s
Coleoptera	Tenebrionidae	*Alphitobius diaperinus* (Panzer, 1797)	Larva
		Tenebrio molitor L., 1758	Larva
		Zophobas atratus (Fabricius, 1775)	Larva
Lepidoptera	Bombycidae	*Bombyx mori* L., 1758	Larva Chrysalis (without cocoon)
	Pyralidae	*Achroia grisella* (Fabricius, 1794)	Larva
		Galleria mellonella (L., 1758)	Larva
Orthoptera	Acrididae	*Locusta migratoria* (L., 1758)	Nymph Adult
		Schistocerca americana (Drury, 1773)	Adult
	Gryllidae	*Acheta domesticus* (L., 1758)	Adult
		Gryllodes sigillatus (Walker, 1869)	Adult

Since 2018, the marketing of edible insects has been subject to European legislation on “Novel Foods” [Regulation (EU) No 2015/2283], rather than being determined by national policy. Consequently, only foods that have been approved by the European Commission are permitted for marketing within the European market, including Belgium (see **Table 1-2** in 1.6.6 Legislation; Caparros Megido *et al.*, 2024). However, article 35(2) of the “Novel Foods” regulation stipulates an exception for foods that were lawfully authorised for marketing by a country of the EU prior to 1st January 2018 (*i.e.* the date of application of the EU regulation). Such foods may remain on the national market of the country in question for a specified period, provided that certain conditions are met (Pippinato *et al.*, 2020).

In 2020, the country had 7 companies engaged in the value chain of insect-based foods, representing the largest number in the EU. This observation may be partly attributed to the fact that marketing authorisations for insect-based foods were granted earlier in Belgium than in most other European countries (Pippinato *et al.*, 2020).

Since then, several of these Belgian companies have disappeared due to various factors including covid-19 pandemic, legislative constraints and a lack of investment. To illustrate, whereas previously there were five Belgian companies producing edible insects, only one remains in operation in 2024. This remaining producer, Entomobio, is headquartered in Frasnes-lez-Anvaing (Hainaut) and is responsible for the annual production of 3000 tons of fresh *T. molitor*. All these insects are sold in the form of dried insects or insect powder to processing companies, which then produce a variety of foods for human consumption (Trends tendances, 2024).

In Belgium, there are only a few companies involved in the processing of edible insects (**Table 1-6**). The insect-based foods produced in the country, apart from whole insects and insect powders, typically contain between 3% and 15% of insects. These foods are produced using only three insect species: *A. domesticus*, *L. migratoria*, and *T. molitor*, which are usually not visible to the consumer in the final product. Most of these insect-based foods are snacks, combining insects with familiar flavours.

Table 1-6. List of Belgian processing companies and their main insect-based products.

Company	Insect-based product	Flavour/Type	Percentage of insects	Insect species incorporated
Beetles Beer[1]	Beer	Blond	-	*L. migratoria*
		IPA	-	*A. domesticus* *L. migratoria* *T. molitor*
		Stout	-	*A. domesticus* *T. molitor*
		Triple	-	*A. domesticus* *L. migratoria*
Les pâtes des Frangines[2]	Pasta	Hemp	3%	*A. domesticus*
		Natural	10%	*T. molitor*
		Smoked		
		Tomato		
Kriket	Crackers[3]	Cheese and Italian bouquet	3%	*A. domesticus*
		Cumin and Oriental spices		
		Rosemary and flax seeds		
		Sea salt and pumpkin seeds		
		Tomatoes and Mediterranean herbs		
	Crispbread[3]	Herbs and pepper		
		Multigrain		
	Granola	Chocolate	5%	
		Date and pecan		
		Hazelnut		
	High protein bar	Black currant and dark chocolate	13%	
		Coconut and dark chocolate		
		Peanut and salted caramel	12%	
	Insect powder	/	100%	
	Muesli bar	Chocolate and almond	4.8%	
		Date and cashew	4.6%	
		Hazelnut and cinnamon	4.7%	
	Oven roasted insects	Chili and lime	90%	
	POP bar	Cocoa	6.2%	

Company	Insect-based product	Flavour/Type	Percentage of insects	Insect species incorporated
		Coconut	6.3%	
Nimavert	Chips	Chili	10%	*A. domesticus*
		Garlic		
		Original		
	Coated dried insects	Dark chocolate	-	
		Milk chocolate		
		White chocolate		
	Dried insects	Original	-	*A. domesticus* *L. migratoria* *T. molitor*
		Garlic and parsley		*A. domesticus* *T. molitor*
		Smoked		
		Tomato		
	Edible spoons	/	-	*A. domesticus*
	Insect powder	/	100%	*A. domesticus* *T. molitor*
	Gin	/	-	*T. molitor*
	Hummus	/	12%	*A. domesticus*
	Tapenade	Eggplant	15%	

Updated in September 2025.

1: Beetle beer has been Dutch since the end of 2023, but because of its Belgian roots (created in Belgium, beer brewed in Belgium, *etc*.), it is included in this list. 2: Les pâtes des Frangines markets its products under the "Aldento" brand. 3: These foods are marketed under the "Yuma" brand, but have been owned by Kriket since early 2024, when "Yuma" was acquired. - : unknown. Sources: Little Bugs (2024) and the websites of each company.

In Belgium, insect-based foods are sold in supermarkets (*e.g.*, Carrefour, Delhaize), specialist shops (*e.g.*, BioPlanet) and at other points of sale (*e.g.*, petrol stations). In addition to these physical outlets, e-commerce is also very present in the edible insect sector. For example, 60% of Kriket's sales are made online (Trends tendances, 2024). The advantage of this type of platform is that it not only reduces storage and maintenance costs, but it also reaches more consumers (Pippinato *et al.*, 2020).

Beside producers and processing companies, other actors of the value chain (*e.g.*, distributor) are missing in Belgium. Moreover, the country is confronted with competition from neighbouring countries such as France and the Netherlands, which have invested considerable amount of money in the sector. As one Belgian expert observed: "We have the brains and the knowledge in Belgium, but we lack the companies and the investors" (Trends tendances, 2024).

3.2. Gabon

Gabon is situated in Central Africa and is characterised by a tropical climate (**Figure 1-4B**). The population of Gabon is approximately 2.5 million, with most of the population living in urban areas (91% in 2023). The largest urban area in Gabon is Libreville (*i.e.* the capital), where almost 35% of the Gabonese population lives. The population of Gabon is also characterised by a large ethnic diversity, as almost 40 ethnic groups coexisting within the country. In terms of the economy, Gabon is considered as an upper-middle-income country with a high level of poverty and unemployment (Central Intelligence Agency (CIA), 2024b).

The tropical climate of the country is particularly conducive to the development of insect farming and harvesting. In this context, several insect species have been identified as food items in Gabon in the wider literature on African entomophagy (van Huis, 2003; Kelemu *et al.*, 2015). However, prior to the present thesis, no country-specific study has been conducted to gain knowledge into this Gabonese food habit. In Gabon, as in many other Central African countries, entomophagy may contribute to addressing the prevalent issues of malnutrition and food insecurity in these regions (Niassy *et al.*, 2016; Payne *et al.*, 2016; FAO, 2021). Additionally, other benefits associated with this food practice (*e.g.*, employment opportunities, and environmental benefits) may be considered as further drivers for the development of Gabonese entomophagy.

4. Research questions and objectives

In this context, the present thesis contributes to the scientific literature by addressing the main gaps identified in section 2 (Research gaps). In addition to these gaps, the lack of information on entomophagy in Gabon represents an additional research gap highlighted above. To fill these gaps, the thesis investigates eight research questions:

- RQ1: What edible insects are currently available to consumers in Gabon?
- RQ2: What are the characteristics of the current Gabonese demand?
- RQ3: How do Western youngsters perceive entomophagy?
- RQ4: To what extent does culture influence knowledge, attitudes, practices, and willingness-to-pay for insect-based foods?
- RQ5: How does the consumer’s professional field influence the acceptance of entomophagy?
- RQ6: Are adult-oriented strategies transferable to younger populations?
- RQ7: What is the most appropriate context for entomophagy?
- RQ8: Can active participation in the preparation of insect-based foods enhance acceptance among Western consumers?

To address these questions, the thesis adopts an article-based format, consisting of five scientific articles that have been published in international journals or are currently under review. Each article explores one or more of the research questions above, ensuring that all eight questions are addressed across the five articles. These articles correspond to the five chapters that follow (Chapters 2 to 6). Together, these articles pursue a dual objective: (i) understanding entomophagy in both traditional and non-traditional cultural contexts, and (ii) identifying social determinants and practical strategies that may promote the sustainable integration of edible insects into modern diets. **Table 1-7** provides an overview of the purpose of the five following chapters.

Table 1-7. Scope of the following five chapters.

Objectives		*Research questions*		Chapters				
				2	3	4	5	6
1. Understanding entomophagy in traditional and non-traditional cultural contexts (*Global view*)	*Supply*	*RQ1*	*What edible insects are currently available to consumers in Gabon?*					
	Demand	*RQ2*	*What are the characteristics of the current Gabonese demand?*					
		RQ3	*How do Western youngsters perceive entomophagy?*					
		RQ4	*To what extent does culture influence knowledge, attitudes, practices, and willingness-to-pay for insect-based foods?*					
2. Identifying social determinants and practical strategies for sustainable integration of edible insects into modern diets (*Local view*)		*RQ5*	*How does the consumer's professional field influence the acceptance of entomophagy?*					
		RQ6	*Are adult-oriented strategies transferable to younger populations?*					
		RQ7	*What is the most appropriate context for entomophagy?*					
		RQ8	*Can active participation in the preparation of insect-based foods enhance acceptance among Western consumers?*					

Each chapter addresses one or more research questions.

The eight research questions and two objectives of this thesis are illustrated in **Figure 1-5**. As shown, the demand for edible insects constitutes the central concept of the study. Consequently, the consumer is placed at the core of this doctoral research, with the aim of assessing demand in the two study areas, identifying the sociodemographic factors that may influence it, and exploring strategies to promote entomophagy. Among these strategies, the appropriate context for consuming insects is designed with consumers, thereby reinforcing their key role. Such context may ultimately influence supply, encouraging insect companies to align their insect-based foods with consumer expectations.

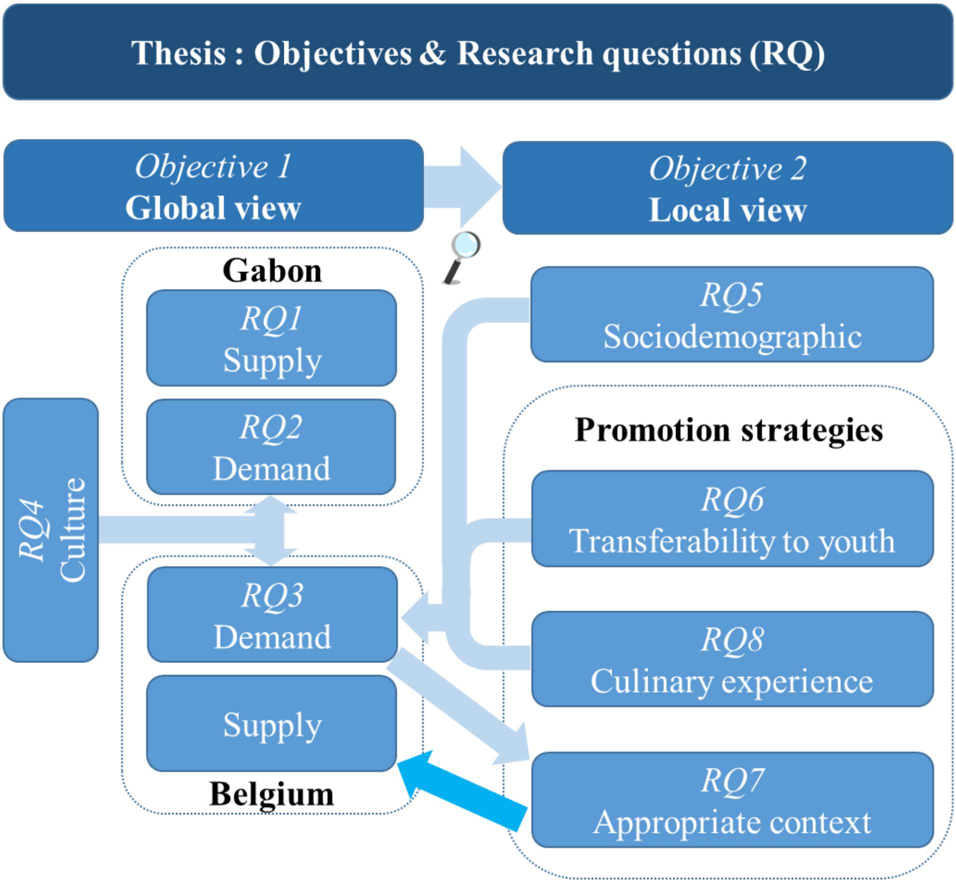

Figure 1-5. Outline of the thesis based on the objectives and research questions.

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Chapter 2

Entomophagy in Gabon across the African context

Study area: Gabon

Research questions addressed in this chapter:

- What edible insects are currently available to consumers in Gabon? (RQ1)
- What are the characteristics of the current Gabonese demand? (RQ2)

This chapter is adapted from the following research article:
Detilleux L., Poligui R.N., Iannello L., Dogot T., Francis F. & Caparros Megido R., 2021. Entomophagy in Gabon across the African context. *J. Insects as Food Feed* **8**(7), 711–720, DOI:10.3920/JIFF2021.0064.

Abstract

Entomophagy is well established in the food habits of Africa; however, country-wide knowledge remains limited for several countries, including Gabon. Here, two surveys on entomophagy were conducted in Gabon through face-to-face interviews. The first survey collected information on insect eating habits from 169 potential consumers. Edible insects formed part of the diet of most Gabonese people, with more than 60% of consumers within participants, and were particularly common among the Teke ethnic group (93%). Familiarity with edible insects was influenced by culture and family, but not by gender or study level. The second survey focused on edible insect species and their host plants, by interviewing a sample of 113 both villagers and retailers. Seventy-five species of insects from six insect orders (Coleoptera, Hemiptera, Isoptera, Lepidoptera, Odonata and Orthoptera) were consumed in Gabon, and were collected from 48 species of host plant. Many insects were formerly reported in the literature related to entomophagy; however, 13 species were newly reported as edible in this study: *Bidessus batekensis*, *Bunaeopsis licharbas*, *Copelatus ateles*, *Copelatus confinis*, *Copelatus fizpaci*, *Copelatus tondangoyei*, *Gonobombyx angulata*, *Gonometa titan*, *Hydrocyrius columbiae*, *Oxychirus semisericeus*, *Philobota* sp., *Psara* sp. and *Ptyelus flavescens*. Consequently, these surveys highlighted that entomophagy is common in Gabon. However, strategies to promote edible insects are needed to have a significant impact on food issues in Gabon (*e.g.*, food insecurity and dependence on foreign food supplies). Additional researches on entomophagy in Gabon are required to further develop these strategies.

Keywords

Edible insects, Africa, Consumption habits, Insect species, Host plants

1. Introduction

Entomophagy is currently recognized to occur in Sub-Saharan Africa as part of a long time cultural alimentary behaviour (Tchibozo *et al.*, 2016). In some areas of this African region, food crises and famines are regularly recorded, and are facilitated by natural (*e.g.*, droughts, floods and pests) and non-natural (*e.g.*, economic recessions and conflicts) phenomena (Kelemu *et al.*, 2015). Unfortunately, the impacts of climate change and continuous demographic expansion are expected to worsen the food situation, with malnutrition already exceeding 20% in this area of Africa (FAO, 2018; FAO *et al.*, 2019; United Nations, 2019). Thus, interest in the sustainable diet concept is growing; namely, "diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations" (Sustainable Development Commission, 2009; FAO, 2010; Macdiarmid, 2013; Johnston *et al.*, 2014; Tilman *et al.*, 2014; Springmann *et al.*, 2018; Barone *et al.*, 2019). Sustainable diets are promoted by the Food and Agriculture Organization (FAO), and include innovative food ingredients, such as micro-algae and edible insects (FAO, 2010; Premalatha *et al.*, 2011; van Huis *et al.*, 2013; Vigani *et al.*, 2015; Caparros Megido *et al.*, 2017; Mishyna *et al.*, 2020).

Among the reported benefits of edible insects, breeding them requires less land, water, feed and energy than conventional livestock, along with a lower impact on global warming; however, few studies are available on these potential benefits (**Table 2-1**). The environmental impact of insects could further be reduced by selecting multivoltine species with high fecundity rates (*e.g.*, up to 500 eggs per female mealworm), and by improving insect breeding systems, such as automation and feed optimization (Durst *et al.*, 2010; Oonincx *et al.*, 2012; Rumpold *et al.*, 2013; Siemianowska *et al.*, 2013). Regarding feed composition, some highly polyphagous insect species are able to develop on organic waste (*e.g.*, manure, slurry, compost and food waste) and slightly degradable organic residues (*e.g.*, lignin and lignocellullosic plant material) (Durst *et al.*, 2010; van Huis *et al.*, 2013; Rumpold *et al.*, 2017). In addition to environmental aspects, edible insects have major nutritional benefits, as they contain all the nutrients required in a healthy diet, including high levels of good quality proteins and lipids (Gahukar, 2013; Rumpold *et al.*, 2013; Feng *et al.*, 2018).

Table 2-1. Comparison of environmental impacts for mealworms and livestock.

	Mealworms	Chicken	Pork	Beef
Land use	18	51	63	254
Water use	23	34	57	112
Feed conversion ratio	2.2	2.5	5	10
Global warming potential	14	36	53	170
Energy use	173	152	237	273

Mealworms: *Tenebrio molitor* L. 1758 (Coleoptera: Tenebrionidae); Land use: m^2/kg of edible protein (Oonincx *et al.*, 2012); Water use: l/g protein (Miglietta *et al.*, 2015); Feed conversion ratio: kg of feed/kg liveweight gain (Collavo *et al.*, 2005; Oonincx *et al.*, 2012; van Huis, 2013); Global warming potential: kg of $C0_2$ eq/kg edible protein (de Vries *et al.*, 2010; Oonincx *et al.*, 2012); Energy use: mega joules/kg of edible protein (Oonincx *et al.*, 2012).

In Africa, the awareness of environmental and nutritional benefits of edible insects is considered to be the main driver for the current increase in demand for insects (Ebenebe *et al.*, 2020). Kelemu *et al.* (2015) estimated that over 470 insect species are currently consumed in cities and rural areas across Africa (Das, 2020). Most of these edible insects belong to the orders of Lepidoptera, Orthoptera and Coleoptera, and are mainly collected in the wild by children and women (Niassy *et al.*, 2016; Raheem *et al.*, 2019; van Huis, 2020). Harvesting methods depend on insect behaviour (*e.g.,* gregarious vs. solitary behaviour; ground-dwelling vs. flying insects), with specific tools being used to collect insects, such as glue, stick or nets. Unfortunately, the availability of many seasonal insects (*e.g.*, grasshoppers and cicadas) varies year-round; consequently, most edible insects cannot be consumed year-round without implementing conservation and breeding methods (van Huis, 2003, 2020; Raheem *et al.*, 2019; Ebenebe *et al.*, 2020).

Despite a high-level acceptance of edible insects across countries in Africa, differences in eating habits exist (Raheem *et al.*, 2019). To identify the drivers related to these different consumption patterns, many country-wide studies have been carried out across Benin (Riggi *et al.*, 2016; Hongbété *et al.*, 2017), Democratic Republic of the Congo (Nsevolo *et al.*, 2016; Payne *et al.*, 2016; Bomolo *et al.*, 2017), Ghana (Anankware *et al.*, 2016, 2017), Kenya (Pambo *et al.*, 2016; Homann *et al.*, 2017; Kinyuru *et al.*, 2020) and Nigeria (Agbidye *et al.*, 2009; Alamu *et al.*, 2013; Ebenebe *et al.*, 2017). General studies on edible insects reported a tradition of consuming edible insects in Gabon, but no specific study has been conducted to the best of our knowledge on edible insect practices in this country (van Huis, 2003; Kelemu *et al.*, 2015). Gabon is a Sub-Saharan African country where food security is not guaranteed for the entire population, and food supply largely depends on foreign countries (FAO, 2013; Donn *et al.*, 2016). The promotion of edible insects might, consequently, contribute towards improving the food situation. Such promotion will face to popular misconception relative to entomophagy from one part of the Gabonese population. They sometimes persecuted insect consumers by accusing them, for example, of selling flies when they were actually selling other insect species (Walters, 2010). This study aimed to collect information on entomophagy in Gabon, and to contextualize the country in the entomophagous landscape of Africa. For this purpose, field data collection on entomophagous practices, species consumed and their host plants was implemented.

2. Material and methods

2.1. Study area

This study was conducted from June to August 2019 in two areas of Gabon: Libreville City and Haut-Ogooué Province. Libreville is the capital of Gabon, and is the most populated city in the country, with 37.38% of the Gabonese population living there (CIA, 2020). This town was selected because it is a cultural melting pot where many ethnic groups coexist. Haut-Ogooué Province is located in the south-east of the country, and is the second most populated province in Gabon (13.85% of the Gabonese population) (Direction Générale de la Statistique, 2015). This province is considered to be the most insect consuming area in Gabon (Walters, 2010). Several places in Haut-Ogooué Province were visited during this study, including 2 cities (Franceville and Moanda), where practices of entomophagy were obviously displayed on marketplaces, and 11 villages (**Table 2-2**). These 11 villages were randomly selected from a set of villages with easy access. All study sites are shown in **Figure 2-1**.

Table 2-2. List of villages visited during the study.

Village	Geographic coordinates	Village	Geographic coordinates
Abouyi	S 01°35.050' - E 014°14.746'	Odjouma	S 01°15.574' – E 014°26.236'
Akou	S 01°41.043' - E 014°23.330'	Okouya	S 00°59.009' - E 014°03.445'
Aliga	S 00°55.189' - E 014°05.037'	Oloua	S 00°51.192' - E 014°16.135'
Ayogo	S 00°53.847' - E 014°13.617'	Ossouélé	S 01°04.919' - E 014°22.365'
Eau claire	S 01°34.379' - E 014°11.692'	Souba	S 01°35.237' - E 014°03.383'
Kabala	S 01°40.429' - E 014°25.243'		

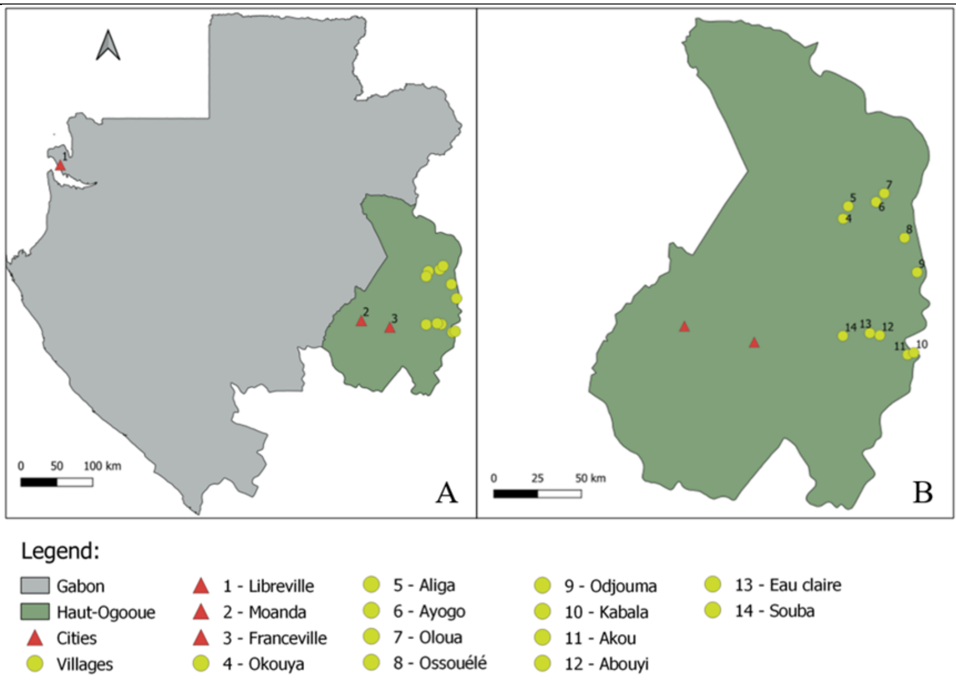

Figure 2-1. Location of the study sites in Gabon (A) and Haut-Ogooué Province (B).

2.2. Consumption habits

2.2.1. Survey design

This survey consisted of a face-to-face interview related to insect consumption habits, and was conducted with urban workers from four Gabonese public administrations: National Center for Scientific and Technological Research (Libreville), Ministry of Higher Education and Scientific Research – Central Human Resources Department (Libreville), Governorate (Franceville) and University of Science and Technology of Masuku (INSAB/USTM; Franceville). These groups were selected as they were aware of existing scientific research, and were potentially more likely to participate in surveys. Respondents were randomly selected among these public administrations, based on their willingness to participate to this study. The interviews took place in the offices of respondent, and involved a questionnaire. The interviewer read the questions chronologically, and completed the questionnaire with answers of participants. The interview was conducted in French, but clarification was also possible from the interviewee and/or interviewer in the native language of the respondent.

2.2.2. Questionnaire

The questionnaire was divided in three parts: (1) sociodemographic profile, (2) arthropod consumption and (3) insect consumption. First, a list of open-ended questions related to the sociodemographic situation of the respondents (nationality, age, gender, study level and native language) were asked. Second, information about arthropod consumption (crab, shrimp and insect) was collected via three questions: (1) Do you consume this food? (personal consumption), (2) If yes, what is the consumption frequency of this food? (frequency) and (3) Did your parents consume this food? (parental consumption). Answers related to personal and parental consumption were limited to “yes” and “no”, whereas respondents had to select the most appropriate answer for frequency: several times/week, once/week, several times/month, once/month, several times/year and once/year. All questions were repeated the three groups. Information for crab and shrimp consumption were not used for the study; however, questions related to these common foods helped to build trust with participants. The last part of this questionnaire focused on insects as food, and was only completed by insect consumers (*i.e.* respondents who answered “yes” to personal consumption related to insects). These respondents had to state which insect species they have already eaten out of caterpillars, palm weevils, cockchafer larvae, African crickets, grasshoppers, locusts, termites and cicadas.

2.2.3. Respondents

After excluding 12 incomplete questionnaires, 169 responses were included. All respondents were from Gabon, and had a mean age of 43.79 ± 8.14 years old. Other sociodemographic characteristics of respondents are presented in **Table 3.3**.

Table 2-3. Sociodemographic profile of respondents (n = 169; %).

Workplace	Libreville	Franceville	
	31.36	68.64	
Gender	Male	Female	
	50.89	49.11	
Study level	Low	Medium	High
	30.77	30.77	38.46
Native language	Fang	Mbete	Ndjabi
	18.93	24.85	15.38
	Punu	Teke	Other
	14.20	17.16	9.47

Study level; participant answers were classified in three groups: low (baccalaureate and lower), medium (from baccalaureate to licence degree) and high (higher degree than licence). Native language; participant answers were classified in language groups based on (Mouguiama-Daouda, 2005): Fang, Mbete, Ndjabi, Punu, Teke and Other (Other = grouping together several language groups with low numbers of representatives in the study).

2.2.4. Statistical analysis

Chi-square tests were performed the survey data in Minitab® v.19 (State College, PA, USA) for Windows. Answers to personal insect consumption were compared between gender, study level, native language and parental consumption.

2.3. Insect species consumed and host plants

2.3.1. Survey design

Retailers and villagers of the study area were interviewed by a face-to-face interview. Retailers originated from several marketplaces in Libreville (Akébé bridge, Akébé plain, PK12, Mombouët, Awendje and Banana market), Franceville (Score and Wendje) and Moanda (Central market and Lekolo). The interview was only conducted with retailers that sold insects or claimed to sell insects during the year. All villagers lived in the Haut-Ogooué Province, and belonged to the Teke ethnic group (*i.e.* ethnic group whose native language is Teke). This group has historically consumed insects; thus, it was assumed that the Teke people would be the most insect consuming ethnic group in Gabon (Tchibozo, 2018). Consequently, this group likely had more information about edible insects to share. The interview was only conducted with villagers claiming to eat insects. The villagers were randomly selected, based on their willingness to participate to this interview. The French language was mainly used during interviews, but some details (*e.g.*, insect and plant names) were given in the native language of the respondent. Following the interviews, some insect species had to be identified, with this being conducted with the help of entomologists from the University of Sciences and Technologies of Masuku (INSAB/USTM; Franceville, Gabon), the Royal Museum for Central Africa (Tervuren, Belgium) and the Royal Belgian Institute of Natural Sciences (Brussels, Belgium). Local human resources and systematic books on local plants helped to set identification of host plants (White *et al.*, 1997; Meunier *et al.*, 2015; Vande weghe *et al.*, 2016).

2.3.2. Interviews

All respondents were invited to list the names of the insects collected for their personal consumption or to sell, plus the host plant name. During interviews, a picture set was used to ensure the clear communication of insect names given in Teke. The pictures represented potential edible insects from Gabon, which were selected from literature based on the knowledge of the authors (Bouyer *et al.*, 2004; Lisingo *et al.*, 2012; Latham, 2016; Lautenschläger *et al.*, 2017). Where any doubt existed, insect samples were collected for further identification.

2.3.3. Insect identification

The samples were either purchased as dried on marketplaces or collected in the wild with villagers. Insects from the wild were collected by hand or with a net and then, they were preserved in plastic vials with 70% ethanol. All of these collected insects were identified by Dr. Poligui, a Gabonese entomologist from INSAB/USTM. Identification was based on morphological characteristics and literature (Bouyer *et al.*, 2004; Lisingo *et al.*, 2012; Latham, 2016; Lautenschläger *et al.*, 2017). Finally, insects which could not be identified in Gabon were sent to Belgium for further identification.

2.3.4. Respondents

One-hundred and thirteen interviews were completed; namely 16 interviews with retailers in Libreville, 23 interviews with retailers in Franceville, 9 interviews with retailers in Moanda and 65 interviews with villagers from the Haut-Ogooué Province. The interviews were limited both by the scarcity of insect retailers during the survey time, and the unwillingness of some retailers asking to be paid before answering.

3. Results

3.1. Consumptions habits

One hundred and five respondents (62.13%) ate edible insects, with different patterns of insect consumption. Specifically, several times/week for 1.90% of respondents, once/week for 9.52%, several times/month for 8.57%, once/month for 10.48%, several times/year for 14.29%, once/year for 19.05% and unknown for 36.19%. Study level (Chi-square = 2.688, $p = 0.261$) and gender (Chi-square = 2.100, $p = 0.147$) were not discriminatory factors for personal insect consumption (**Figure 2-2**). However, this consumption habit was influenced by parental consumption (Chi-square = 68.409, $p < 0.001$). Most respondents (82.84%) had a similar behaviour to their parents. For instance, 80.16% of respondents who ate edible insects, confirmed that their parents had too. In comparison, 90.70% of those who did not eat edible insects, stated that their parents had not either. Insect consumption was also associated with the native language of respondents (Chi-square = 25.626, $p < 0.001$; **Figure 2-2**). Most participants (93.10%) from the Teke ethnic group consumed edible insects.

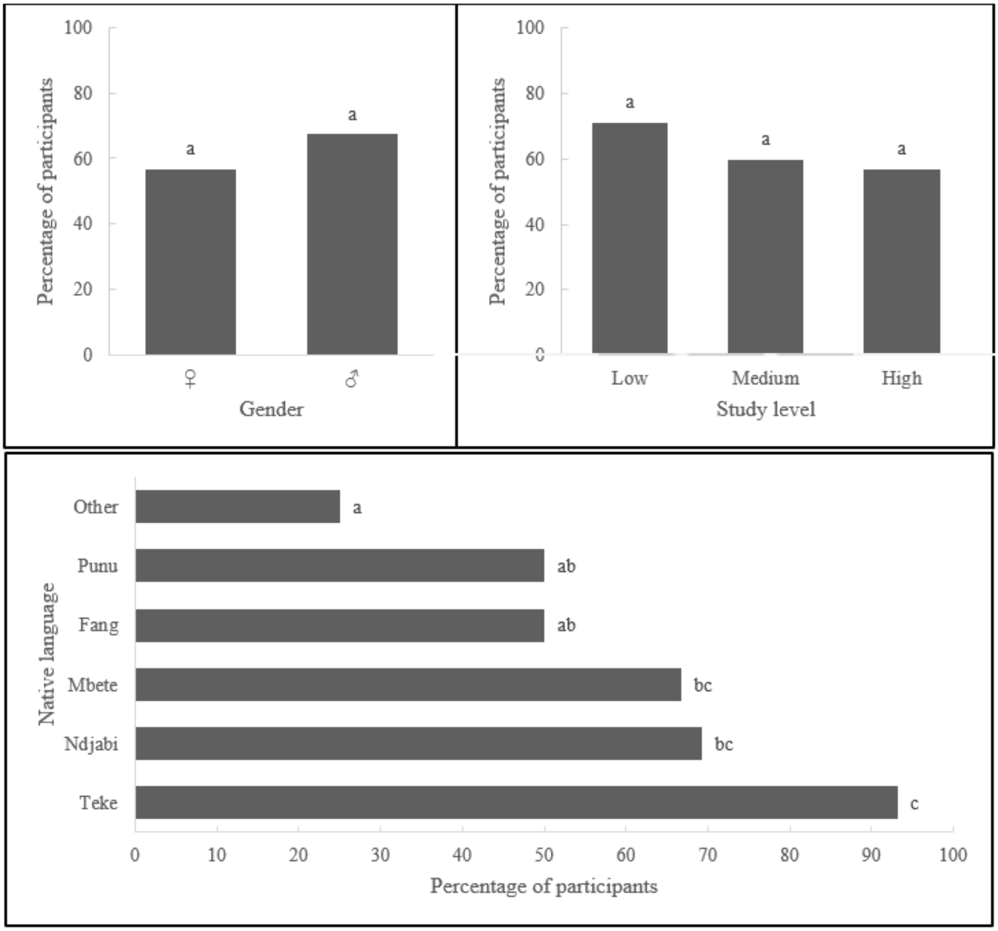

Figure 2-2. Percentage of participants who ate insects in relation to their sociodemographic characteristics.
Different superscript letters indicate a significant difference.

Palm weevils were the most frequently reported to be eaten by respondents (55.62%) out of the list of edible insects, followed by caterpillars (43.79%), termites (28.57%), African crickets (15.24%), cockchafer larvae and grasshoppers (13.33%), locusts (11.43%) and cicadas (6.67%).

3.2. Insects species consumed and host plants

Seventy-five edible insect species were mentioned by retailers and villagers, including *Bunaeopsis licharbas*, *Gonobombyx angulata*, *Gonometa titan, Hydrocyrius columbiae*, *Oxychirus semisericeus*, *Philobota* sp., *Psara* sp. and *Ptyelus flavescens* (all taxa mentioned are listed in **Supplementary Table 2-4**; **Figure 2-3**). However, 14 of these insects were not fully identified (*i.e.* missing family and/or scientific name). Six orders were represented, with Lepidoptera being the most abundant with 47 species (62.67% of all recorded species in this study).

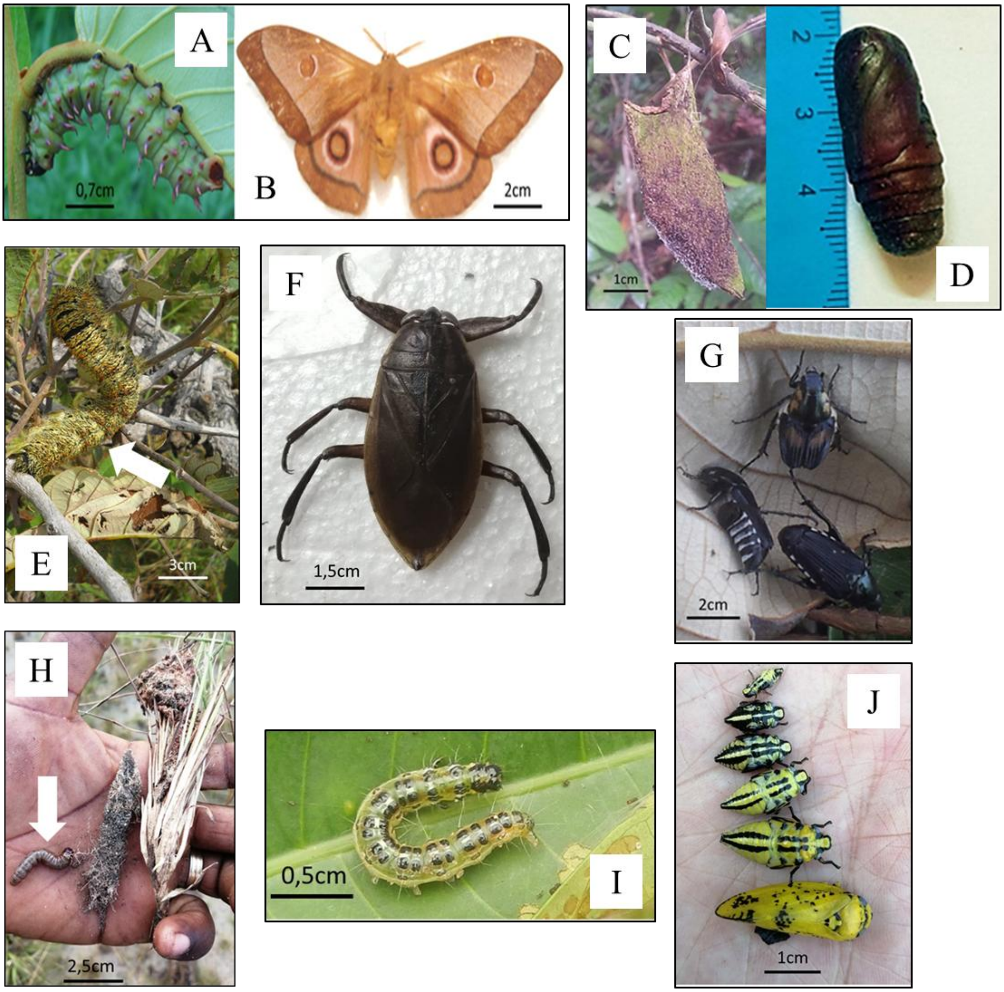

Figure 2-3. Several edible insects collected in Gabon.
A-B: *B. licharbas* (larva and adult stage); C-D: *G. angulata* (cocoon and chrysalid); E: *G. titan* (larva); F: *H. columbiae* (adult stage); G: *O. semisericeus* (adult stage); H: *Philobota* sp. (larva); I: *Psara* sp. (larva); J: *P. flavescens* (larvae and adult stage).

Edible insects were collected by respondents on 48 host plants, including two unidentified plants (**Supplementary Table 2-5**). More than one-fifth of plants (22.92%) belonged to Fabaceae.

4. Discussion

4.1. Consumption habits

Entomophagy was common in Gabon, supporting suggestions by Kelemu *et al.* (2015) and van Huis (2003); however, the percentage of insect consumers was lower compared to that in other Sub-Saharan countries (from 79.60% to 84.53%) (Nsevolo *et al.*, 2016; Anankware *et al.*, 2017; Manditsera *et al.*, 2018). This trend might be partially explained by the survey design of this study. All respondents from the first part of the study were urban, with urban populations being more likely to be unfamiliar with entomophagy, due to their being more oriented towards western culture (*i.e.* a willingness to adopt western habits, including general rejection of entomophagy) (Vantomme, 2015; Manditsera *et al.*, 2018). The inclusion of the rural population would have probably increased the percentage of insect consumers.

Gender and study level had no influence on insect consumption in Gabon. These findings contrasted with most published studies in Sub-Saharan Africa (Niassy *et al.*, 2016; Anankware *et al.*, 2017; Ehounou *et al.*, 2018; Manditsera *et al.*, 2018). However, the correlations between these two factors and insect consumption varied across studies, being poorly defined at the continent scale. Further investigation is required to explain general trend or differences among African countries.

Entomophagy in Gabon was influenced by the ethnic group of the respondents. Differences in culture could lead to differences in food practices related to edible insects. Such variations have been previously reported between countries (Hartmann *et al.*, 2015; Tan *et al.*, 2015; Brunner *et al.*, 2019), and among cultural groups within the same country (Alamu *et al.*, 2013; Bomolo *et al.*, 2017; Hongbété *et al.*, 2017; Hlongwane *et al.*, 2021). As predicted before the study, the Teke ethnic group was the biggest consumer of insects.

Most respondents continued the insect eating behaviour from their parents. This parental influence demonstrated that family plays a major role in the entomophagy experience, as suggested by other studies (Sogari, 2015; Sogari *et al.*, 2018; Barton *et al.*, 2020; Detilleux *et al.*, 2021). Such influence could be useful in the promotion of edible insects. Developing strategies to promote entomophagy (*e.g.*, tasting sessions) among people unfamiliar with edible insects could be effective on a larger scale, by also impacting families (Sogari, 2015; Sogari *et al.*, 2018).

Palm weevils and caterpillars were the most familiar edible insects identified in the current study. All development stages of palm weevils are consumed in many countries from western and central Africa, while caterpillar eating is especially widespread in Sub-Saharan Africa (Hlongwane *et al.*, 2020; van Huis, 2020; Kelemu *et al.*, 2015; Raheem *et al.*, 2019).

4.2. Insect species consumed and host plants

Bunaea alcinoë, Epanaphe carteri and *Eumeta* sp. have been previously recorded in the published literature related to entomophagy in Gabon (van Huis, 2003; Kelemu *et al.*, 2015). Most of the other insects had been previously identified as edible insects in other African countries, except for *Palpopleura* sp. and *Xyleutes* sp., which were only observed on other continents (Hlongwane *et al.*, 2020; van Huis, 2003; van Huis *et al.*, 2013; Kelemu *et al.*, 2015; Latham, 2016; Malaisse *et al.*, 2017; Tchibozo *et al.*, 2016; Thangjam *et al.*, 2020). Thirteen insect species from this study had never been listed in the literature as edible insects. These included: *Bidessus batekensis*, *Bunaeopsis licharbas*, *Copelatus ateles*, *Copelatus confinis*, *Copelatus fizpaci*, *Copelatus tondangoyei*, *Gonobombyx angulata*, *Gonometa titan*, *Hydrocyrius columbiae*, *Oxychirus semisericeus*, *Philobota sp.*, *Psara* sp. and *Ptyelus flavescens*. Interestingly, some species supposedly consumed in Gabon were not recorded in this study, including Coleoptera from the Cerambycidae family (*Ancylonotus tribulus* (Fabricius 1775) and *Petrognatha gigas* (Fabricius 1793)), Lepidoptera from the Brahmaeidae family (*Dactyloceras lucina* Drury 1782) and the Saturniidae family (*Anthocera teffraria* [5]; *Melanocera menippe* Westwood 1849 ; *Saturnia marchii* [5] and *Urota sinope* Westwood 1849) (van Huis, 2003; Kelemu *et al.*, 2015). These differences are likely explained by the study design, as some ethnic groups were not interviewed and the entire country was not visited.

5. Limitations of this study

The first part of the study was only conducted with workers from Gabonese public administrations, who were not representative of all Gabonese people. To illustrate, respondent's age ranged from 25 to 62 years old in this survey while this age class represented less than 40% of all Gabonese population (CIA, 2020). Interviewing a larger population would have led to a better representation of the current situation.

According to people in Gabon, the availability of edible insects was highest during the rainy season (from September to December). As the study was conducted from June to August, all insects were not available to check the answers of respondents and to identify insect species in cases of doubt. The data collected for the second part of the study were consequently more related to the statements of respondent. The same approach could be applied to host plants.

6. Conclusion

Entomophagy is widespread across Africa, with Gabon being no exception. Yet, familiarity with edible insects seemed to be lower in Gabon than in other African countries; however, this phenomenon was associated with the representativeness of the panel of the population surveyed here. Gender and study level did not appear to influence insect consumption in Gabon. At the level of Africa, the influence of these factors on entomophagy remains unclear and could be country-specific, requiring further studies. As highlighted by previous studies, culture and family were key factors. They should therefore be included in the development of entomophagy promotion programmes. Most insects consumed in Gabon were also eaten in other African countries, while some were newly documented for Africa and globally. Edible insects represent readily available foods that can contribute towards reducing food

[5] Full taxonomic name is not available

insecurity and dependence on foreign food supplies to Gabon. However, strategies to promote this food source are needed to increase familiarity with edible insects. Research relative to entomophagy in Gabon is consequently initiates with this study but many topics in this field still have to be investigated.

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Supplementary material

Supplementary Table 2-4. List of insect species consumed in Gabon.

Order	Family	Species	Local name
Coleoptera	Cerambycidae	*Ceroplesis* sp. Serville 1835	(E)Ntsuntsuogi
	Dryophthoridae	*Rhynchophorus phoenicis* Schoenherr 1825	(A)Mbouo (larva) (E)Kankorogo (imago)
	Dynastidae	*Augosoma centaurus* (Fabricius 1775) *Oryctes* sp. Hellwig 1798	(A)Pfuru (larva)
	Dytiscidae	*Bidessus batekensis* Bilardo & Rocchi 2013 *Copelatus ateles* Guignot 1955 *Copelatus confinis* Bilardo & Rocchi 1999 *Copelatus fizpaci* Bilardo & Rocchi 2013 *Copelatus tondangoyei* Bilardo & Rocchi 2013	(E)Kambalaga (E)Kambwambaraga
	Melolonthidae	*Eulepida mashona* Arrow 1902 *Eulepida nitidicollis* Kolbe 1894	(A)Pfuru (larva) (E)Kamvatou
		Oxychirus semisericeus Quedenfeldt 1888	(E)Kanginiņa
		UI	(A)Pfuru ma payi
Hemiptera	Aphrophoridae	*Ptyelus flavescens* (Fabricius 1794)	(E)Kantsogi
	Belostomatidae	*Hydrocyrius columbiae* Spinola 1850	Mparikaaya
	Cicadidae	*Afzeliada afzelii* (Stal 1854)	(E)Kayiè
Isoptera	Termitidae	*Macrotermes bellicosus* (Smeathman 1781)	Ntsama
Lepidoptera	Cossidae	*Xyleutes* sp. Hübner 1820	(E)Opaambu
	Crambidae	*Psara* sp. Snellen 1875	Embimbina Enkula Enkunkuta Enkuta
	Erebidae	*Achaea catocaloides* Guenée 1852	(A)Yii
		Sciatta inconcisa Walker, 1869	(E)Ompwono
	Hesperiidae	*Coeliades libeon* Druce 1875	(E)Ombimbe Ntintogo
	Lasiocampidae	*Gastroplakaeis rubroanalis* Wichgraf 1913	(E)Otsaaya Etchayi
		Gonobombyx angulata Aurivillius 1893	Apoulla (E)Kantoni
		Gonometa titan Holland 1893	Kubakubù
		UI	(A)Ngakoro
	Limacodidae	UI	Engabari
	Lymantriidae	*Rhypopteryx poecilanthes* Collenette 1931	Enchuè
		UI	(A)Lua
		UI	(E)Omwala
	Noctuidae	*Spodoptera exempta* Walker 1856	(E)Ontsintseri
	Notodontidae	*Anaphe panda* Boisduval 1847	Afugufugu Entchogo Ewogi
		Anaphe venata Butler 1878	(E)Ompfuugu
		Antheua insignata Gaede 1928	(E)Obvura
		Antheua sp. Walker 1855	Engènepe

		Antheua sp. Walker 1855	(E)Onbvumva
		Elaphrodes lactea Gaede 1932	Entsug'ambaa Ombimba
		Elaphrodes sp. Bethune-Baker 1909	Engoungou Esyellé
		Epanaphe carteri Walsingham	(A)Kuraku Mbimbaga
		Epidonta brunneomixta Mabille 1879	(E)Pimpa
		UI	Apupu Okwulu
		UI	Esyéllè
	Nymphalidae	*Cymothoe caenis* Drury 1773	(E)Ontsagá
	Oecophoridae	*Philobota* sp. Meyrick 1883	Ngbaaringba Ombimbaari
	Psychidae	*Eumeta* sp. Mörch 1868	(E)Kantsaaba
	Saturniidae	*Bunaeopsis licharbas* Maassen & Weymer 1886	(E)Kankelè k'ondolo
		Bunaeopsis sp. Bouvier 1927	Enkele b'elyè
		Bunaea alcinoe Stoll 1780	Embanya ba obuboŋon
		Cirina forda Westwood 1849	Endongolo
		Holocerina sp. Pinhey 1956	Katata Mbaa Ndjaami
		Imbrasia alopia Westwood 1849	Embanya b'omangulu
		Imbrasia epimethea Drury 1773	(E)Ombii
		Imbrasia obscura Butler 1878	(E)Kantsuba (E)Kantsubabaa Entulatáma
		Imbrasia petiveri Guérin-Méneville 1845	Engyè
		Imbrasia truncata Aurivillius 1909	Embimangu
		Lobobunaea phaedusa Drury 1780	(A)Mbágá
		Micragone cana Aurivillius 1893	(E)Ossakubu Enkukulu
		Pseudantheraea discrepans Butler 1878	(E)Ombanya
	Sphingidae	*Acherontia atropos* (Linnaeus 1758)	Ompimpemè
		Platysphinx sp. Rothschild & Jordan 1903	(E)Kampininampi
		UI	Ngwamakuga
	UI	UI	Angamou
		UI	Mbulamekoro
		UI	Ngoui
Odonata	Libellulidae	*Palpopleura* sp. Rambur 1842 *Trithemis* sp. Brauer 1868	Kantulugu (larva)
	UI	UI	
Orthoptera	Acrididae	*Acrida bicolor* (Thunberg 1815)	(E)Okaka (E)Yuoyo
		Locusta migratoria (L. 1758)	(E)Oyara
		Schistocerca gregaria (Forskål 1775)	(A)Tsará
		UI	(A)Mpari

	UI	Kafoui
Gryllidae	*Brachytrupes membranaceus* (Drury 1770)	(A)Ndjyè (A)Ngoundjiè (A)Tityè
Pyrgomorphidae	*Zonocerus variegatus* (L. 1758)	(A)Mpari ambaama
Tettigoniidae	*Ruspolia differens* (Serville 1838)	Oŋeyè

UI means unidentified. The local name is in Teke language. The letter in brackets refers to the plural form of the local name (often used orally).

Supplementary Table 2-5. List of host plants in Gabon.

Host plants			Insects
Family	**Species**	**Local name**	**Species/Local name**
Achariaceae	*Caloncoba welwitschii* (Oliv.) Gilg	Ontsaga	*Cymothoe caenis* *Eumeta* sp.
Anacardiaceae	*Mangifera indica* L.	Omangulu	*Imbrasia alopia* *Imbrasia obscura* *Lobobunaea phaedusa*
	Sorindeia juglandifolia (A. Rich.) Planch. ex Oliv.	(A)Loua	(A)Lua
Annonaceae	*Annona senegalensis var. oulotricha* Le Thomas	Ololo Ondolo	*Bunaeopsis licharbas* Engabari *Eumeta* sp. *Gonometa titan* *Holocerina* sp. *Lobobunaea phaedusa* *Oxychirus semisericeus* *Ptyelus flavescens*
Apocynaceae	*Landolphia foretiana* (Pierre ex Jum.) Pichon	Andambi Liana Ontina Ovouna	*Anaphe panda* *Imbrasia obscura*
	Tabernaemontana sp. Plum. ex L.	Ombiina	*Psara* sp.
Arecaceae	*Elaeis guineensis* Jacq.	Oba	*Augosoma centaurus* *Oryctes* sp. *Rhynchophorus phoenicis*
	Raphia gentiliana De Wild.	Pigi	*Augosoma centaurus* *Oryctes sp.* *Rhynchophorus phoenicis*
	Raphia palma-pinus (Gaertn.) Hutch.	Baaya	*Augosoma centaurus* *Oryctes sp.* *Rhynchophorus phoenicis*
	Sclerosperma mannii H.Wendl.	Maagha Mbaagha	*Rhynchophorus phoenicis*
Athyriaceae	*Diplazium sammatii* (Kuhn) C. Chr.	Kassiélè	Esyéllè
Burseraceae	*Dacryodes edulis* (G.Don) H.J. Lam	Osigi	*Lobobunaea phaedusa*
Clusiaceae	*Symphonia globulifera* L. fil	Kándá Onchué	*Rhypopteryx poecilanthes*
Combretaceae	*Terminalia catappa* L.	Badamier	*Bunaea alcinoe*
Commelinaceae	*Palisota* sp. Rchb.	Liloro	*Achaea catocaloides*
Connaraceae	*Agelaea pentagyna* (Lam.) Baill.	Sagimpaŋa	*Oxychirus semisericeus*
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn	Kassiélè	Esyéllè
Euphorbiaceae	*Macaranga monandra* Müll.Arg.	Ontsintsenè Ontsuma	*Anaphe venata*
	Manihot esculenta Crantz	Manioc (cutting)	*Ceroplesis* sp.
	Ricinodendron heudelotii (Baill.) Heckel	Osongo Osouŋo	*Imbrasia epimethea* *Imbrasia petiveri*
Fabaceae	*Albizia adianthifolia* W.Wight	Olu Osyelè	Esyéllè *Imbrasia obscura* *Imbrasia petiveri*
	Albizia altissima Hook.f.	Osyelè	*Elaphrodes lactea*
	Detarium macrocarpum Harms	Yandja	*Gastroplakaeis rubroanalis* *Gonobombyx angulata* Ngoui

	Dialium englerianum Henriq.	Obwerè	*Eulepida mashona* *Eulepida nitidicollis* *Imbrasia obscura*
	Eriosema glomeratum (Guill. & Perr.) Hook.f. *Eriosema psoraleoides* (Lam.) G.Don	Ombaga	*Epanaphe carteri*
	Millettia eetveldeana (Micheli) Hauman	Emvumva	*Antheua* sp. (Engèneŋe) *Antheua* sp. ((E)Onbvumva) *Epidonta brunneomixta*
	Millettia laurentii De Wild.	Otogo	*Antheua insignata* *Coeliades libeon* Mbulamekoro Ngwamakuga Okwulu *Platysphinx* sp.
	Parkia bicolor A.Chev.	Lempaga	*Imbrasia obscura*
	Pentaclethra eetveldeana De Wild. & T.Durand	Kaama	*Achaea catocaloides*
	Pentaclethra macrophylla Benth.	Ompaayi	*Achaea catocaloides*
Gentianaceae	*Anthocleista schweinfurthii* Gilg	Opupugu	*Micragone cana*
	Anthocleista vogelii Planch.	Okori	*Lobobunaea phaedusa*
Irvingiaceae	*Klainedoxa gabonensis* Pierre	Kantsagi	(A)Ngakoro *Gastroplakaeis rubroanalis* *Pseudantheraea discrepans*
Lamiaceae	*Vitex doniana* Sweet	Oko b'ondolo	*Imbrasia petiveri*
Lecythidaceae	*Petersianthus macrocarpus* (P.Beauv.) Liben	Ombii	*Imbrasia epimethea*
Moraceae	*Ficus recurvata* De Wild.	Ompwono	*Sciatta inconcisa*
	Ficus umbellata Vahl	Ompaa	*Sciatta inconcisa*
Myristicaceae	*Staudtia kamerunensis var. gabonensis* (Warb.) Fouilloy	Kasugu	(A)Ngakoro *Gastroplakaeis rubroanalis* *Gonobombyx angulata* *Pseudantheraea discrepans*
Myrtaceae	*Syzygium guineense* (Willd.) DC.	Okukulu	*Micragone cana*
Phyllanthaceae	*Hymenocardia acida* Tul.	Ongaraga	*Afzeliada afzelii* *Eumeta* sp. *Imbrasia obscura* *Lobobunaea phaedusa*
	Uapaca mole Pax	(E)Ontsiami	*Acherontia atropos* *Imbrasia alopia* *Imbrasia obscura* *Imbrasia truncata*
Poaceae	*Loudetia* Hochst. ex A. Braun	Okáala	*Philobota* sp.
Rubiaceae	*Nauclea latifolia* Sm.	Obuboŋon	*Bunaea alcinoe*
	Psydrax moandensis Bridson	Omwala	(E)Omwala
Sapindaceae	*Allophylus africanus* P. Beauv.	Ombimbaa	*Elaphrodes lactea*
UI	UI	Liane opaambu	*Xyleutes* sp.
	UI	Ntcheri	(A)Mpari *Locusta migratoria* *Spodoptera exempta* *Ruspolia differens* *Zonocerus variegatus*

UI means unidentified. The local name is in Teke language. The letter in brackets refers to the plural form of the local name (often used orally).

Chapter 3

Consumers of insect-based foods: a cross-cultural study between Belgium and Gabon

Study area: Belgium and Gabon

Research questions addressed in this chapter:

- What are the characteristics of the current Gabonese demand? (RQ2)
- To what extent does culture influence knowledge, attitudes, practices, and willingness-to-pay for insect-based foods? (RQ4)

This chapter is adapted from the following research article:

Detilleux L., Bayendi Loudit S., Le Gall P., Francis F., Caparros Megido R. & Dogot T., 2024. Consumers of insect-based foods: a cross-cultural study between Belgium and Gabon. *J. Insect Sci.* **24**(3), DOI:10.1093/jisesa/ieae051.

Abstract

Human consumption of insects has previously been examined in cross-cultural studies. However, such studies rarely include African countries and willingness-to-pay for insect-based food has never been assessed in cross-cultural studies. The current study presents a cross-cultural study conducted with 409 urban dwellers from Belgium (191 male; 218 female) and 412 urban dwellers from Gabon (219 male; 193 female). Each respondent was surveyed with a questionnaire following the Knowledge, Attitude and Practices model and included questions relative to willingness-to-pay for two insect-based foods (insect baguette and insect burger). More than 90% of respondent from both countries were familiar with edible insects. However, acceptance of entomophagy was lower in respondents from Gabon than in respondents from Belgium. Intercultural differences were also recorded between Gabonese ethnic groups. Most respondents who accepted entomophagy were willing to eat the insect baguette and/or the insect burger. These findings confirm that entomophagy could further develop in Belgium and Gabon. Willingness-to-pay varied between countries and between insect-based foods. In Belgium, the average prices of comparable conventional foods (*i.e.* same foods but without insects) were lower than the average willingness-to-pay for insect-based foods. In Gabon, respondents were not willing to pay extra for insect-based foods. Setting the right price for insect-based foods is a necessary step to promote more frequent insect consumption.

Keywords

Entomophagy, Novel food, European country, African country, Willingness-To-Pay

1. Introduction

In 1975, Meyer-Rochow suggested that the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) look at edible insects as a possible solution to the problem of global protein shortages (Meyer-Rochow, 1975). Almost 40 years later, the FAO followed his recommendation and published a paper ("Edible insects: future prospects for food and feed security") reporting on all aspects of insects as food and feed (*e.g.*, nutrition, animal farming, history, environment, food safety, legislation, economics, *etc*.) for the first time. This report provided a benchmark for the insect value chain and boosted interest from both the public and private sectors. The trend was also followed by the scientific community with an increasing number of scientific articles, including cross-cultural studies relative to edible insects (van Huis *et al.,* 2013; Mancini *et al.,* 2022).

With globalization, the food industry tends to standardize food throughout the world while the perception of food generally differs from one culture to another (Ghosh *et al.,* 2018; Jeong *et al.,* 2021). Such differences are highlighted by cross-cultural studies (Tan *et al.,* 2015). Consequently, cross-cultural studies are essential for understanding specific characteristics of each culture so as to develop appropriate food strategies. Most cross-cultural studies relating to entomophagy include European and/or Asian countries while cross-cultural studies including African countries are uncommon (Lensvelt *et al.,* 2014; Hartmann *et al.,* 2015; Ruby *et al.,* 2015; Tan *et al.,* 2015). The few cross-cultural studies involving an African country included Ethiopia, Mozambique, or South Africa (Cunha *et al.,* 2015; Castro *et al.,* 2019a,b; Ghosh *et al.,* 2020).

The current cross-cultural study examines entomophagy in a European (*i.e.* Belgium) and an African country (*i.e.* Gabon). Belgian people, as most Westerners, generally do not eat insects, although some companies in Belgium produce insect-based foods (*e.g.*, Aldento, Bugood Food, Kriket, *etc*.) (Van Thielen *et al.,* 2018). However, Belgium was a European pioneer in approving ten insect species for human consumption in 2014 (FASFC *et al.,* 2014). The list was implemented pending European legislation which appeared some years later with the marketing authorisation for four insect species (Vale-Hagan *et al.,* 2023). Many studies related to edible insects were conducted in Belgium to specifically identify factors supporting entomophagy development in Belgium and in other Western countries (Caparros Megido *et al.,* 2014; Caparros Megido *et al.,* 2016; Schouteten *et al.,* 2016; Van Thielen *et al.,* 2018; Detilleux *et al.,* 2021b). Three cross-cultural studies that included Belgium were also carried out; however, they were all based on the same online survey (Sogari *et al.,* 2023; Tzompa-Sosa *et al.,* 2023a,b). In Gabon, as in some other African countries (*e.g.*, Democratic Republic of the Congo, Kenya, Nigeria, *etc*.), it is common for people to eat insects. Seventy-five species of edible insects are eaten in Gabon and entomophagy depends on culture, as some Gabonese ethnic groups consume more insects than other. However, to date there has been only one study on entomophagy in Gabon (Detilleux *et al.,* 2021a).

Prior to becoming regular insect consumers, people must be willing to taste edible insects. The initial motivation for eating insects is often related to curiosity or desire to be more environmentally friendly (House, 2016). Initial motivation has been assessed by several studies that included tasting sessions with edible insects (Caparros Megido *et al.,* 2014; Lensvelt *et al.,* 2014; Caparros Megido *et al.,* 2016; Schouteten *et al.,* 2016; Sogari *et al.,* 2017; Tan *et al.,* 2017; García-Segovia *et al.,* 2020; Petersen *et al.,* 2020). Integrating insects into daily menus appears to be influenced by more practical factors such as taste, availability, compatibility with current habits, and price (House, 2016; Ghosh *et al.,* 2018). In the field of marketing, pricing is a complex strategy which requires knowledge about potential buyers, including their willingness-to-pay (WTP). WTP is defined as "the highest price an individual is willing to accept to pay for some good or service", and it is influenced by the perceived value and the utility of the good/service (Breidert, 2005). Different methods exist to estimate WTP, and they are based on market data, experiments, or surveys (Breidert *et al.,* 2006). Many studies on entomophagy have included a measurement of WTP for insect-based foods. Most of time, insect-based foods studied were familiar foods (*e.g.*, pasta, buns, cookies, sushi, *etc*.) containing non-visible insects (Pascucci *et al.,* 2013; Alemu *et al.,* 2017; Collins *et al.,* 2019; Lombardi *et al.,* 2019; Giotis *et al.,* 2021). Such features are recommended to make insect-based foods more readily accepted (Caparros Megido *et al.,* 2016).

The aim of the current cross-cultural study was to explore the potential of developing insect-based foods in Belgium and Gabon. Such aim focused on consumers and was divided into three secondary objectives: (1) to characterize and compare entomophagy in Belgium and Gabon, (2) to examine ethnic disparities in Gabon regarding entomophagy, and (3) to assess the WTP for two insect-based foods. These secondary objectives were performed using a Knowledge, Attitude and Practices questionnaire. This type of questionnaire distinguishes between what the participants know about entomophagy (*i.e.* Knowledge), what they are willing to do (*i.e.* Attitude), and what they actually do (*i.e.* Practices) (Gumucio *et al.,* 2011). Such questionnaires are used to record Knowledge, Attitude and Practices around specific topics (*e.g.*, entomophagy) and to target future strategies (*e.g.*, promotion of edible insects). For example, the assessment of knowledge helps to develop information and education programs by identifying areas where efforts are still required (Gumucio *et al.,* 2011).

2. Material and methods

2.1. Study design

Data were collected from surveys with respondents from Belgium and Gabon. Both countries are characterised by predominantly urban populations whose purchasing habits are oriented towards supermarkets and the consumption of processed foods (Central Intelligence Agency (CIA), 2023a,b; The Global Alliance for Improved Nutrition (GAIN), 2023). Such features were particularly relevant to the current study. Respondents were recruited from two cities in each country: Namur (N50°27'59"-

E4°51’58”) and Ottignies Louvain-la-Neuve (N50°39’55”-E4°33’37”) in Belgium; and Libreville (N0°24’31”-E9°26’31”) and Franceville (S1°38’4”-E13°35’22”) in Gabon. Namur and Ottignies Louvain-la-Neuve are located in Wallonia (*i.e.* the French-speaking part of Belgium), and they are one of the most populated urban areas in their respective province (Statbel, 2022). Libreville is the capital of Gabon and the largest city of the country, while Franceville is located further south-east and is the main city of the Haut-Ogooué Province (Direction Générale de la Statistique, 2015; Central Intelligence Agency (CIA), 2023a).

Surveys were conducted at the entrance to supermarkets, with permission from the managers. Each customer was invited to participate for a few minutes in an anonymous survey related to scientific research. Once agreed, customers answered a questionnaire which was read and recorded by a surveyor (*i.e.* one of the authors of the current study). The survey was conducted in French with data collected on a tablet in Belgium and on paper in Gabon. The questionnaire was designed with Typeform (Barcelona, Spain) on the tablet and with Microsoft Word v.2016 (Santa Rosa, California, USA) on paper. The days and times of data collection and the supermarkets were varied to obtain a variety of respondent profiles. On average, the administration of a questionnaire took 1 minute and 40 seconds per respondent. However, the length of the questionnaire (from 9 to 16 questions) depended on the participants’ answers (see below). Surveys were conducted over a two-month period in 2022: throughout April in Gabon and from mid-June to mid-July in Belgium. The cross-cultural study received ethical approval (n°20211224) from the Human and Social Sciences Ethics Committee of University of Liège.

Sociodemographic parameters of each participant including gender, age, nationality, native language (only for Gabonese people), education level, and monthly income level were collected from participant declarations. Concerning questions relative to education and income levels, the list of possible answers varied between Belgium and Gabon to reflect the reality of the country. However, answer modalities of each country were grouped into categories for comparisons between countries. The native languages of Gabonese people were grouped into language groups based on the work of Mouguiama-Daouda (Mouguiama-Daouda, 2005).

After the surveys, data were excluded from participants that were younger than 18 as no parental consent was obtained. In addition, data from non-European respondents in Belgium and non-African respondents in Gabon were excluded to limit the cultural complexity of the study. In all, 19 surveys were excluded, leaving a total of 409 respondents in Belgium and 412 respondents in Gabon. In Belgium, 56.23% of the data came from Ottignies Louvain-la-Neuve, while 57.28% of the Gabonese data were collected in Libreville. The sociodemographic profile of the respondents from both countries is presented in **Table 3-1**.

Table 3-1. Sociodemographic profile of respondents – overall and by country.

		Total (n = 821)	Belgium (n = 409)	Gabon (n = 412)
Gender	Female	411	218	193
	Male	410	191	219
Age class	[18-25]	148	101	47
	[26-40]	309	98	211
	[41-65]	315	165	150
	> 65	49	45	4
Nationality	Native	754	381	373
	Non-native	67	28	39
Education level	None	12	3	9
	Very low	18	5	13
	Low	296	113	183
	Medium	217	137	80
	High	278	151	127
Monthly income level	No answer	75	31	44
	Very low	168	85	83
	Low	244	133	111
	Medium	224	124	100
	High	110	36	74
Native language	Fang	-	-	99
	Mbete	-	-	59
	Ndjabi	-	-	39
	Punu	-	-	81
	Teke	-	-	45
	Other	-	-	50

Nationality: native (Belgian; Gabonese), non-native (another nationality than Belgian; Gabonese). Education level; answers were grouped into five categories: none, very low (primary school for both), low (secondary school for Belgium; secondary school and baccalaureate degree for Gabon), medium (bachelor's degree for Belgium; licence degree for Gabon), and high (master's degree and higher for both). Monthly income level; answers were grouped into five categories: no answer, very low (< 1 000 € for Belgium; < 80 000 FCFA for Gabon), low (1 000-2 000 € for Belgium; 80 000-250 000 FCFA for Gabon), medium (2 000-3 000 € for Belgium; 250 000-600 000 FCFA for Gabon), and high (> 3 000 € for Belgium; > 600 000 FCFA for Gabon); €: euro; FCFA: Franc of the Financial Community of Africa. Native language (for natives from Gabon only); answers were grouped into six language groups based on the work of Mouguiama-Daouda (2005): Fang, Mbete, Ndjabi, Punu, Teke, and Other (Other = several language groups with low number of representatives in the study).

2.2. Knowledge, Attitude and Practices relative to entomophagy

The first question focused on Knowledge, and introduced the topic of the study: "Do you know that some insects can be eaten by humans?" (entomophagy knowledge).

Then, participants were questioned about their knowledge of edible insect supply points (supply knowledge): "Do you know where to get edible insects?" and "If yes, where?" with one or several answers ranging from markets, specialist shops, supermarkets, restaurants, webshops, in nature, and other.

Attitude of respondents was investigated through acceptance of entomophagy ("Would you accept to eat insects?"). Respondents who refused to eat insects were asked to specify the reason(s) for refusal from several statements: "insects are scary", "eating insects is dangerous", "I get no benefit", "I do not need it", "It is not in my culture", "I am allergic to insects", "I do not want to taste new food", "Eating insects is disgusting", "I do not have enough information about this food", and "other".

Questions relating Practices were only answered by respondents who accepted eating insects (entomophagy acceptors). Such participants were categorized into insect eaters and insect non-eaters with the following question: "Have you already consumed edible insects?" (entomophagy experience). Insect eaters specified their consumption frequency of edible insects by selecting the most appropriate answer: several times/week, once/week, several times/month, once/month, several times/year, or once/year (frequency).

2.3. WTP for insect-based foods

Before the WTP assessment, entomophagy acceptors had to choose which insect-based food they would eat (none, one, or both) from a baguette made of insect flour (*i.e.* insect baguette) and an insect burger. Their choice was based on names and pictures of foods. Pictures were images of the comparable conventional foods (*i.e.* same foods but without insects) to highlight that insect-based foods were similar by showing no sign of visible insects, as previously recommended (Caparros Megido *et al., 2*016). Then, respondents received the payment card(s) corresponding to their food choice. The payment card is a WTP assessment method which has recently been used in studies on entomophagy (Giotis *et al.,* 2021; Sogari *et al.,* 2022). In this method, participants were placed in a hypothetical purchasing scenario, and they were asked to select the amount that most closely matched the maximum amount they were willing to pay for a food item (Riccioli *et al.,* 2020). Payment cards were country and food specific: the median amount was the average price of the similar conventional food and other amounts corresponded to plus and minus 10%, 25%, 50% and 100% of this average price. In the questionnaire, the amount "minus 100%" was replaced by the statement "No desire to purchase". The average price for each food was determined during an exploratory survey in several outlets of each country. After completing the payment card(s), participants had to select the expected benefit(s) of the selected food(s) compared to conventional food(s). Their choice was made from a list of several types of benefits: environmental, nutritional, sensorial, economical, ethical, other, or none.

2.4. Statistical analysis

All statistical tests were performed with Minitab v.19 (State College, PA, USA) for Windows. Chi-square tests were applied on the Knowledge, Attitude and Practices data to identify similarities and differences between countries and between Gabonese ethnic groups. Regarding WTP for insect-based foods, a one-sample t-test was applied in each country to compare WTP to the average of the comparable conventional food. Several tests used ΔWTP instead of WTP because the price difference between the two insect-based foods and the currency difference between the two countries made the WTP comparison irrelevant. ΔWTP represented the relative difference between WTP for insect-based food and the average price of the comparable conventional food. The first test on ΔWTP involved an analysis of variance (ANOVA) with a generalised linear model (GLM) for all socio-demographic factors, except nationality which was correlated with other factors: 2 (country) X 2 (gender) X 4 (age class) x 5 (education level) x 5 (monthly income level). The purpose of this test was to determine whether the homeland (*i.e.* factor "Country") had an influence on ΔWTP for insect-based foods and whether this influence was due to any interaction with another socio-demographic factor. Then, statistical differences found by the GLM were tested with a Kruskal-Wallis test, as the assumptions of one-way ANOVA (*i.e.* population normality and variance homogeneity) were not met. Finally, multiple comparisons were evaluated using Dunn's test. These two tests enabled a more in-depth study of the previously identified influences. The same approach was applied to examine the difference of ΔWTP between the two insect-based foods.

3. Results

3.1. Knowledge, Attitude and Practices relative to entomophagy

Entomophagy knowledge was more widespread in Belgium than in Gabon (chi-square = 23.423, $p < 0.001$). Despite this statistical difference, over 90% of respondents in each country were acquainted with this food practice (98.78% in Belgium and 91.50% in Gabon). A reverse trend was observed for supply knowledge (chi-square = 43.818, $p < 0.001$), as the percentage of respondents who identified edible insect supply points was higher in Gabon (66.50%) than in Belgium (43.52%). Nature was the most frequently cited supply point in Gabon (64.60%), followed by markets (54.01%), and restaurants (10.58%). In Belgium, the most frequent answer was specialist shops (87.08%), followed by webshops (38.20%), and the supermarkets (25.28%).

Regarding attitude, urban people from Belgium were more prone to eat insects than people from Gabon (chi-square = 10.495, $p = 0.001$; acceptance in Belgium: 68.22%; acceptance in Gabon: 57.28%). Reasons given for refusal to eat insects were similar in both countries, with "It is not in my culture" (33.08% in Belgium and 46.02% in Gabon) and "Eating insects is disgusting" (39.23% in Belgium and 42.61% in Gabon) as the most frequent responses. In Gabon, acceptance of entomophagy varied between ethnic groups (chi-square = 18.827, $p = 0.002$; **Figure 3-1**).

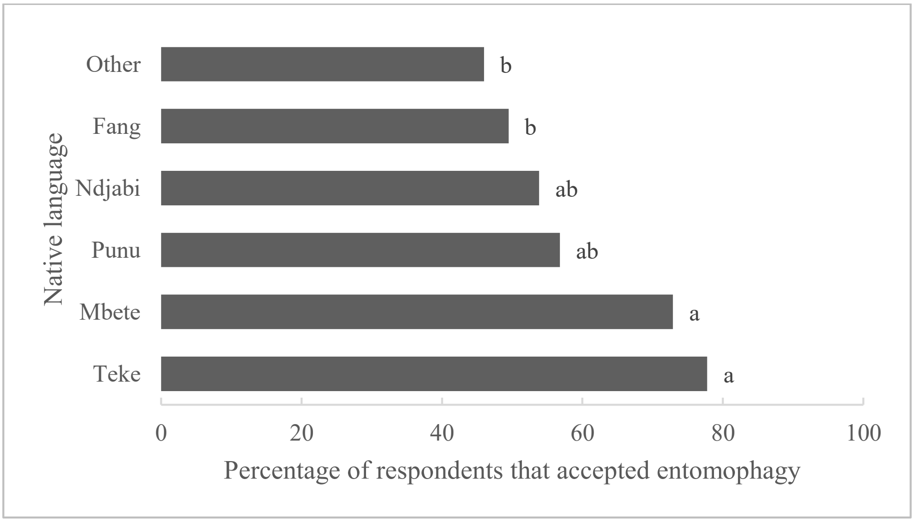

Figure 3-1. Percentage of entomophagy acceptors in relation to their native language (n = 373).
Different superscript letters indicate a significant difference.

Among entomophagy acceptors, there were more respondents from Gabon who ate insect (81.78%) than respondents from Belgium (67.74%; chi-square = 13.152, $p < 0.001$). In Gabon, the ethnic group of the respondents influenced entomophagy experience (chi-square = 29.613, $p < 0.001$; **Figure 3-2**) with the most experience in the Teke ethnic group. In both countries, most insect eaters (93.12% in Belgium and 58.02% in Gabon) consumed edible insects once/year.

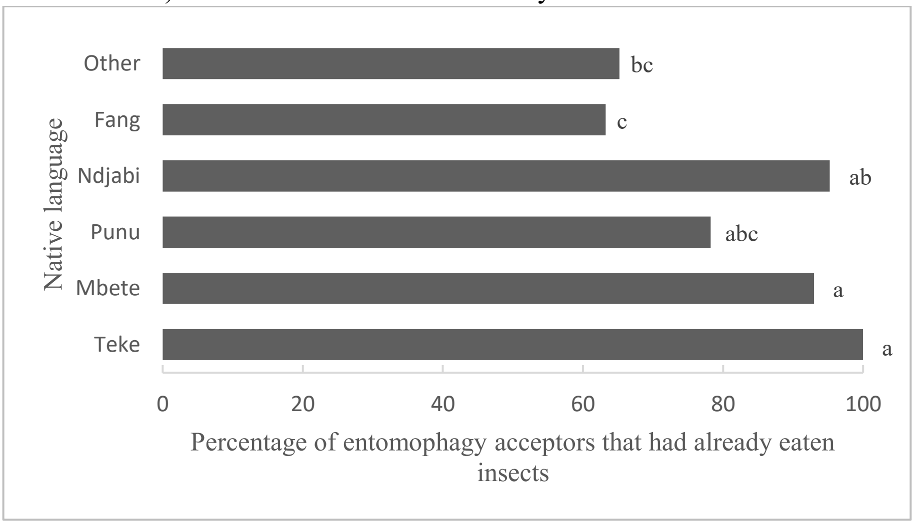

Figure 3-2. Percentage of insect eaters in Gabon by native language.
The percentages were calculated based on entomophagy acceptors (n = 217). Different superscript letters indicate a significant difference.

3.2. WTP for insect-based foods

A total of 269 participants from Belgium responded that they would eat at least one of the insect-based foods, with a strong preference for the insect baguette, as 84.59% of entomophagy acceptors said they would eat this food. In Gabon, 84.75% of entomophagy acceptors were ready to eat the insect baguette and/or the insect burger (**Figure 3-3**).

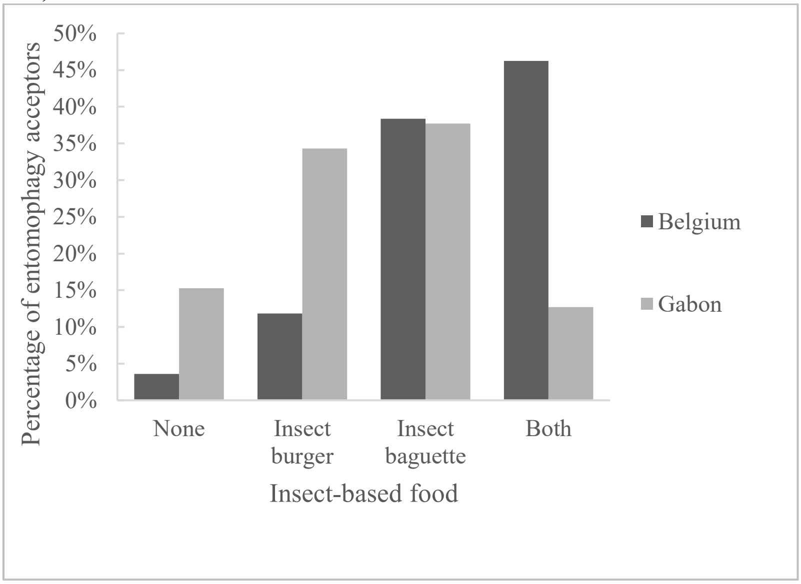

Figure 3-3. Choice of insect-based food.
Percentages were calculated based on entomophagy acceptors ($n_{Belgium}$ = 279 and n_{Gabon} = 236).

The GLM for the WTP for an insect burger found an interaction between the factors "Country" and "Education level" (**Table 3-2**). However, the Kruskal-Wallis test did not confirm this effect, as there was no significant difference between education levels within the same country (Belgium: $H_{4,162} = 5.78$, $p = 0.216$; Gabon: $H_{4,111} = 6.41$, $p = 0.171$). Findings relative to correlation between education level and WTP for the insect burger were similar. Education level was identified as a discriminatory factor by the GLM (**Table 3-2**), but was not significant according to the Kruskal-Wallis test ($H_{4,273} = 6.66$, $p = 0.155$).

Table 3-2. Results of the GLM on the ΔWTP (%) for the insect-based foods.

Factor	DF	F	*p*	DF	F	*p*
	Baguette			Burger		
Country	1	7.62	***0.006***	1	35.94	***< 0.001***
Gender	1	3.38	0.067	1	0.05	0.828
Age class	3	0.36	0.783	3	0.66	0.580
Education level	4	1.21	0.307	4	3.54	***0.008***
Monthly income level	4	1.08	0.366	4	1.01	0.401
Country * Education level	-	-	-	4	2.56	***0.039***

ΔWTP for insect baguette and insect burger: relative difference between WTP for insect-based food and the average price of the comparable conventional food. Country: Belgium and Gabon. Gender: male and female. Age class: [18-25], [26-40], [41-65], and >65 years old. Education level: none, very low, low, medium, and high. Monthly income level: no answer, very low, low, medium, and high. DF: degree of freedom. F: F-statistic. *p*: significance level. Bold data indicate significant results. Only significant interaction effects are included in the table, but all others were checked when it was possible (*i.e.* when interaction was not correlated with other factors/interactions of the GLM or when interaction had enough different combinations of the interacting factors).

The influence of the homeland (*i.e.* factor "Country") on the WTP for insect-based foods was also observed (**Table 3-2**). The ΔWTP for both insect-based foods were greater in participants from Belgium than respondents from Gabon (**Table 3-3**).

Table 3-3. ΔWTP (%) for the insect-based foods (mean value ± standard deviation).

	Belgium	Gabon	Statistical analysis	*p*
Insect baguette	15.34 ± 36.53^{a}	3.66 ± 34.70^{b}	$H_{1,355} = 10.37$	***0.001***
Insect burger	8.36 ± 27.25^{a}	-13.74 ± 34.66^{b}	$H_{1,273} = 37.60$	***< 0.001***

ΔWTP for insect baguette and insect burger: relative difference between WTP for insect-based food and the average price of comparable conventional food. Different superscript letters indicate significant differences between countries. Bold data indicate significant results.

Approximately 50% of participants from Belgium would pay the same price for an insect-based food compared to a similar conventional food (**Figure 3-4**). In Belgium, on average, respondents were willing to pay extra for an insect baguette (T = 6.45, $p < 0.001$) and an insect burger (T = 3.91, $p < 0.001$). In Gabon, the average WTP for the insect baguette was not significantly different than the average price of a conventional baguette (T = 1.15, $p = 0.253$). However, the WTP for an insect burger was lower than a conventional burger for respondents from Gabon (T = - 4.18, $p < 0.001$).

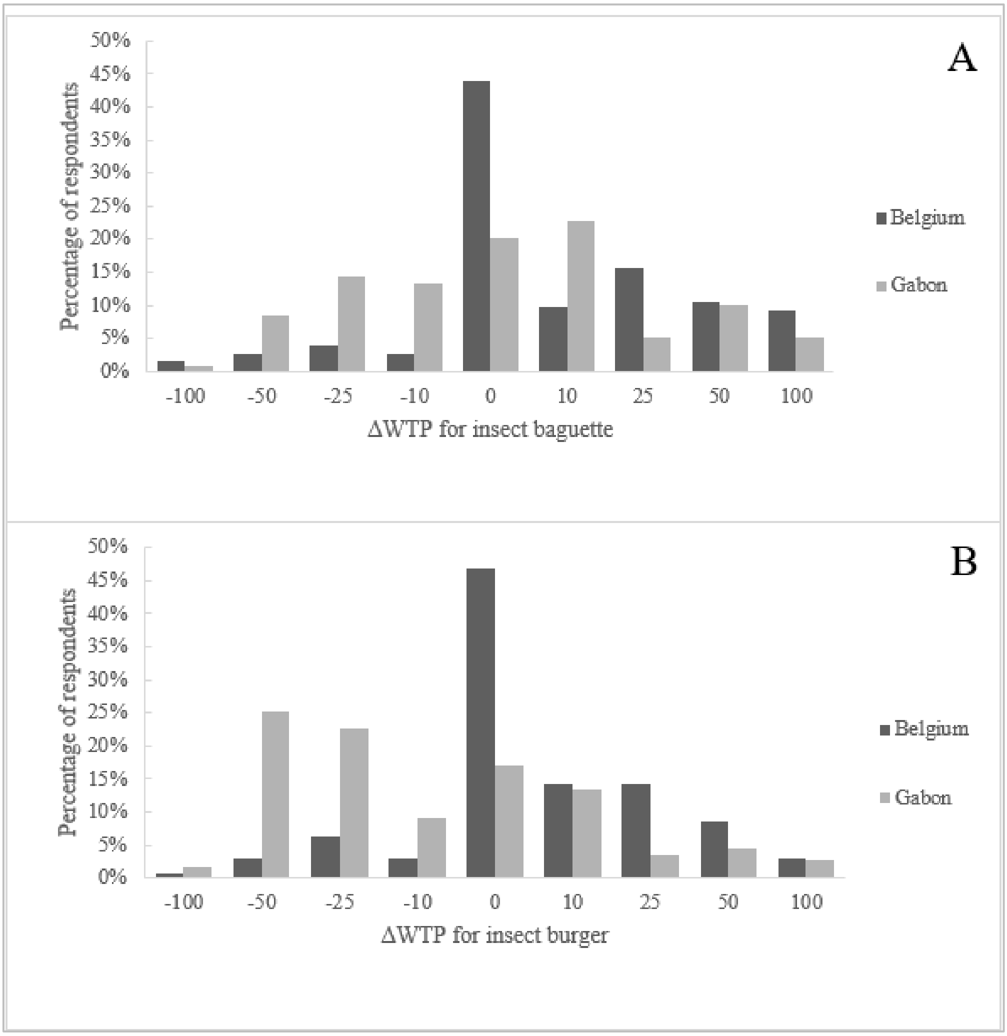

Figure 3-4. Distribution of ΔWTP (%) for insect baguette (A) and insect burger (B). The ΔWTP was calculated by the relative difference between WTP for insect-based food and the average price of the comparable conventional food. The percentages of respondents were calculated from those that were willing to eat the insect-based food (Insect baguette: $n_{Belgium} = 236$ and $n_{Gabon} = 119$; Insect burger: $n_{Belgium} = 162$ and $n_{Gabon} = 111$).

The ΔWTP was higher for insect baguette (ΔWTP = 11.42 ± 36.30) than for the insect burger (ΔWTP = - 0.62 ± 32.31; $H_{1,628} = 16.13$, $p < 0.001$).

In both Belgium (64.31%) and Gabon (78.50%), the most frequently noted benefit associated with entomophagy was nutrition. In contrast, 20.07% of respondents from Belgium and 10.50% of respondents from Gabon cited no benefit from eating insect-based foods.

4. Discussion

4.1. Knowledge, Attitude and Practices relative to entomophagy

Entomophagy knowledge and acceptance of eating insects were higher in respondents from Belgium than in respondents from Gabon, whereas entomophagy experience was lower in Belgium than in Gabon. The dynamics of entomophagy were significantly different between Belgium and Gabon.

In Belgium, entomophagy is viewed as a new food habit advertised by the media, scientists, and some companies (Van Thielen *et al.,* 2018; Detilleux *et al.,* 2021b). Eating insects is mainly promoted as a healthy and sustainable food practice which contributes to food well-being among Western consumers (Batat *et al.,* 2020). This message may be important to some individuals and could spark curiosity to try insect-based food, which is a key predictor of consumer acceptance (Sogari *et al.,* 2017; Stone *et al.,* 2022). The growing awareness led to an increase in knowledge about entomophagy in Belgium over the last few years: from 61.9% in 2013 to 78.7% in 2017 and 98.8% in 2022 (Caparros Megido *et al.,* 2014; Van Thielen *et al.,* 2018). However, the European entomophagy sector is therefore still in the development phase: the first species have only recently been approved for marketing, the start-ups are becoming well-established companies, the investments are increasing, and insect-based foods are diversifying (Payne *et al.,* 2019; Mancini *et al.,* 2022; Vale-Hagan *et al.,* 2023). In this context of developing novelty, insect-based foods are still scarce in stores. In the current study, respondents from Belgium thought that edible insects were mainly sold in specialist shops. This knowledge likely corresponds to the current market situation in Belgium. Participants also claimed to act like traditional Westerners, as their consumption events were scarce and likely limited to special events and travel (Tan *et al.,* 2015; Detilleux *et al.,* 2021b).

Concerning Gabon, as in other cultures familiar with entomophagy, urban dwellers tend to modernize their diet and avoid traditional eating habits, such as consuming edible insects (Vantomme, 2015; Müller, 2019). The lower Knowledge, Attitude and Practices related to entomophagy might therefore be explained by the high level of urbanization in Gabon. Moreover, as recorded in another Gabonese study, attitude and practices toward edible insects were different between ethnic groups with the Fang and the Punu as the least entomophagic groups (Detilleux *et al.,* 2021a). The Fang and the Punu were precisely the largest ethnic groups in Gabon, but also in the current study (Central Intelligence Agency (CIA), 2023a). Belonging to an ethnic group is the best predictor of food preferences and influences the selection of insect species and the way they are cooked (Ghosh *et al.,* 2018). In the current study, supply knowledge was consistent with the history and existing market of entomophagy in the country. In many African countries, edible insects have been a habitual food item for many years with a subsistence economy. In most of these countries, insects are collected in the wild for household consumption or bought in the consumer market. The Gabonese consumer markets are also supplied by imports of edible insects from neighbouring countries (Muafor *et al.,* 2015; Ebenebe *et al.,* 2020). Regarding practices, most participants with entomophagy experience reported consuming edible insects only once per year. Such finding is in agreement with a prior study in Gabon, suggesting that edible insects are considered a delicacy and are eaten only on special occasions or possibly by the seasonal availability of edible insects (Bomolo *et al.,* 2017; Detilleux *et al.,* 2021a).

Despite the differences between Belgium and Gabon, reasons for rejection of insect eating were similar in both countries with disgust and cultural incompatibility as the most cited reasons. This finding is consistent with prior literature (Ruby *et al.,* 2015; Sogari *et al.,* 2017; Van Thielen *et al.,* 2018; Kröger *et al.,* 2022).

4.2. WTP for insect-based foods

Only 8.9% of all entomophagy acceptors said they would refuse to eat an insect baguette and/or an insect burger. Such foods are salty and show no obvious visual signs of insects, meeting expectations of potential insect-based food consumers relative to flavour and appearance (Tan *et al.,* 2015; Caparros Megido *et al.,* 2016; Tan *et al.,* 2017; Detilleux *et al.,* 2021b). However, respondents were unable to consider certain parameters that may have influenced their decision, such as the odour of the foods (Ghosh *et al.,* 2018). These foods did not exist in the Belgian or Gabonese market but similar conventional foods were familiar in both countries. The present study was the first to use insect baguette; however, similar bakery foods with insects such as bread, biscuits, cookies, brownies, *etc*. were previously proposed in several tasting sessions (Lensvelt *et al.,* 2014; Alemu *et al.,* 2017; Sogari *et al.,* 2017; García-Segovia *et al.*, 2020; Petersen *et al.,* 2020). The insect burger has already been used in studies evaluating insect-based foods, as insects are often seen as meat substitute (Caparros Megido *et al.,* 2016; Schouteten *et al.,* 2016).

The WTP for an insect baguette and/or an insect burger was not influenced by sociodemographic factors, except by culture. Prior literature on WTP for insect-based food has also reported no effect of gender and education level (Collins *et al.,* 2019; Lombardi *et al.,* 2019; Giotis *et al.,* 2021). The results of the current study, reporting that income does not influence WTP for insect-based food, are in agreement with Collins *et al.* (2019); but they are contrasted with Giotis *et al.,* (2021) which reported that income positively affects WTP (Collins *et al.,* 2019; Giotis *et al.,* 2021). While the current study found no influence of age on WTP for insect-based food, this correlation varies greatly across the literature. Two studies report that age and WTP are negatively associated, while another study reports a positive association (Collins *et al.,* 2019; Lombardi *et al.,* 2019; Giotis *et al.,* 2021). Variability in the findings pertaining to age and acceptance of insect-based food have also previously been reported (Kröger *et al.,* 2022). Concerning the influence of culture, respondents from Belgium had a higher WTP for both insect-based foods than respondents from Gabon. Further research is needed to study the influence of sociodemographic factors on WTP, especially for culture, as this study is the first cross-cultural study which assessed WTP for insect-based foods.

The current study found that WTP varied by product, as respondents from both countries had a higher WTP for the insect baguette than for the insect burger. These findings are in agreement with Lombardi *et al.* (2019) who stated that carriers (*i.e.*

baguettes and burgers in this study) influenced WTP for insect-based foods (Lombardi *et al.,* 2019). In Belgium, respondents were on average willing to pay extra for the insect baguette and the insect burger. This trend is in agreement with Alemu *et al.* (2017), but it differs from two other studies finding that most people would pay less for insect-based foods compared to similar conventional foods (Collins *et al.,* 2019; Giotis *et al.,* 2021). The difference in findings may be explained by the carrier used. The current study used the baguette and the burger, the study of Alemu *et al.* (2017) used bread, whereas other studies have used minced meat, energy bars, and cookies. Compared with these three foods, the baguette, the burger, and the bread are more familiar, ready to eat, and salty. These attributes are known factors in favouring insect consumption (Caparros Megido *et al.,* 2014; Lensvelt *et al.,* 2014; Hartmann *et al.*, 2015; Tan *et al.,* 2015; Caparros Megido *et al.,* 2016; Tan *et al.,* 2017; Collins *et al.,* 2019; Detilleux *et al.,* 2021b). The visual aspect of insect baguettes and insect burgers (*i.e.* no visible sign of insect) is also likely a key factor, as visible insects in food tend to negatively affect WTP for insect-based foods (Pascucci and de-Magistris, 2013). Other studies have reported that individuals were willing to pay more for insect-based foods or for poultry fed with insects when they were first informed of the benefits of entomophagy (Lombardi *et al.,* 2019; Sogari *et al.,* 2022). In the current study, respondents were not informed about edible insects, however the majority was already aware of the benefits associated with insect consumption. Similar to other studies, nutrition was the most frequently cited benefit among respondents (Ruby *et al.,* 2015; Van Thielen *et al.,* 2018). As suggested by those respondents, edible insects are nutritious. However, the nutritional profile of insects varies greatly between species and is quite similar to that of meat. Promoting the insect burger over a conventional meat burger for its nutritional value is therefore inadequate, especially with certain insect species that are rich in energy, sodium, and saturated fats, which can aggravate problems related to over-nutrition (Payne *et al.,* 2016; Orkusz, 2021).This statement is particularly true for Belgium and Gabon, where obesity rates are increasing. However, in Gabon, an increasing proportion of the population is also undernourished (FAO, 2021). For the latter, consuming food enriched with edible insects, such as insect baguettes, can be an effective way to combat nutritional deficiencies (Payne *et al.,* 2016).

Despite the average WTP being higher for insect-based foods, many respondents from Belgium wanted to pay the same price both for foods with and without insects. These results suggest that insect-based foods should not be excessively higher priced than conventional foods, as this will discourage insect consumption (Tuccillo *et al.,* 2020). Such situation is currently applied in European countries and represents a barrier to the development of entomophagy (House, 2016). In contrast, the WTP for an insect burger was lower for respondents from Gabon. An explanation for this finding could be that the average price of a conventional burger, used as a reference, was perceived as too high. By judging a product combination (*i.e.* here, insects in burger), respondents also judged the appropriateness of the combination. In the case of unfamiliar food, food appropriateness has more impact than some relevant factors as sensory liking and an inappropriate combination could lead to a low WTP (Tan *et al.,* 2016; Lombardi *et al.,* 2019).

5. Limitations of this study

The contingent valuation method used to measure the WTP for insect-based foods has several flaws: respondents tend to overlook the foods' characteristics and the constraints associated with buying foods (*e.g.*, availability of foods or their competitors, household budget, *etc*.) to focus only on prices of foods; their estimations of WTP remain statements and can differ from their real attitude; even if their attitude reflects reality, it may never translate into practices; estimating WTP for unfamiliar foods as insect-based foods is difficult for respondents; *etc*. (Breidert *et al.,* 2006; Le Gall-Ely, 2009). In the case of this study, the foods were only presented as pictures, and they were not present in the markets of both countries. WTP for insect burger and insect baguette were therefore evaluated on the basis of respondents' prejudices (*e.g.*, level of interest, expected benefits, neophilia, *etc*.) rather than their experience with these foods (Caparros Megido *et al.,* 2016).

In Gabon, edible insects are more readily available during the rainy season (from September to December), whereas the Gabonese data for this study were collected in April. Therefore, it is possible that this seasonal pattern influenced the question about the consumption frequency of edible insects.

6. Conclusion

Most urban dwellers from both Gabon and Belgium were accepting of including edible insects in their diet. Advertisement from the entomophagy sector seems effective in Belgium, as participants were aware and curious about eating insects. In Gabon, knowledge and the acceptance of entomophagy were lower than that in Belgium but this may be partially due to the modernization of food habits which occurs especially in urban areas. The edible insect sector in Gabon could therefore draw on the Belgian advertising strategy to improve the acceptance of entomophagy. People from Gabon had more experience in eating insects than respondents from Belgium, but they both consumed them infrequently. Many respondents were acquainted with the benefits of entomophagy, especially nutritional benefits. In Gabon, ethnic groups differed in their acceptance and practice of insect eating.

Many respondents who accepted the consumption of edible insects were willing to eat both the insect baguette and the insect burger. Such insect-based foods could potentially be successfully marketed if entomophagy develops. However, more studies on optimal formulation, sensory liking, *etc*. are necessary to develop a more favourable product. Other carriers are also promising, but they need to have characteristics such as being salty, familiar or without obvious visual signs of insects. In Belgium, the average WTP for insect-based foods was higher than the average prices of comparable conventional foods while participants from urban Gabon were willing to pay less for an insect burger and the same price for an insect baguette compared to similar conventional foods. In both countries, it is crucial for the edible insect sector to refrain from setting excessively high prices to avoid hindering the growth of entomophagy. WTP varied between the two insect-based foods and between Belgium and Gabon. However, cross-cultural studies assessing WTP should be replicated to confirm the influence of culture on WTP. The impact of other sociodemographic factors, such as age or income, on WTP for insect-based food also warrants further attention.

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Chapter 4

Edible insects, what about the perceptions of Belgian youngsters?

Study area: Belgium

Research questions addressed in this chapter:

- How do Western youngsters perceive entomophagy? (RQ3)
- Are adult-oriented strategies transferable to younger populations? (RQ6)

This chapter is adapted from the following research article:

Detilleux L., Wittock G., Dogot T., Francis F. & Caparros Megido R., 2021. Edible insects, what about the perceptions of Belgian youngsters? *Br. Food J.* **123**(6), 1985–2002, DOI:10.1108/BFJ-08-2020-0754.

Abstract

Purpose: Edible insects are considered as a novel food in Western countries, with their introduction to cuisine having to overcome major barriers, such as disgust. The studies related to acceptance of entomophagy have exponentially grown since 2015. However, such studies generally focus on people older than 18 years old. The purpose of this study was to assess the perceptions of youngsters towards edible insects.

Study design/methodology/approach: A survey associated with an optional tasting session was conducted to record opinion of 151 youngsters in Belgium (9 to 17 years old).

Findings: Many respondents are acquainted with entomophagy, and had already eaten insect based-food. Most youngsters associated insects as snacks and salty foods, and they agreed to consume processed insects (falafel) during the tasting session. Tasters had to evaluate the falafel, and higher ratings were recorded in male respondents, as highlighted in studies including adults. More negative evaluations would be expected among older respondents if unprocessed insects were served, as they were more willing to consume processed insects than entire insects. Finally, attitudes towards entomophagy evolved positively after the tasting session. Such events are consequently recommended to promote entomophagy across Western youngsters.

Originality/value: Few studies explored the attitude of Western youngsters towards entomophagy. This paper aims to fill this gap by focusing on this young component of the Belgian population.

Keywords

Entomophagy, Novel food, Western consumers, Tasting session, Teenagers, Children

1. Introduction

As human population and pressure on land or water resources are constantly growing, our traditional food system requires a fundamental redesign to overcome future challenges. One issue is the search of new protein sources, with potential candidates including *in vitro* meat, seaweed, duckweed, rapeseed, fungi, and insects (Godfray *et al.*, 2010; Hashempour-Baltork *et al.*, 2020; van Huis *et al.*, 2017; van der Spiegel *et al.*, 2013).

In Western countries, edible insects currently represent a possible alternative, with entomophagy already being widespread in other parts of the world, with more than 2000 estimated species being consumed (van Huis *et al.,* 2017; Jongema, 2017; Raheem *et al.*, 2019). Considered as delicacies where they are consumed, insects are also nutritious foods, depending on intrinsic parameters (*e.g.*, species and stage of development) and external factors, such as temperature (Chen *et al.*, 2009; Durst *et al.,* 2010; Gahukar, 2013; Hanboonsong, 2010; Nowak *et al.*, 2014; Oonincx *et al.,* 2012; Ramos-Elorduy, 1997; Rumpold *et al.,* 2013; Sönmez *et al.,* 2008; Yi *et al.*, 2013). The main nutrient of edible insects is protein, with around 60% in dry matter for many species (Finke *et al.,* 2014; Rumpold *et al.,* 2013). Insect proteins are good quality, with high digestibility and an amino acid composition that generally meets the amino acid requirements for adults established by World Health Organisation (WHO) (Caparros Megido *et al.*, 2018; Finke *et al.,* 2014; Rumpold *et al.,* 2013; WHO, 2007). Lipids are another major nutrient found in edible insects, ranging from 10% to 60% dry matter, with high linoleic acid proportion (DeFoliart, 1991; Kouřimská *et al.,* 2016; Rumpold *et al.,* 2013). Insects are also a good source of vitamin B, copper, manganese, iron, and zinc (Bukkens, 1997; Michaelsen *et al.*, 2008; Rumpold *et al.,* 2013).

Insects have also environmental benefits, as they produce less greenhouses gases and ammonia, and need less water and breeding area compared to conventional livestock (Durst *et al.,* 2010; van Huis, 2013; Oonincx *et al.*, 2010). Furthermore, insect breeding does not require significant investment in terms of cost, time, and best practice techniques (Caparros Megido *et al.*, 2014; Ramos-Elorduy, 1997).

In Western countries, despite the advantages of insects, they are often associated as being pests, causing contamination and disease, resulting in a general disgust for edible insects (Jensen *et al.,* 2019; Looy *et al.*, 2014). Disgust is considered as the main predictor of entomophagy rejection, but other factors also influence consumer acceptance (Barton *et al.*, 2020; Lammers *et al.*, 2019; Ruby *et al.*, 2015). Such factors are related to (1) the product (or food; *e.g.*, price and quality), (2) social trust and norms (*e.g.*, prior attitude), and (3) psychological factors (*e.g.*, food neophobia) (Lensvelt *et al.,* 2014; Siegrist, 2008). Strategies to trigger the entomophagy in Western culture can consequently have multiple targets, and recent studies have tried to identify them. Association between insects and traditional flavours, such as chocolate or paprika, has been highlighted by several studies, as well as disguising insects in familiar food preparation (Caparros Megido *et al.*, 2014, 2016; Hartmann *et al.*, 2015; Lensvelt *et al.,* 2014; Schösler *et al.*, 2012; Tan *et al.*, 2016).

Communication about entomophagy is also seen as an effective strategy to enhance consumer acceptance (Barsics *et al.*, 2017; Mancini *et al.*, 2019b).

Entomophagy and its growth potential has been studied in Western countries by questioning the general population (Caparros Megido *et al.*, 2014; Lensvelt *et al.,* 2014). Targeting certain age groups within a population is common in determining the acceptance of edible insects; however, people younger than 18 years old tend to be overlooked (Brynning *et al.*, 2020; Caparros Megido *et al.*, 2016; Cicatiello *et al.*, 2020; Clarkson *et al.*, 2018; Hartmann *et al.*, 2015; Kostecka *et al.*, 2017; Myers *et al.,* 2018; Sogari *et al.*, 2017; Sogari *et al.,* 2019b; Tan *et al.*, 2016, 2017, 2015; Verbeke, 2015; Videbæk *et al.,* 2020). Food surveys with this young component of population require an adapted methodology due to their basic vocabulary, their limited food knowledge, and their difficulty to remember their diets (Baranowski *et al.,* 1994; Boyden *et al.,* 1997; Fargas-Malet *et al.*, 2010; Foster *et al.,* 2014; Rockett *et al.,* 1997). Furthermore, they are not the primary food buyers within families, because this role is mainly performed by their parents. Yet, children influence food purchases, and their impact on the buying process increases with their knowledge of food (Baldassarre *et al.*, 2016; Thomson *et al.*, 2007). During their childhood, children also construct eating habits that are likely to be maintained as adults (De Backer, 2013; Kelder *et al.*, 1994). Therefore, the study evaluated the acceptance of edible insects as a processed food (falafel) by the young component of population (Belgium), in which acceptance is supposedly already higher (Sogari *et al.,* 2019b; Verbeke, 2015). The main goals of this study were to: (i) explore the potential of developing entomophagy in youngsters (9 to 17 years old), and (ii) identify similarities and differences between youngsters and adult participants from other studies. The comparison was based on parameters which are usually recorded in studies related to entomophagy (*i.e.* entomophagy knowledge and experience, insect eating practices, and attitudes during and after a tasting session), and on factors identified as discriminatory in studies with adults (**Figure 4-1**). Such goals assess the relevance of developing specific strategies for youngsters to promote entomophagy.

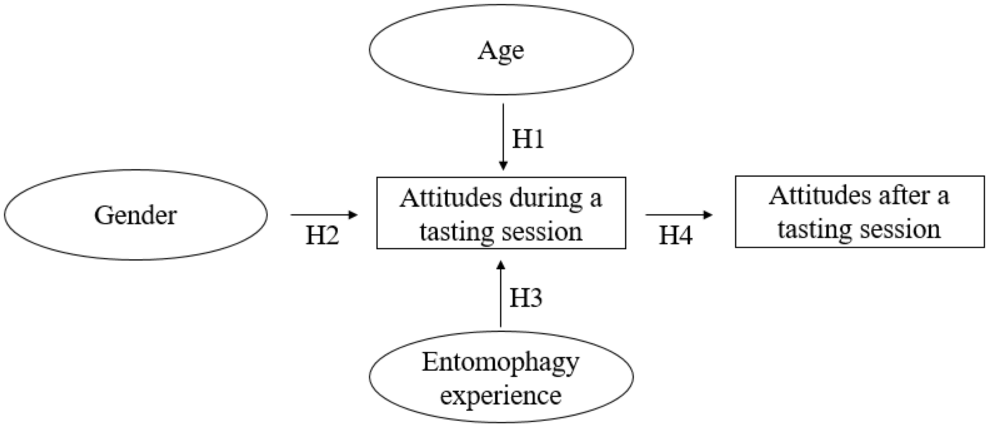

Figure 4-1. Conceptual framework.
Several hypothesis (H) were tested in this study, based on findings from studies with adults. H1: young people are more likely to eat insects than old people (Sogari *et al.,* 2019b; Verbeke, 2015) ; H2: men are more likely to eat insects than women (Hartmann *et al.*, 2015; Menozzi *et al.*, 2017; Ruby *et al.*, 2015; Verbeke, 2015) ; H3: entomophagy experience affects positively future insect consumption (Hartmann *et al.*, 2015; Hartmann *et al.,* 2016; Homann *et al.*, 2017; Lammers *et al.*, 2019; Lensvelt *et al.,* 2014; Schlup *et al.,* 2018) ; H4: attitudes evolve positively after a tasting session (Barton *et al.*, 2020; Caparros Megido *et al.*, 2014, 2016; Lensvelt *et al.,* 2014; Looy *et al.,* 2006; Menozzi *et al.*, 2017).

2. Material and methods

2.1. Participants

Respondents were selected from three Belgian schools: Ecole Servites de Marie (Uccle), Ecole de Calevoet (Uccle), and Lycée de Berlaymont (Waterloo). These schools were randomly selected in the French-speaking part of the country around Brussels. The two first schools are elementary schools with people under 13 years old, while the third school is high school with students from 14 to 19 years old. As these two age groups are mainly minors, parents were asked to sign a paper agreement allowing their children's participation. Besides the agreement, a description of the aim and study procedure was provided to reassure parents about hygienic standard compliance, and to identify respondents with a crustacean or house dust mite allergy. When respondents were not allowed to taste insect-based food that had been prepared, they were invited to participate in the survey without the tasting session.

After the survey with or without the tasting session, 24 incomplete questionnaires were excluded. A total of 151 participants were included. The terms "children" and "teenagers" were used in this study to differentiate respectively respondents from primary and secondary schools.

2.2. Study design

This study consisted of a survey associated with an optional tasting session. These two activities took place in a room of each school for a maximum of 30 minutes, and these rooms could easily hold up to 25 participants. Each participant was spaced out from their classmates to complete the paper-based survey and the tasting session. The study was divided in three parts, consisting of three questionnaires: (1) before, (2) during, and (3) after the tasting session (**Figure 4-2**). Each questionnaire was submitted separately. An interviewer read systematically each questionnaire to ensure that it was understood by all respondents, and he answered any questions in case of misunderstanding. At the end of the study, a fifteen-minutes presentation was given to educate students on entomophagy, to avoid interfering with respondent answers. The Human and Social Sciences Ethics Committee of ULiège granted ethical approval for this study (n°20200601).

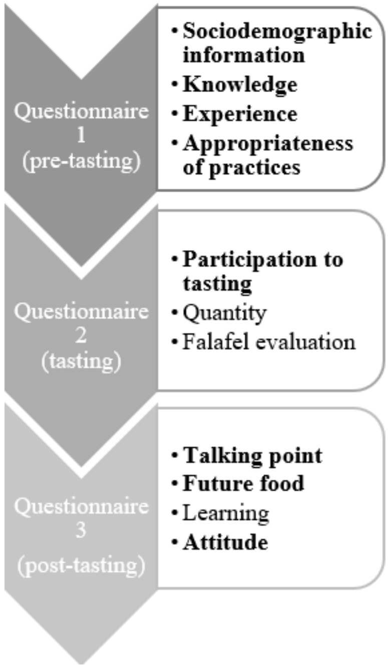

Figure 4-2. Questionnaire design.

Bold factors represent benchmarks in the comparison between youngsters and adults.

2.2.1. Respondent profile and perception of entomophagy

Before the tasting session, sociodemographic information (age, gender, origin and study level) was collected by using multiple choice questions. Gender balance was close to parity, with 54.30% of boys and 45.70% of girls representing the 151 participants. Most participants were of European origin (82.78%), with the remainder coming from Africa (9.27%), Asia (5.30%), and America (2.65%). All respondents were minors, but belonged to two different age classes: eighty-four respondents were between 9 and 13 years old, and sixty-seven were between 14 and 17 years old. The first age class was from elementary school (*i.e.* children), and the second age class was from secondary school (*i.e.* teenagers).

After these preliminary questions, respondents answered ("yes" or "no") to questions related to knowledge on entomophagy (Have you already heard about edible insects?), and insect consumption experience (Have you already eaten edible insects?). Respondents had also to select the most appropriate practices involving eating insects: (1) insects as salty or sweet foods (*i.e.* flavour), (2) insects as snacks or ingredients in a meal (*i.e.* function), and (3) disguised versus entire insects (*i.e.* visibility).

2.2.2. Tasting session

Food preparation consisted of a single falafel served in a cardboard cup. Falafels were made from a mixture of organic flour (Joannusmolen, Cuijk, Holland) and 20% mealworm flour. Mealworms, *Tenebrio molitor* L. 1758 (Coleoptera: Tenebrionidae), were provided by the Functional and Evolutionary Entomology Laboratory of Gembloux Agro-Bio Tech – ULiège. Insects were reared with feed composed of wheat flour and several fruits. Before being killed by freezing, insects were starved for 24 h to reduce the microbial count in the insect digestive tract. Once dead, insects were boiled for 1 min to ensure consumer safety, baked at 140 °C for 15 min in an oven, and milled into a mealworm flour (Caparros Megido *et al.*, 2018). Each falafel was calibrated (diameter: 3 cm) and prepared before the experiment in the Smart Gastronomy Lab (Gembloux, Belgium). Falafel was cooked in a pan with organic olive oil (Boni Bio, Halle, Belgium) for 10 min at high heat to have a browning effect.

The tasting session was optional, except for participants for whom the parents had not allowed them to participate. The optional status meant that they had the option to consume the prepared food, and they could stop eating whenever they wanted. Each participant received the tasting session questionnaire, regardless of the parents' agreement and their own willingness to taste. This questionnaire began with two questions: (1) Did you taste food preparation? and (2) Did you eat all the prepared food (all, more than half or less than half)? Participants who consumed the prepared food had to give their opinion on taste, visual and global evaluations. These evaluations were presented using a Likert 5-point scale ranging from "I dislike very much" to "I like very much". The questionnaire was given at the same time as the prepared food, tableware, napkin, salt-free rusk, and glass of water. These last two components were used by participants to neutralize their taste before the tasting (Caparros Megido *et al.*, 2014).

2.2.3. Opinions post-tasting session

Following the tasting session, the opinions of respondents were obtained for the four last questions: (1) Will you talk to your parents about this study? (*i.e.* talking point), (2) Would you like your parents to cook insects in the future? (*i.e.* future food), (3) Would you like to know more about edible insects? (*i.e.* learning), and (4) Do you have a more positive attitude toward edible insects after this experience? (*i.e.* attitude). Answers to these questions were limited to "yes" and "no".

2.3. Statistical analysis

Data from this study were analysed in Minitab® v.18 (State College, PA, USA) for Windows. Qualitative data collected during the study were reviewed with Chi-square tests. Results of taste, visual and global evaluations were performed using a 2 (gender) x 2 (age class) x 4 (origin) x 2 (knowledge) x 2 (experience) x 2 (flavour) x 2 (function) x 2 (visibility) x 3 (quantity) analysis of variance (ANOVA) with a generalized linear model (GLM). Statistical differences found with this method were evaluated using one-way ANOVA. Tukey's method was applied to characterise multiple comparisons. Kruskal-Wallis test was used when assumptions of one-way ANOVA (*i.e.* population normality and variance homogeneity) were not verified by respectively Ryan-Joiner normality test and Levene's method. In such cases, multiple comparisons were performed with Dunn's test.

3. Results

3.1. Perception of entomophagy

Before this study, some respondents had never heard about edible insects, and this information concerned children more than teenagers (Chi-square = 4.007, $p = 0.045$). Almost all teenagers (95.52%) were already acquainted with entomophagy, whereas 85.71% of children were informed about this eating practice. In contrast, no difference was found between children (73.81%) and teenagers (67.16%) concerning experience of insect consumption (Chi-square = 0.797, $p = 0.372$).

Children and teenagers primarily associated insects with salty foods and snacks (Flavour: Chi-square = 0.579, $p = 0.447$; Function: Chi-square = 0.847, $p = 0.357$; **Figure 4-3**). However, they had divergent opinions on insect visibility as food (Chi-square = 13.239, $p < 0.001$). Just under half of children (45.24%) would be more likely to consume disguised insects rather than entire insects, whereas this choice was made by most older respondents (74.63%).

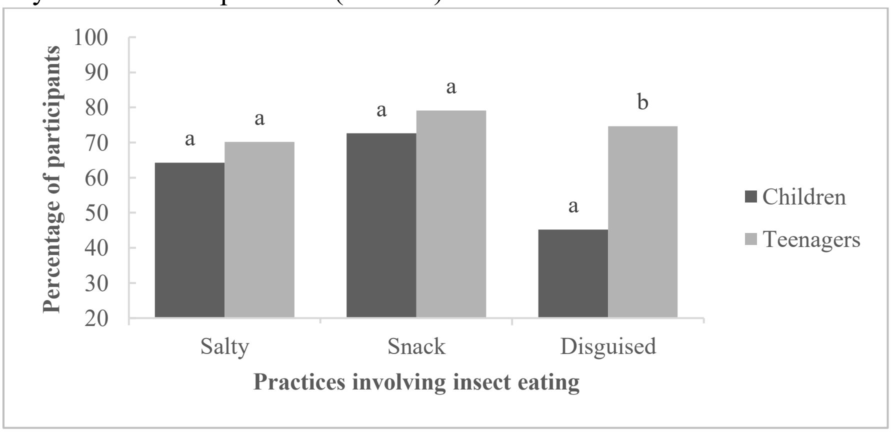

Figure 4-3. Selection of the most appropriate practices involving insect eating.
Different superscript letters indicate a significant difference.

3.2. Tasting session

Following written agreement by parents, eight refusals of tasting participation were recorded, all for children not teenagers. The main reason cited by parents was linked to allergy to house dust mites.

Sixty-seven children (79.76%) and sixty teenagers (89.55%) agreed to consume the mealworm-based falafel, and no statistical difference was found between these two groups (Chi-square = 2.672, $p = 0.102$). Children and teenagers showed similar eating behaviour, with more than 70% of them (77.61% for children and 71.67% for teenagers) eating all of the falafel (Chi-square = 0.972, $p = 0.615$).

The ANOVA with GLM highlighted that the evaluation of parameters depended on the amount of falafel that was tasted, and the sex of respondents (**Table 4-1**). Respondents eating less than half of the falafel assigned a lower score to the three criteria (**Table 4-2**).

Table 4-1. Results of the GLM test on the evaluation of falafel.

Factor	DF	F	*p*	DF	F	*p*	DF	F	*p*
	Global			Appearance			Taste		
Sex	1	5.03	***0.027***	1	3.9	0.051	1	6.64	***0.011***
Age class	1	0.73	0.396	1	1.64	0.202	1	0.81	0.370
Origin	3	0.74	0.531	3	2.36	0.075	3	0.06	0.983
Knowledge	1	0.02	0.889	1	0.15	0.695	1	0	0.968
Experience	1	0.45	0.504	1	0.73	0.396	1	0.16	0.691
Flavour	1	1.2	0.276	1	0.03	0.852	1	5.75	***0.018***
Function	1	2.37	0.127	1	1.4	0.239	1	4.17	***0.043***
Visibility	1	0	0.994	1	0.76	0.386	1	0.74	0.392
Quantity	2	17.36	***< 0.001***	2	6.83	***0.002***	2	12.93	***< 0.001***
Flavour * Function	1	7.93	***0.006***	1	2.90	0.093	1	2.31	0.132
Flavour * Visibility	1	8.35	***0.005***	1	0.08	0.774	1	1.80	0.184
Function * Visibility	1	4	***0.049***	1	3.85	0.054	1	0.17	0.679

Global evaluation, appearance and taste of falafel. Age class: children or teenagers; Knowledge: Have you already heard about edible insects?; Experience: Have you already eaten edible insects?; Flavour: Would you rather eat insects as salty or sweet foods?; Function: Would you rather eat insects as snacks or ingredients in a meal?; Visibility: Would you rather eat meal with disguised insect or meal with entire insects?; Quantity: Did you eat all the prepared food (all, more than half, less than half)?. DF: Degrees of Freedom; F: F statistic; *p*: significance level. Bold data mean significant results. All interaction effects were tested but only those with significant result were reported in the table.

Table 4-2. Evaluation of falafel in relation to the amount of falafel that was tasted (mean value ± standard deviation).

	< Half (n = 23)	> Half (n = 9)	All (n = 95)	Statistical analyses	p
Global	2.39 ± 1.27^a	4.00 ± 1.23^b	4.06 ± 1.04^b	$H_{2,127} = 6.80$	***< 0.001***
Appearance	2.65 ± 1.47^a	3.78 ± 1.20^b	3.75 ± 1.00^b	$H_{2,127} = 11.05$	***0.004***
Taste	2.57 ± 1.27^a	3.89 ± 1.45^b	4.00 ± 0.99^b	$F_{2,127} = 16.45$	***< 0.001***

Global evaluation, appearance and taste of falafel. Different superscript letters indicate a significant difference. Bold data mean significant results.

With respect to gender, boys provided a better global and taste evaluation than girls. A nearly significant difference was found on the appearance assessment for the two sexes (**Table 4-3**).

Table 4-3. Evaluation of falafel based on gender (mean value ± standard deviation).

	Male (n = 71)	Female (n = 56)	Statistical analyses	p
Global	4.00 ± 1.21^a	3.45 ± 1.28^b	$H_{1,127} = 6.80$	***0.009***
Appearance	3.73 ± 1.16^a	3.32 ± 1.18^a	$F_{1,127} = 3.88$	0.051
Taste	3.99 ± 1.18^a	3.41 ± 1.17^b	$F_{1,127} = 7.50$	***0.007***

Global evaluation, appearance and taste of falafel. Different superscript letters indicate a significant difference. Bold data mean significant results.

For the global evaluation, interactions were highlighted between insect eating practices (**Table 4-1**), requiring each practice to be analysed separately (**Table 4-4**). Insect-based falafel was better rated by tasters who perceived insects as salty ingredients compared to those who associated insects with salty snacks. Moreover, participants that preferred disguised insects allocated a lower or similar global evaluation than participants who were more willing to eat entire insects.

Table 4-4. Global evaluation of falafel based on each insect eating practice (mean value ± standard deviation).

Global evaluation		Function		Statistical analyses	*p*	Visibility		Statistical analyses	*p*
		Snack	Ingredient			Disguised	Entire		
Flavour	Salty	3.63 ± 1.35^a	4.38 ± 0.71^b	$H_{1,86} = 4.32$	***0.038***	3.67 ± 1.23^a	4.13 ± 1.24^a	$F_{1,86} = 2.78$	0.099
	Sweet	3.66 ± 1.24^a	3.17 ± 1.72^a	$F_{1,41} = 0.72$	0.401	2.86 ± 1.29^a	3.96 ± 1.16^b	$F_{1,41} = 7.76$	***0.008***
Function	Snack	/	/	/	/	3.43 ± 1.35^a	3.89 ± 1.20^a	$F_{1,97} = 2.97$	0.088
	Ingredient	/	/	/	/	3.73 ± 0.96^a	4.53 ± 1.06^b	$H_{1,30} = 7.84$	***0.005***

Different superscript letters indicate a significant difference. Bold data mean significant results.

Table 4-1 reported also that the taste evaluation was potentially dependent on two insect eating practices (*i.e.* Flavour and Function). The one-way ANOVA did not confirm the difference in taste evaluation for the factor flavour ($F_{1,127} = 3.06$, $p = 0.082$). Concerning the factor function, the falafel was tastier to respondents who identified insects as ingredients of a meal (taste rate = 4.20 ± 0.93) compared to those who preferred to eat them as snacks (taste rate = 3.59 ± 1.25; $H_{1,127} = 5.36$, $p = 0.021$).

3.3. *Opinions post-tasting session*

After the tasting session, children and teenagers intended to talk to their parents about this study (Chi-square = 0.198, $p = 0.656$; **Figure 4-4**). However, older respondents were less willing to integrate insects in their food habits (Chi-square = 14.687, $p < 0.001$), and were less interested in knowing more about edible insects (Chi-square = 4.576, $p = 0.032$). The attitude toward edible insects evolved positively in both age classes, but children were more strongly impacted (Chi-square = 7.340, $p = 0.007$).

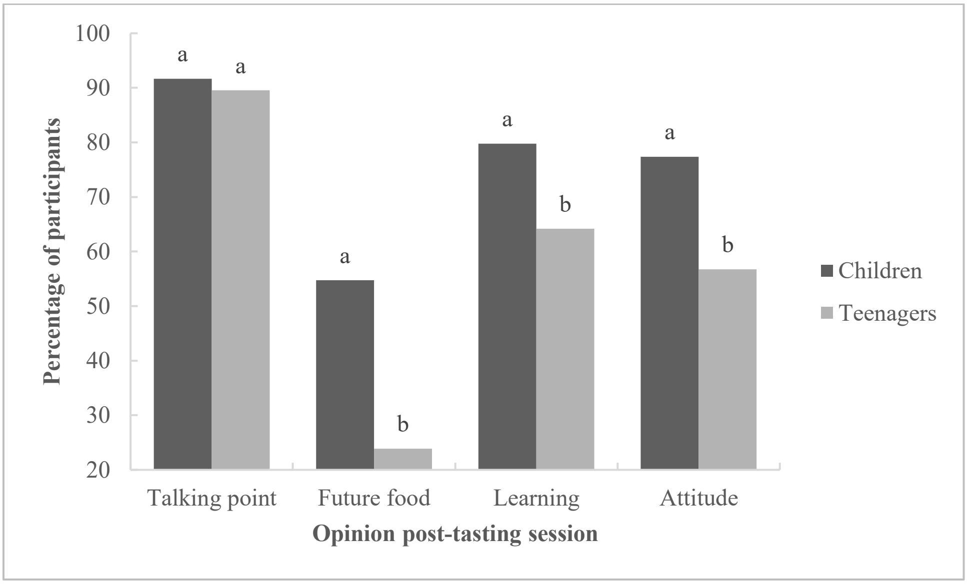

Figure 4-4. Percentage of participants who responded "Yes" for four questions related to their opinion after the tasting session.
Different superscript letters indicate a significant difference.

4. Discussion

4.1. Perceptions of entomophagy

Before the study was implemented, most participants already knew that insects could be used as food. This finding was consistent with a previous study led by Dupont *et al.* (2020), in which entomophagy was widely known by German people aged 9 to 19. However, these results contrasted with those of Caparros Megido *et al.* (2014) concerning Belgian youngsters (< 30% being aware of entomophagy). This difference could be explained by a suggestion raise by Caparros Megido *et al.* (2016) linked to the language used in questionnaires. The authors stated that using the term "entomophagy" in questions would influence answers, as this term is poorly understood by respondents. Consequently, Caparros Megido *et al.* (2014) might have undervalued answers related to knowledge on entomophagy by using this specialist term in their questionnaire. The different results of the studies could also partially be explained by the growing interest in edible insects, which became exponential after 2015 with the promotion of entomophagy through the Food and Agriculture Organization (FAO) report ("Edible insects: future prospects for food and feed security" in 2013) and the Universal Exposition 2015 in Milan (Italy). For instance, the number of published scientific articles mentioning the term "edible insects" increased by more than 400% between 2013 and 2018 (van Huis, 2019; Payne *et al.*, 2019; Shelomi, 2016). Media also recognise the potential of insects as food, both educating people about the existence of this practice and creating a positive perception about edible insects among people (Caparros Megido *et al.*, 2016; Myers *et al.,* 2018; Piha *et al.*, 2016; Shockley *et al.*, 2018). Knowledge about edible insects was also influenced by age in the current study, with teenagers being more informed about this eating practice compared to children. This finding was consistent with the published literature, and is explained by older people having more access and interest in information about insect consumption (Caparros Megido *et al.*, 2014; Verbeke, 2015).

More than two thirds of respondents had already tasted edible insects in the current study, whereas experience of entomophagy was below one third of respondents for other studies in Western countries (Caparros Megido *et al.*, 2016; Cicatiello *et al.*, 2020; Dupont *et al.,* 2020; Hartmann *et al.*, 2015; Kostecka *et al.*, 2017; Tan *et al.*, 2016; Videbæk *et al.,* 2020). Most consumption events usually tend to be unique, being limited to special events or travel, as insects do not form part of traditional Western food (Hartmann *et al.*, 2015; Tan *et al.*, 2015). The higher results obtained in the current study might be explained by the high number of tasting events implemented within the context of Belgian legislation towards the favourable development of insect-based products and companies (Mancini *et al.*, 2019a). However, being exposed to insect-based products does not mean that participants tasted the foods. The high level of previous experience of eating insects in this study could also be explained by the young target population being known to be more likely to try insects as food (Tan *et al.*, 2016).

Most respondents in the current study perceived edible insects as salty foods and snacks. At present, the Western market is proposing insects as salty snacks to consumers (*e.g.*, mustard shortbread by Jimini's, entire insects with paprika by Essento, and crackers by Yuma), as well as several studies on edible insects, probably because of the original size and form of insects (Brynning *et al.*, 2020; Caparros Megido *et al.*, 2014; Cunha and Ribeiro, 2019; Sogari *et al.*, 2019a). Moreover, insects are mainly considered as meat alternatives and, therefore, are not strongly associated with sweet flavour (Caparros Megido *et al.*, 2016; Shelomi, 2015; Tan *et al.*, 2015, 2016, 2017). However, knowledge remains limited on how the style of insect preparation (*e.g.*, snack, trimming and main dish) impacts consumer acceptance (Hartmann *et al.,* 2017; Sogari *et al.*, 2019a).

An appealing appearance is characterised by no sign of being alive or aversive texture, both of which lead to low rejection rates (Hartmann *et al.*, 2015; Martins *et al.,* 2006). For insect-based products, an appealing appearance can be reached by hiding insects in prepared food (Caparros Megido *et al.*, 2016; Schösler *et al.*, 2012; Tan *et al.*, 2015). This strategy was also indicated by teenagers in the current study, as they would be more likely to eat disguised insects. In comparison, children were more readily to consume entire insects. Thus, children were probably associated with a high social acceptance, low food neophobia and a willingness to engage in new experiences (Clarkson *et al.*, 2018; Hartmann *et al.*, 2015).

4.2. Tasting sessions

More than 80% of participants in the current study chose to taste insect-based product, with similar response rates being detected in other studies (Caparros Megido *et al.*, 2014; Sogari *et al.*, 2017). The acceptance rate calculated by Caparros Megido *et al.* (2014) and Sogari *et al.* (2017) was based on people who were recruited on a voluntary basis, with bias towards curious people or those ready to try insects as food (Sogari, 2015). Consequently, the opinion of the general population was masked, impacting acceptance rates. To illustrate, the acceptance rate recorded by Caparros Megido *et al.* (2014) dropped from 82% to 40% when people excluded by selection were included in the calculation method. The current study had no selection process as no invitation was transmitted to respondents before the survey. The acceptance rate was still influenced by parental agreement, because, in cases of refusal, willingness to taste falafel did not only depend on participant' judgment. However, refusal was limited to 5.3% of all respondents, of which all were children. The main reason of refusal was allergy to house dust mites, with a potential risk of cross-reactivity between house dust mites and insects (van Broekhoven *et al.*, 2016; Ribeiro *et al.*, 2018). As no difference was observed in acceptance rate between children and teenagers, H1 could not be confirmed.

The high acceptance rate in this study was probably associated with the high previous experience of eating insects by participants, as recorded in a study with Kenyan people aged 5 to 10 (Homann *et al.*, 2017). This suggests that H3 was confirmed with youngsters. Prior insect eating counteract psychological barriers, and ease future insect consumptions (Hartmann *et al.*, 2015; Hartmann *et al.,* 2016; Homann *et al.*, 2017; Lammers *et al.*, 2019; Lensvelt *et al.,* 2014; Schlup *et al.,* 2018). As reported by Mancini *et al.* (2019b), an experience of eating insects increases social appeal of entomophagy (*i.e.* perceived safety and social appropriateness) which enhances personal acceptance. Another explanation for the high acceptance rate could be the choice of the insect-based product. Falafel probably helps overcome the disgust of insects by Western culture, by hiding any sign of insects and looking like familiar food (Caparros Megido *et al.*, 2014, 2016; Hartmann *et al.*, 2015; Schösler *et al.*, 2012; Tan *et al.*, 2015, 2017; Wansink, 2002). This finding primarily corresponded to the answers of teenagers, who mentioned preferring eating disguised insects. Thus, the use of unprocessed insects in this study would likely have led to a lower acceptance rate or to a decrease in positive evaluations by teenagers.

When evaluating falafel, youngsters that consumed less than half of the falafel allocated the lowest rates, meaning that the food was less palatable to them. Palatability (or pleasure) is associated with liking, and has impact on human eating behaviour (*i.e.* start, maintain or stop eating). Cessation of an eating episode is also influenced by the concept of wanting (*i.e.* appetite or craving) (Berridge, 1996; Dalton *et al.,* 2013; Lemmens *et al.*, 2009). However, this influence was not recorded in this study, and some respondents may have stopped eating due to lack of craving or appetite.

As suggested by H2, gender was also a discriminatory factor for taste and global evaluations of falafel. Male tasters allocated higher rates to these criteria compared to female tasters. Gender-based differences have already been recorded by other studies, which highlighted that men more readily accepted eating insects compared to women (Hartmann *et al.*, 2015; Menozzi *et al.*, 2017; Ruby *et al.*, 2015; Verbeke, 2015).

Insects were presented as ingredients of a salty food in falafel. When the associations of participants in terms of flavour and function were close to actual food in which insects were presented, the rates for global and taste evaluation were higher. Contrasting results were obtained for visibility. Respondents preferring unprocessed insects gave similar or higher global evaluations, despite falafel showing no sign of visible insects. People with a high willingness to eat unprocessed insects are mainly considered to be neophilics, who generally evaluate novel food more favourably than neophobics (Hartmann *et al.*, 2015; Raudenbush *et al.,* 1999; Tuorila *et al.*, 1994).

4.3. Opinions post-tasting session

Most participants (90%) stated that they would share their insect eating experiences with their parents. In other studies, participants in insect tastings went beyond simply sharing their experience by recommending that their loved ones participate in similar tastings (Barton *et al.*, 2020; Sogari *et al.*, 2018). The opinion of family and friends is considered as a main driver in promoting entomophagy (Sogari, 2015; Sogari *et al.*, 2017). Consequently, youngsters may have encouraged their parents to taste insects in the future, by sharing this eating experience. The attitude of youngsters toward edible insects also improved by the end of the study, supporting H4 and previous studies with tasting sessions (Barton *et al.*, 2020; Caparros Megido *et al.*, 2014, 2016; Lensvelt *et al.,* 2014; Looy *et al.,* 2006; Menozzi *et al.*, 2017). However, most participants (59%) were not willing to integrate insects in their diet. This result lies between the low percentages (15% to 30%) assessed by studies with tasting session (Caparros Megido *et al.*, 2014, 2016), and the high percentage (80%) recorded by study with no tasting (Verbeke, 2015). The difference in study design may explain these extreme results, because tasting sessions reveal to participants the real insect sensory properties. Tasters can consequently base their answers on experience, and not just on feelings (Caparros Megido *et al.*, 2016). The willingness to taste the insect-based food was higher than the willingness to integrate insects in food habits, as recorded by Dupont *et al.* (2020) and Lammers *et al.* (2019). Transition from one stage to another depends on practical and contextual factors (*e.g.*, compatibility with existing practices). Such factors required attention for future studies (House, 2016). Changes to attitude and willingness to integrate insects in food habits were greater for children, supporting the hypothesis of their higher social acceptance and lower incidence of food neophobia. Finally, teenagers requested additional information about this eating practice, but children were even more interested about it. This difference might be associated to the initial difference between the two groups in terms of knowledge. Specifically, children were initially lesser informed about entomophagy and, consequently, required more additional information than teenagers.

5. Limitations of this study

Beyond this study, insect-based falafels are available in some Western supermarkets and restaurants (Berger *et al.*, 2018; McClements, 2019). However, the choice of falafel as food sample may be questionable. Firstly, falafel is originally a vegetarian dish made from chickpeas, fava beans, or a mix of both (Ismail *et al.,* 2017; Katz *et* *al.,* 2002). Adding mealworm flour in the recipe convert falafel to an animal-based product. Such change can create confusion among respondents, especially those who associate entomophagy as a way to reduce meat consumption (Kauppi *et al.,* 2020). Secondly, falafel originates from the Middle East, and it is currently promoted as meat replacer product in Western (House, 2019; Ismail *et al.,* 2017; Schösler *et al.,* 2018). However, falafel is not yet widely included in Western dietary habits and, most respondents of this study were probably unfamiliar with this food. Insect-based falafel may have therefore introduced two novelties (*i.e.* falafel and insects as food) for tasters. Asking degree of familiarity with falafel and/or including a traditional falafel in the tasting session could possibly reduce bias in answers due to unfamiliarity with the falafel recipe.

6. Conclusion

Eating insects is not a Western food habit, but youngsters are aware and familiar of this practice. Most children and teenagers agreed to consume insect-based falafel in this study, but a lower acceptance rate would be expected with unprocessed insects, especially in older respondents. As highlighted in adults, male respondents are the most positive towards edible insects, and insect tasting session improves the tasters' attitude towards entomophagy. Increasing the number of such events is consequently a strategy to promote entomophagy in all age categories. Children and teenagers also agreed with the general opinion that they associated insects with snacks and salty foods. However, the relationship between the style of preparation and consumer acceptance requires further investigation. The use of the term "entomophagy" in the questionnaires also needs to be investigated to avoid unrepresentative data.

Youngster attitudes are generally positive towards entomophagy, and close to adult attitudes assessed in other studies. Stakeholder strategies to promote entomophagy must therefore be relatively similar. As mentioned above, such strategies are mainly related to the insect-based product (*e.g.*, visual aspect), and to the opportunity of insect tasting. Other strategies (*e.g.*, information session on edible insects) are effective in adults to promote entomophagy, but their effectiveness has yet to be assessed in youngsters. Attention should also be paid to factors triggering repeat consumption.

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Chapter 5

Consumer acceptance of entomophagy in Belgium: insect-based food appropriateness and influence of personal factors

Study area: Belgium

Research questions addressed in this chapter:

- How does the consumer's professional field influence the acceptance of entomophagy? (RQ5)
- What is the most appropriate context for entomophagy? (RQ7)

This chapter is adapted from the following research article:
Detilleux L., Dogot T., Franceschini S., Francis F. & Caparros Megido R., 2024. Consumer acceptance of entomophagy in Belgium: insect-based food appropriateness and influence of personal factors. *J. Insects as Food Feed* **11**(6), 965–972, DOI:10.1163/23524588-00001244.

Abstract

The issue of consumer acceptance is largely investigated in the literature relative to entomophagy, as edible insects are not a common part of European food habits. This topic was also discussed in the current study, which analysed 1382 responses to an online survey in Belgium. The first aim of this research was to study the potential influence of personal factors, including field of work, on consumer acceptance. The second objective was to determine the most appropriate context for entomophagy, regarding timing and style of preparation. Gender, nationality and field of work of respondents were identified as influencing factors, while age was identified as a factor that did not impact consumer acceptance. Personal factors that influenced acceptance must be used as discriminating factors to select willing consumers of edible insects. Regarding context, edible insects were not appropriate at breakfast, while they were considered as snacks. Such considerations provide useful information in determining the most appropriate insect-based food for European markets.

Keywords

Edible insects, Novel food, Context, Western consumers

1. Introduction

Edible insects have been consumed for ages; and today, approximately 2,000 insect species are eaten around the world, particularly in Africa, Asia, and Latin America (Jongema, 2017; Raheem *et al.*, 2019). In Europe, entomophagy has gained attention from many sectors in the past decade. Since 2021, policy makers have granted marketing authorizations for four insect species (namely *Acheta domesticus*, *Alphitobius diaperinus* larvae, *Locusta migratoria*, and *Tenebrio molitor* larvae) for food purposes. Concurrently, number of industries have made significant investments, amounting to up to 25 million euros, in the production of edible insects and insect-based foods (Mancini *et al.*, 2022; Vale-Hagan *et al.*, 2023). Additionally, the scientific community has published over one thousand studies on edible insects between 2015 and 2021 (Boukid *et al.*, 2023). Despite this progress, insects are still not part of European food habits (Mina *et al.*, 2023).

Numerous studies have investigated factors influencing the acceptance of edible insect consumption by consumers (Kröger *et al.*, 2022; Mina *et al.*, 2023). Alhujaili *et al.* (2023) identified two categories : personal factors (socio-demographic, psychological, and familiarity), and factors relating to marketing mix (product, price, promotion, and place). Alhujaili *et al.* (2023) were able to characterize willing consumers of insects: educated and curious young men with an interest in the environment and new foods, who have already eaten insects. Willing consumers of insects, or consumers who accept entomophagy, are likely to constitute the best candidates for the creation of an initial market. The literature suggest identifying and targeting such consumers to gain insight into how to develop and market insect-based foods that meet their expectations (House, 2016; Rovai *et al.*, 2021; Verbeke, 2015). The description of willing consumers is relatively complete in terms of socio-demographic features, except for the lack of professional characteristics (*e.g.*, income, occupation, field of work) and household characteristics (*e.g.*, composition, size). Marketing mix-related factors that affect consumer acceptance include many characteristics of the insect-based food: species, degree of visibility, and amount of insects, as well as sensory attributes, carriers, food appropriateness, and perceived benefits and/or risk. (Alhujaili *et al.*, 2023; Kröger *et al.*, 2022). For example, the literature suggests that an insect-based food is more likely to be accepted by a Western consumer if it is a familiar salty food showing no visible sign of deriving from an insect (Caparros Megido *et al.*, 2016; Detilleux *et al.*, 2021; Tan *et al.*, 2015).

However, offering a food with the recommended sensory attributes is not enough. For instance, a delicious stew may not be liked if it were to be served for breakfast (Tan *et al.*, 2017). Food is part of a context including many dimensions such as audience, place, timing, and social environment (Jaeger *et al.,* 2017). Such factors require attention in the literature on entomophagy, as they are often overlooked by scholars (House, 2016; Tan *et al.*, 2016). Defining the most appropriate context for insect consumption would provide valuable information to the insect industry to shape insect-based food development (Cardello *et al.,* 1996).

This study aims to gain a better understanding of the portrait of willing consumers by studying the potential influence of consumers' field of work on acceptance. The term "field of work" is employed throughout the present study as a generic term encompassing the current field of work of workers and the field of study of students, which can be assimilated to their prospective future field of work. The influence of other personal factors (*i.e.* age, gender, nationality) was also tested to confirm findings of previous studies. The current study also focused on the appropriateness of insect consumption as related to two contextual factors: timing and style of preparation. The second objective is only investigated with willing consumers to determine their expectations in relation to these two factors.

2. Material and methods

2.1. *Study design*

Respondents were selected from a Belgian university in this study for two main reasons: (1) to ensure selecting educated respondents whereas other personal traits of willing consumers were tested; (2) to have a diverse range of fields of work. Staff and students at the University of Liège (*i.e.* ULiège) were invited by email to participate in an online survey related to edible insects. The email explained that the participation was voluntary, and that completion of the survey would require only a few minutes. The email also contained a link to the questionnaire and a link to the corresponding privacy policy. The online questionnaire was available for two weeks in June 2023. A total of 1386 respondents took part in the study, but data from 4 participants was excluded because the respondents were minors or provided incomplete questionnaire. The study was approved by the Human and Social Sciences Ethics Committee of ULiège (n°2023-11).

2.2. *Questionnaire*

The questionnaire was developed in French with Typeform (Barcelona, Spain).

2.2.1. General information about entomophagy

The acceptance of entomophagy among respondents was assessed through the following question: "Would you accept to eat insects?". In the case of rejection of entomophagy, respondents were asked to identify the reason(s) for this rejection from a selection of statements identified by Detilleux *et al.* (2024). After this question, participants who rejected edible insects only answered questions about their socio-demographic profile. Respondents who accepted entomophagy were asked about their experience ("Have you already consumed edible insects?"), as well as their intention to eat edible insects on a regular basis ("Would you accept to include edible insects in your meals on a regular basis?"). For the three questions described above, respondents could only answer "yes" or "no".

2.2.2. Context for insect consumption

The context for insect consumption was assessed through food appropriateness, which can be measured using the item-by-use (IBU) technique. This technique presents several associations of food and context, and respondents must rate the appropriateness of each association on a seven-point scale ranging from "Not at all appropriate" to "Very appropriate". The IBU technique is suitable for many foods and contexts (Jaeger *et al.,* 2017). In the present study, food consisted of edible insects and context included timing of insect consumption (breakfast, lunch, dinner, between meals) and style of insect preparation (main dish, trimming, snack). Respondents were asked to "Rate the different situations associated with the consumption of edible insects", such as "Eating insects for breakfast" or "Eating insects as a trimming". In this way, a total of seven associations between food and context were rated by respondents.

2.2.3. Sociodemographic profile

Questions related to sociodemographic information queried field of work, gender, age, and nationality. The field of work factor was the affiliation of the respondents to one of the 11 faculties of ULiège. The faculties were then grouped into the following sectors: Health Sciences, Human Sciences, and Sciences and Technologies. A fourth group, designated "Others", included respondents from the university's administration or who were uncertain about their faculty affiliation. Answers related to nationality were grouped into three categories: Belgian, European, and extra-European.

2.3. Respondents

Respondents were aged between 18 and 88 years old, with a mean age of 30.28 ± 13.27 years old. They were predominantly Belgian (88.71%), followed by other European nationalities (8.25%) and extra-European nationalities (3.04%). The sample comprised 61.22% women, 37.48% men, and 1.30% non-binary gender. The field of work most common among respondents was Human Sciences (42.19%), followed by Sciences and Technologies (37.05%), Health Sciences (14.04%), and Others (6.73%).

2.4. Statistical analysis

R software v.4.2.3 (Vienna, Austria) was used as statistical software for data analysis. The influence of personal factors (*i.e.* field of work, age, gender, and nationality) on acceptance of entomophagy was assessed using a binary logistic regression model. This methodology has already been used in studies relating to the acceptance of edible insects (Orkusz *et al.*, 2020; Ribeiro *et al.*, 2022; Verbeke, 2015). In the current study, all personal factors other than age were considered as categorical predictors; age was considered as a continuous factor. The model provided p-values to assess the influence of each personal factor on acceptance, using the likelihood ratio test. In the case of significant effect ($p < 0.05$), the pairwise comparison examines each level of the same personal factor in pairs, by providing other *p-values* and the odds ratio (*i.e.* the ratio between the odds of acceptance for a respondent belonging to level A of the personal factor and the odds of acceptance for another respondent belonging to level B of the same personal factor). These *p-values* were obtained by calculating contrast between each pair and adjusting for multiple comparisons with Tukey's method.

Concerning the context for insect consumption, a Kruskal-Wallis test was applied, as data did not meet the assumptions required for one-way analysis of variance (*i.e.* population normality and variance homogeneity). After each Kruskal-Wallis test, the evaluation of multiple comparisons was performed with Dunn's test which is the multiple comparisons method advised after a Kruskal-Wallis test.

3. Results

3.1. Acceptance of entomophagy

The binary logistic regression model highlighted that all personal factors investigated affected acceptance of entomophagy, except for age (**Table 5-1**).

Table 5-1. Potential influence of personal factors on acceptance of entomophagy (n = 1382).

Personal factors	DF	Chi-square	*p*
Field of work	3	43.19	***< 0.001***
Age	1	1.86	0.173
Gender	2	16.16	***< 0.001***
Nationality	2	19.31	***< 0.001***

Field of work: Health Sciences, Human Sciences, Sciences and Technologies, and Others. Age: continuous factor (from 18 to 88 years old). Gender: male, female, or non-binary. Nationality: Belgian, European, or extra-European. DF: degrees of freedom. Bold data indicate significant results.

Regarding field of work, respondents in Sciences and Technologies tended to accept edible insects more readily than respondents in other fields of work, except for those in the "Others" category (**Table 5-2** and **Figure 5-1**). More specifically, respondents from Sciences and Technologies were 2.42 times more likely to accept entomophagy than respondents from Human Sciences, and 1.66 times more likely to accept entomophagy than respondents from Health Sciences.

Table 5-2. Potential differences between fields of work on acceptance of entomophagy (p-value; n = 1382).

	Health Sciences	Human Sciences	Sciences and Technologies
Human Sciences	0.154	/	
Sciences and Technologies	***0.041***	***< 0.001***	/
Others	0.998	0.554	0.128

Bold data indicate significant differences.

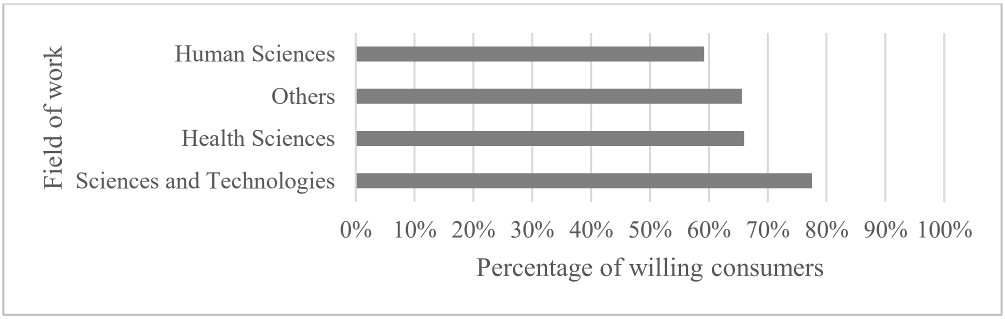

Figure 5-1. Acceptance of entomophagy according to respondent's field of work (n = 1382).

With respect to gender, a man was 66% more likely to accept entomophagy than a woman ($p < 0.001$). Concerning the nationality factor, the chances of accepting edible insects among people from extra-European countries were 4.04 times lesser than among respondents from Belgium ($p < 0.001$), and 2.92 times lesser than among respondents from other European countries ($p = 0.015$).

Among 1382 study participants, 931 accepted the consumption of edible insects. Among the willing consumers of insects, 70.68% had already eaten edible insects, and 67.24% declared that they would accept to eat insects on a regular basis.

Among respondents who refused entomophagy, the reasons given for this refusal were mainly related to disgust ("Eating insects is disgusting"; 59.20%), following by cultural incompatibility ("It is not in my culture"; 34.81%) and fear ("Insects are scary"; 31.49%).

3.2. Context for insect consumption

3.2.1. Timing of insect consumption

According to the 931 willing consumers of edible insects, breakfast was considered as the least appropriate time to consume edible insects ($H_{3,931} = 628.34$; $p < 0.001$; **Figure 5-2**).

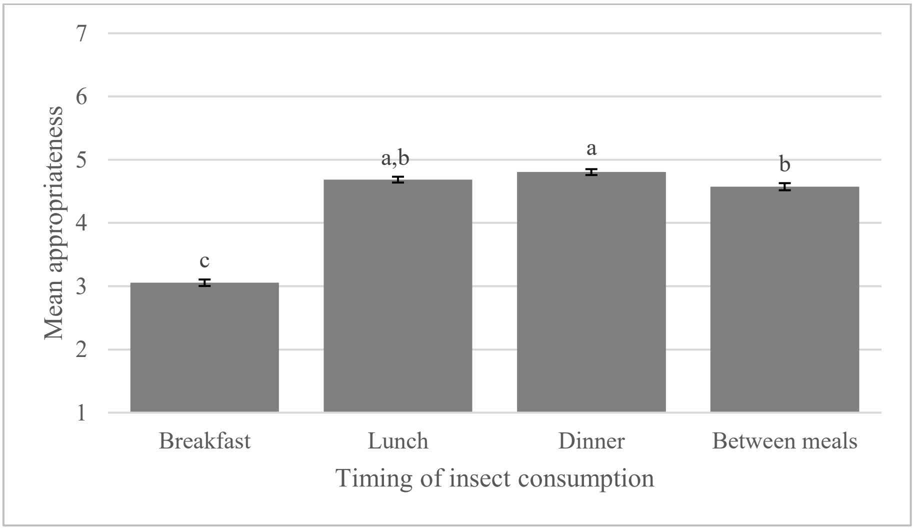

Figure 5-2. Appropriateness for 4 timings of insect consumption (mean value ± standard error; n = 931).

Different superscript letters indicate a significant difference.

3.2.2. Style of insect consumption

As reported in **Figure 5-3**, proposing edible insects as snack or trimming was more appropriate than as main dish ($H_{2,931} = 722.42$; $p < 0.001$).

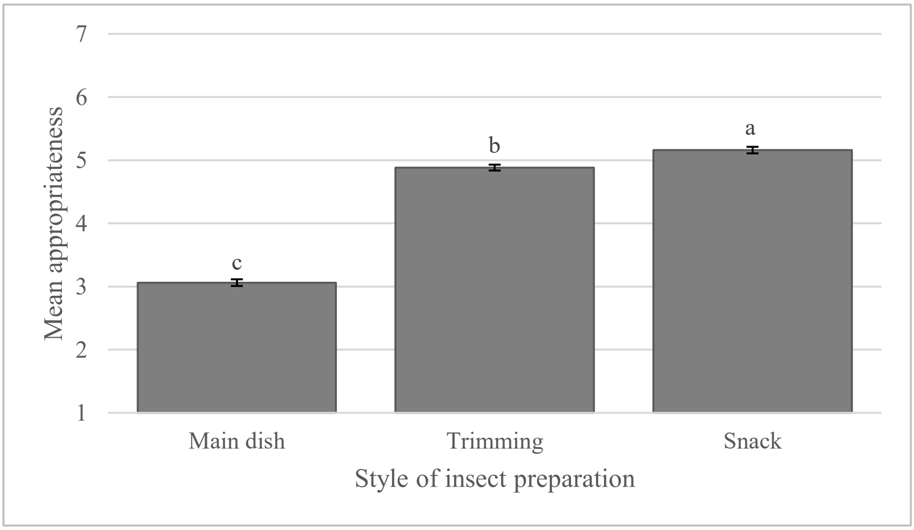

Figure 5-3. Appropriateness of 3 styles of insect consumption (mean value ± standard error; n = 931).

Different superscript letters indicate a significant difference.

4. Discussion

4.1. Acceptance of entomophagy

Acceptance of entomophagy was influenced by all tested personal factors, except age. Most studies relating to acceptance had already reported these findings for gender and nationality. Moreover, men have already been identified as being more likely to be willing consumers of insects. However, conclusions in the published literature are more divergent for age, with some studies on acceptance highlighting an influence and others not. When there is influence, the effect of increased age is often negative, as young people are more attracted to edible insects than old people (Alhujaili *et al.*, 2023; Kröger *et al.*, 2022). Regarding field of work, Menozzi *et al.* (2017) highlighted that students from food- and environmental-sciences were more prone to eat insects than students of social sciences. Other studies have focused on the relationship between acceptance of edible insects and respondent occupation. However, this relationship remains poorly studied and unclear, as one study found an influence while another did not (Lee *et al.,* 2023; Woolf *et al.*, 2019). For the focus on field of work in this study, acceptance of entomophagy was particularly high among respondents from Sciences and Technologies compared to other fields of work. Respondents from Sciences and Technologies were more likely to be aware of sustainable food sources, including edible insects, and their benefits through conferences and lessons. This heightened sensitivity could explain their greater willingness to eat edible insects. Several studies support this assumption as they have shown that being informed about entomophagy leads to a more positive attitude towards eating edible insects. Providing information about the environmental and nutritional benefits of eating insects was particularly effective in improving this attitude (Barsics *et al.*, 2017; Lombardi *et al.*, 2019; Menozzi *et al.*, 2017; Woolf *et al.*, 2019).

The percentages of respondents in Belgium who agreed to eat insects and who had already eaten them were similar to those recorded by Detilleux *et al.* (2024) (Acceptance: 68.22%, Experience: 67.74%). In both studies, most willing consumers of insects had already engaged in entomophagy (Detilleux *et al.*, 2024). These findings thus support the hypothesis that prior experience of eating insects increases familiarity with and acceptance of entomophagy (Kröger *et al.*, 2022). Despite results indicating that the Belgian population is open to entomophagy, as already suggested by Caparros Megido *et al.* (2014) and Detilleux *et al.* (2024), it seems that not all willing consumers would accept to eat insects on a regular basis: 33% in the current study and 32% in another Belgian study (Caparros Megido *et al.*, 2016). This finding could be explained by several practical and contextual factors affecting regular consumers of edible insects. One of these factors is the price, which remains relatively high in the European market: 2 to 3 times higher than meat or vegetarian alternatives, and even higher for foods with high insect content (up to 55.4 €/100 g) (House, 2016; Pippinato *et al.*, 2020). However, prices could fall rapidly in the future in the case that various stages of the edible insect value chain are automated (*e.g.,* rearing, harvesting, processing and distribution) (Rumpold *et al.,* 2013). Regarding respondents who refused entomophagy, the main reasons for this choice were similar to those reported in previous studies (Barton *et al.*, 2020; Detilleux *et al.*, 2024). Among these reasons, disgust is typically identified as a key negative factor influencing consumer acceptance. In Western countries such as Belgium, many unwilling consumers exhibit a pronounced disgust towards edible insects, perceiving them as unclean and as vectors for disease (Alhujaili *et al.*, 2023; Sogari *et al.*, 2023).

4.2. Context for insect consumption

4.2.1. Timing of insect consumption

In Belgium, breakfast is often associated with sweet foods (*e.g.,* cereals, chocolate spread, croissant, jam), while edible insects are considered as salty foods (Detilleux *et al.*, 2021; Tan *et al.*, 2015, 2016, 2017). This difference could explain why proposing edible insects for breakfast was the worst solution for the respondents in this study. Conversely, other timings of consumption are generally associated with salty foods, and they could more easily include insects. Several salty insect-based foods (*e.g.*, burger, chips, falafel, meatball, pasta) were particularly appreciated by Western participants in other studies (Caparros Megido *et al.*, 2016; Cicatiello *et al.*, 2020; Detilleux *et al.*, 2021; Duda *et al.*, 2019; Tan *et al.*, 2017).

4.2.2. Style of insect consumption

Respondents identified snacks as the most appropriate style of insect consumption, as already recorded in two other Belgian studies (Caparros Megido *et al.*, 2014; Detilleux *et al.*, 2021). These choices are probably related to the European image of the whole insect: its small size and original shape make it look more like chips than a piece of meat (Caparros Megido *et al.*, 2014). Snacks such as biscuits, crackers, chips, or energy bars are already the most popular way of eating insects in Western markets and in studies relating to entomophagy (Brynning *et al.*, 2020; Sogari *et al.*, 2019). In cultures with entomophagy traditions, proposing edible insects as snacks is also common, as can be seen in Japan with crunchy wasp larvae or in Thailand with fried silkworms, and is considered as the modern way of eating insects (Guiné *et al.*, 2021; Müller, 2019).

A snack can be defined as “a small meal or amount of food, usually eaten in a hurry”, and there are many different reasons for eating it: hunger, social pressure, rewarding oneself, enjoying a special occasion, *etc*. (Oxford Dictionnary, 2023; Verhoeven *et al.*, 2015). Such purposes must therefore be considered during the development and the promotion of an insect-based snack. Pricing also requires attention, as one study recorded that Western consumers were unwilling to pay more for insect-based snacks (*i.e.* cookie and energy bar) than for similar traditional snacks (Giotis *et al.,* 2021). However, additional research is needed to investigate the willingness-to-pay for other insect-based snacks, as this factor varies with the carrier used (Lombardi *et al.*, 2019). Whatever the carrier, Gmuer *et al.* (2016) recommend marketing snacks containing processed insect ingredients.

5. Limitations of this study

The sample of the current study was predominantly composed of Belgian university women. However, this sample was not representative of the entire European population or even the Belgian population. For instance, the Belgian population is characterised by a near-equality between men (49.33%) and women (50.67%), whereas this sample was overrepresented by women (Central Intelligence Agency (CIA), 2024). Moreover, the respondents' fields of work were linked to the specific characteristics of the ULiège. Including other (non-)university institutions or countries in the study area would have provided a more representative socio-demographic profile of respondents, reflecting the European and Belgian populations more accurately.

The three questions relating to general information about entomophagy are associated with respondents' attitudes and not on respondent's practices. It is therefore possible that the attitudes expressed by the respondents may not ultimately result in concrete actions (Detilleux *et al.*, 2024). To illustrate, 67% of willing consumers from the current study would accept to eat insects on a regular basis. However, such decision is only based on the opinion of the respondent and not on the actual factors that exert influence in practical circumstances (*e.g.*, availability, price, and taste) (House, 2016).

6. Conclusion

Many socio-demographic factors, including respondent's field of work, influence the acceptance of entomophagy. Consequently, all these factors can be included in the portrait of willing consumers of edible insects. Regarding age, the current study found no impact on acceptance of entomophagy. However, the relationship between age and acceptance of entomophagy remains unclear in the literature and requires deeper attention.

Entomophagy has the potential to develop in Belgium, but future consumers require guarantees (*e.g.*, price of insect-based food) before agreeing to consume insects on a regular basis. Reducing the disgust, the cultural incompatibility, or the fear of eating insects is also a strategy to ease the development of entomophagy in Belgium.

Regarding context for insect consumption, respondents to the current study do not want to integrate edible insects into their breakfast menu. The edible insect industry must therefore consider other times of day for consumption of insect-based foods. However, marketing edible insects as snacks is relevant to this food sector, because they meet consumer expectations.

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Chapter 6

"Would you like to cook an insect-based muffin at home?" – Impact of cooking on attitudes towards entomophagy and sensory liking

Study area: Belgium

Research question addressed in this chapter:

- Can active participation in the preparation of insect-based foods enhance acceptance among Western consumers? (RQ8)

This chapter is adapted from the following research article (under review):
Detilleux L., Faivre A., Dogot T., Goffin D., Richard G., Francis F. & Caparros Megido R., 2026. "Would you like to cook an insect-based muffin at home?" – Impact of cooking on attitudes towards entomophagy and sensory liking. *Br. Food J.* Under review.

Abstract

Purpose: This study explored how preparing insect-based foods at home influences attitudes toward entomophagy and sensory evaluation, filling a gap, as most Western research involves tasting sessions with foods prepared by others.

Study design/methodology/approach: A total of 172 respondents from Belgium participated in this study. Each respondent was invited to consume an insect-based muffin, either self-prepared or prepared by a third party.

Findings: Participants generally held positive views on entomophagy, and neither cooking nor tasting altered these perceptions. Nonetheless, those who prepared the insect-based muffin rated it higher on most sensory attributes compared to non-preparers, demonstrating an "I cooked it myself" effect. This implies that engaging in cooking activities might be a useful strategy to enhance the taste experience of insect-based foods. However, additional research is necessary to verify this finding, as this study is the first to report such an effect in the context of edible insects.

Originality/value: Unlike earlier research in this area, this study involved a subset of participants who prepared the insect-based food they were asked to consume. Additionally, it is the first Western study related to edible insects to document the 'I cooked it myself' effect.

Keywords

Edible insects, Novel food, Tasting session, Belgium, Western consumers

1. Introduction

The study of consumer food choices has a long history. Many researchers have modeled this complex behavior, often identifying sensory attributes such as flavor, texture, and appearance as key factors. These sensory qualities are usually assessed through tasting sessions (Furst *et al.*, 1996; Shepherd, 1999; Brunsø *et al.*, 2002; Ghosh *et al.*, 2018). In the context of entomophagy, these tasting events are frequently documented in Western literature to introduce and promote edible insects as a novel food source. However, in Western countries, the prevalent attitude toward eating insects is one of disgust, creating a significant barrier to acceptance. A positive initial experience with eating insects can help overcome this disgust and negative perceptions, increasing the likelihood of future consumption (Looy *et al.*, 2006; Caparros Megido *et al.*, 2014, 2016, 2025; Lensvelt *et al.*, 2014; Barton *et al.*, 2020; Detilleux *et al.*, 2021; Sogari *et al.*, 2023). The sensory qualities of insect-based foods vary widely depending on the product tested, including whole prepared insects (*e.g.*, boiled, dried, dipped in chocolate, roasted), salty insect products (*e.g.*, biscuits, burgers, chips, falafel, meatballs, spring rolls), sweet insect foods (*e.g.*, brownies, cakes, chocolate bars, cookies, waffles), and insect-based drinks (like dairy drinks, protein drinks, and soups). Despite this variety, a common trend is that consumers prefer foods that meet their expectations. Western consumers generally favor familiar, salty snacks that do not visibly contain insects and are not intended for breakfast (Tan *et al.*, 2015; Caparros Megido *et al.*, 2016; Detilleux *et al.*, 2021; Detilleux *et al.*, 2024b). The insect's developmental stage and the species used in food significantly affect sensory attributes (Mishyna *et al.*, 2020). These insect-specific traits vary across Western tasting studies, but two insect species are most frequently used: the adult house cricket, *Acheta domesticus* (L. 1758), and the mealworm larva, *Tenebrio molitor* (L. 1758) (Caparros Megido *et al.*, 2014, 2016; Sogari *et al.*, 2017; Tan *et al.*, 2017; Barton *et al.*, 2020; Cicatiello *et al.*, 2020; Detilleux *et al.*, 2021; Skotnicka *et al.*, 2023). Beyond the food itself, various tasting conditions differ significantly across Western studies, including the study country (such as Australia, Belgium, Canada, Italy, the United States), the tasting environment (as insectarium, market, school, university), the level of environmental control, and the tasters' profiles. A common issue is that food is often prepared by the study’s stakeholders rather than the tasters, even though individual food preparation can influence personal perceptions. Previous research indicates that suggesting the idea of cooking insects can increase willingness to participate in insect tasting events, whereas personal involvement in preparing insect-based food tends to reduce disgust towards entomophagy (Loo *et al.*, 2013; Deroy *et al.*, 2015; Hamerman, 2016). Additionally, self-prepared foods are generally more enjoyable and consumed in larger quantities than those prepared by others (Dohle *et al.*, 2014). Based on these findings, it is recommended to conduct insect-based tastings in naturalistic home settings, enabling participants to prepare the food themselves to minimize experimental bias and better mimic everyday consumption conditions.

Beyond the literature on entomophagy, our study also connects with research on do-it-yourself (DIY) and handmade products. Wolf *et al.* (2011) show that DIY activities are driven by a combination of economic, hedonic, and self-expression motives, suggesting that consumers may derive additional value from products they have personally created. Williams (2008) similarly argues that DIY consumption is not only a cost-saving strategy but also a way to assert autonomy and competence. In a related vein, Brunneder *et al.* (2018) describe a "self-creation effect", whereby making a product oneself supports more mindful consumption and enhances subjective well-being. More recently, Birau (2025) synthesized evidence that handmade activities can contribute to individual and societal well-being by fostering agency, creativity, and meaningful engagement. Although these studies were not conducted with insect-based foods, they converge on the idea that personal involvement in production can positively shape how products are evaluated and experienced. In the food domain, Comino *et al.* (2021) further illustrate how DIY approaches can be mobilized to valorize by-products into new materials, underlining the potential of hands-on practices to support more sustainable production and consumption systems. Taken together, this literature suggests that asking consumers to prepare insect-based dishes themselves may alter how these foods are perceived, not only because of their sensory properties but also because of the psychological value attached to self-production.

Following this recommendation, the current study conducted a home-based tasting of insect-based food. Some participants were asked to cook the food themselves, while others received a ready-to-eat version prepared by a third party. The primary aim was to explore how cooking might influence attitudes towards entomophagy. If positive effects were observed, incorporating cooking activities into Western strategies could be a viable way to promote entomophagy, echoing previous suggestions for tasting initiatives. Additionally, the study aimed to determine whether personal preparation enhanced sensory evaluation and made the tasting experience more enjoyable. Building on prior research indicating that self-preparation can boost food appreciation and reduce disgust, two hypotheses were tested: whether the positive influence on appreciation observed with traditional foods also applies to edible insects, and whether self-preparation can further improve other attitudes towards entomophagy. It is expected that participants who cook the insect-based food themselves will have more favorable attitudes than those who receive a ready-to-eat meal (H1), and that self-preparation will improve sensory evaluation (H2).

2. Material and methods

All procedures complied with the principles of the Declaration of Helsinki and were approved by the Human and Social Sciences Ethics Committee of the University of Liège (n°2023-11). Before participating, respondents received an information sheet describing the study aims, procedures, potential risks (including allergens), and data protection, and they provided informed consent via the online survey platform. Participation was voluntary, and respondents could withdraw at any time without consequence. No financial compensation was provided.

2.1. Participants

Participants were recruited from a previous study on entomophagy conducted among staff and students of the University of Liège (Detilleux *et al.*, 2024b). In that study, 1382 participants completed an online survey in June 2023. During this survey, respondents who reported accepting the consumption of edible insects were invited to participate in one of two future home-based activities: (1) tasting an insect-based food or (2) cooking and tasting an insect-based food. They could also decline both options. After indicating their choice, participants were asked to report any allergies or intolerances, particularly to crustaceans or dust mites, as well as their email address and the campus they most frequently visit. As suggested by Ribeiro *et al.* (2019), people allergic to crustaceans or dust mites were excluded due to the potential risk of immunologic co-sensitization between insects and crustaceans/dust mites. People allergic/intolerant to any other ingredient of the insect-based food were also excluded, as well as those who provided an invalid email address. For logistical reasons, the study focused on two campuses only: Liège city center and Liège Sart-Tilman. After applying these inclusion and exclusion criteria, 353 participants remained eligible: 144 for tasting and 209 for cooking and tasting. To obtain comparable group sizes, a random selection procedure was applied. Specifically, participants from the larger group (cooking and tasting) were randomly selected and reassigned to the tasting group until balanced group sizes were achieved. No additional stratification criteria were applied. This resulted in two balanced groups: 176 participants in the tasting group (*i.e.* non-preparers) and 177 participants in the cooking and tasting group (*i.e.* preparers).

At the end of February 2024, all eligible respondents were invited by email to collect a package of insect-based food or ingredients from a designated location on each campus. Participation required prior online registration (xoyondo.com) to select a collection time slot. Collection was available over three consecutive weekdays on each campus, from 11 a.m. to 5.30 p.m.

A total of 177 participants collected the study materials on campus. After excluding 5 participants due to incomplete questionnaires, the final sample consisted of 172 participants. Their sociodemographic characteristics are presented in **Table 6-1**. **Figure 6-1** summarises the participant selection process, including the number of individuals at each step and in each activity group (tasting vs. cooking and tasting).

Table 6-1. Sociodemographic profile of respondents – overall and by activity.

		Total (n = 172)	Tasting (n = 83)	Cooking + Tasting (n = 89)
Gender	Female	94	46	48
	Male	77	37	40
	Non-binary gender	1	0	1
Nationality	Belgian	153	75	78
	European	18	8	10
	Extra-European	1	0	1
Age (mean age ± standard deviation)		35.35 ± 15.12	31.60 ± 14.70	38.85 ± 14.75

Nationality: Belgian, European (people from European countries, except Belgium, were grouped), Extra-European (people from extra-European countries were grouped).

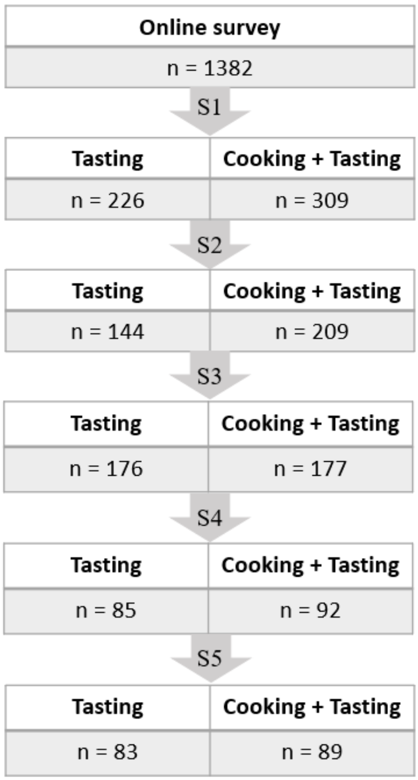


Figure 6-1. Selection process.

Successive steps (S1–S5) describe the transition from the initial population (n = 1382) to the final sample (n = 172). S1: respondents who agreed, during the online survey, to participate in one of the two activities; S2: respondents who reported no allergies to the insect-based muffin ingredients or to crustaceans/dust mites, provided a valid email address, and belonged to selected campuses; S3: random rebalancing of the two groups; S4: participants who registered online and came to collect the ingredients/the insect-based muffin; S5: exclusion of respondents with incomplete surveys.

2.2. Study design

2.2.1. Insect-based food

The choice of insect-based food was guided by two criteria in addition to the recommendations outlined in the Introduction: (1) to minimize the risk of contamination, meat was excluded from the recipe; (2) the recipe also had to be feasible with basic cooking materials, ensuring that all participants could prepare it at home. Therefore, a salty insect-based muffin was selected. The full recipe is available in the Supplementary materiel. Each muffin was baked in a white greaseproof paper muffin case (La Toque d'Or, Poitiers, France). The ingredients for four insect-based muffins as follows: 40 g wheat flour (Everyday, Halle, Belgium), 2 g instant yeast (Bruggeman, Gent, Belgium), 10 g ground mealworms, 30 g grated Emmental (Boni, Halle, Belgium), four green olives (≃ 14 g; Boni, Halle, Belgium), four dried tomatoes (≃ 19 g; Boni, Halle, Belgium), one egg (Boni, Halle, Belgium), and 4 cl semi-skimmed milk (Fairebel, Arlon, Belgium). This formulation, including the proportion of ground mealworm, was determined after several preliminary cooking and tasting sessions with stakeholders in the current study. The process for obtaining ground mealworms followed the method described by Detilleux *et al.* (2021).

Before data collection, muffins for non-preparers were produced at the Laboratory of Gastronomic Sciences (Gembloux, Belgium), in compliance with food safety standards. Each muffin was individually wrapped in a small transparent plastic bag (**Figure 6-2A**). Preparers received a package containing all ingredients required to prepare four muffins (except for the egg and milk), four muffin cases (**Figure 6-2B**), and the recipe. They were instructed to purchase the egg and semi-skimmed milk preparers themselves.

Figure 6-2. Insect-based muffin in its plastic bag for non-preparers (A); Content of package for preparers (B).

2.2.2. Collection procedure

Respondents met the first author of the present study at the scheduled time and date to collect the insect-based food or ingredient package. At that time, they received two documents. The first document contained detailed instructions, including the following key points: refrigerate the insect-based food or ingredients within three hours of collection; prepare and consume the insect-based food at home within four days; consult the allergen list before tasting; complete the tasting and questionnaires individually; rinse the mouth with water before tasting; taste one muffin only (the remaining muffins could be shared or consumed later, for preparers only); and taste the insect-based food without trimming (food or drink). These instructions reminded respondents to respect basic food safety practices in line with national recommendations, such as keeping perishable ingredients refrigerated and avoiding prolonged storage at room temperature. The second document generated using Youmeal software (Ottignies, Louvain-la-Neuve, Belgium), provided detailed information about the muffin's composition, nutritional content, and allergens. The allergen list explicitly listed insect proteins, milk, egg, and cheese, and individuals reporting allergies or intolerances to these ingredients were excluded at the recruitment stage and advised not to consume the product. At the end of the first document, a web link and QR code provided access to the second questionnaire, and before leaving, respondents were invited to scan a QR code and complete the first questionnaire on site.

2.2.3. Questionnaire

Both questionnaires were created using Typeform (Barcelona, Spain) and were linked by a unique identification code. In these questionnaires, five attitudes were assessed: (1) "I am ready to eat insect-based foods"; (2) "I am ready to cook insect-based foods"; (3) "I am ready to buy insect-based foods"; (4) "I am ready to integrate insect-based foods in my food habits"; and (5) "I am ready to recommend eating insect-based foods to my loved ones (family, friends, *etc.*)". Such attitudes have already been studied in previous research on entomophagy (Caparros Megido *et al.*, 2014, 2016; Ruby *et al.*, 2015; Barton *et al.*, 2020; Tuccillo *et al.*, 2020; Detilleux *et al.*, 2021, 2024b). In the present study, these attitudes were assessed individually using the question: "Do you agree with the following statement?" with responses on a seven-point Likert scale ranging from "Totally disagree" to "Totally agree".

The first questionnaire, completed before tasting or cooking, collected participants' initial attitudes and their sociodemographic information (gender, nationality, and age).

The second questionnaire, completed at home during the tasting, included sensory evaluation of the muffin (appearance, odor, texture, taste, and overall liking) on five seven-point Likert scales ranging from "Extremely bad" to "Extremely good". Respondents concluded the second questionnaire by repeating the five attitude assessments.

2.3. Statistical analysis

All statistical analyses were performed using R software v.4.3.3 (Vienna, Austria). The analyses included paired and unpaired t-tests. For both types of tests, the assumption of normality was assessed using the Shapiro–Wilk test. For unpaired data, the assumption of homogeneity of variances was additionally verified using Levene's test. When one or more of these assumptions were violated, the non-parametric Wilcoxon test was applied instead. T-tests for paired data (or Wilcoxon signed-rank tests, when appropriate) were conducted to (1) assess potential changes in attitudes before and after tasting within preparers and non-preparers. T-tests for unpaired data (or Wilcoxon-Mann-Whitney tests, when appropriate) were used to (2) compare changes in attitudes between the two groups (when applicable), and (3) compare sensory ratings between preparers and non-preparers. Effect sizes and their confidence intervals were computed for all statistically significant results to estimate the magnitude of between-group differences and to complement the interpretation of p-values. Cohen's d was reported for unpaired t-tests, and the r effect size was reported for Wilcoxon tests. Effect sizes were interpreted as negligible, small, moderate, and large using thresholds of 0.2, 0.5, and 0.8 for Cohen's d, and 0.1, 0.3, and 0.5 for Wilcoxon r effect size, respectively. Given the exploratory nature of this study and its limited sample size, the analytical strategy relied on multiple t-tests and Wilcoxon tests rather than more complex mixed-effects models. As a result, the analyses should be interpreted as providing initial evidence and patterns rather than definitive causal estimates, and we did not correct for multiple comparisons.

3. Results

3.1. *Attitudes towards entomophagy*

As indicated in **Table 6-2**, respondents from both activities exhibited generally positive attitudes towards entomophagy before participation, and neither activity had a significant impact on these attitudes, which remained stable at the end of both activities. Given the absence of significant pre–post changes in attitudes within both groups, between-group comparisons of attitude changes were not considered further.

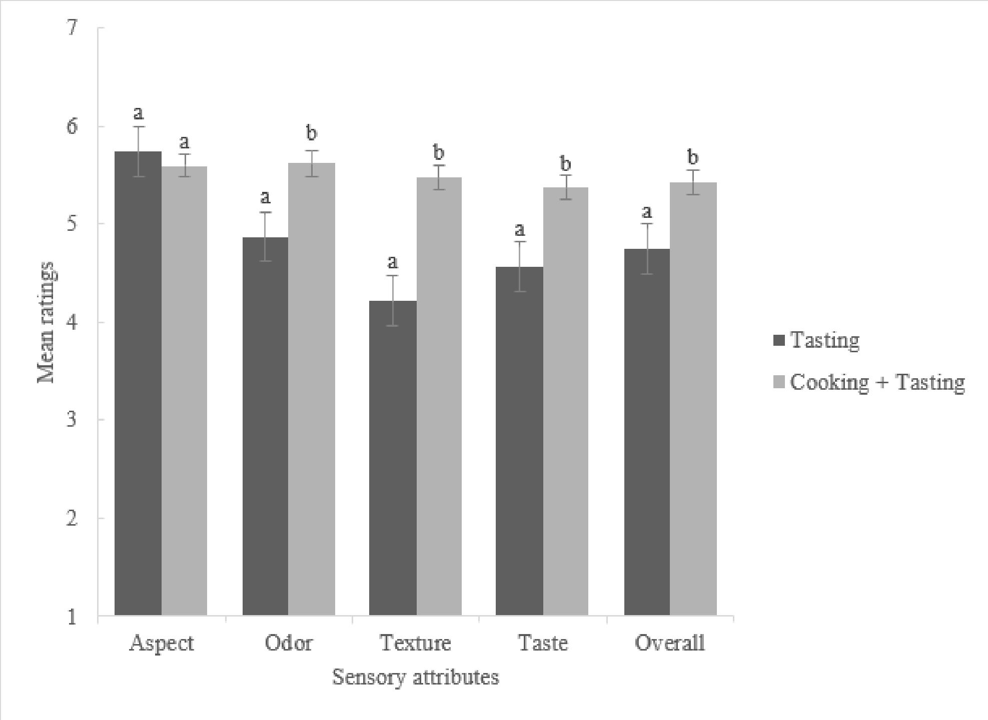
Table 6-2. Evaluation of attitudes before and after tasting insect-based muffin (mean value ± standard deviation).

	Tasting (n = 83)					Cooking + Tasting (n = 89)				
	Before	After	Df	t	*p*	Before	After	Df	t	*p*
Eat	6.01 ± 0.13[a]	5.93 ± 0.15[a]	82	-0.575	0.567	6.34 ± 0.10[a]	6.17 ± 0.12[a]	88	-1.208	0.230
Cook	5.42 ± 0.14[a]	5.36 ± 0.17[a]	82	-0.431	0.667	6.33 ± 0.10[a]	6.19 ± 0.12[a]	88	-1.202	0.310
Buy	5.60 ± 0.14[a]	5.60 ± 0.16[a]	82	0	1	5.82 ± 0.13[a]	5.85 ± 0.13[a]	88	0.219	0.827
Food habits	5.34 ± 0.14[a]	5.17 ± 0.18[a]	82	-1.370	0.192	5.51 ± 0.13[a]	5.62 ± 0.15[a]	88	0.770	0.444
Recommendation	5.40 ± 0.14[a]	5.20 ± 0.16[a]	82	-1.189	0.230	5.48 ± 0.13[a]	5.56 ± 0.14[a]	88	0.533	0.595

The five attitudes were evaluated on Likert seven-point scales. Eat: "I am ready to eat insect-based foods"; Cook: "I am ready to cook insect-based foods"; Buy: "I am ready to buy insect-based foods"; Food habits: "I am ready to integrate insect-based foods in my food habits"; Recommendation: "I am ready to recommend eating insect-based foods to my loved ones (family, friends, *etc.*)". Different superscript letters indicate a significant difference.

3.2. Sensory evaluation

Preparers rated the insect-based muffin higher than non-preparers across all sensory attributes except aspect (**Figure 6-3**).



	Aspect	Odor	Texture	Taste	Overall
Statistical analysis	Wilcoxon	T-test	T-test	Wilcoxon	T-test
Test value	W = 942	t = -3.858	t = -6.363	W = 555	t = -3.665
p-value	0.287	***1.62*10⁻⁴***	***2.01*10⁻⁹***	***6.52*10⁻⁴***	***3.33*10⁻⁴***
Interpretation	ns > 0.05	< ***0.001***	< ***0.001***	< ***0.001***	< ***0.001***
Effect size	r = 0.06	d = 0.589	d = 0.971	r = 0.260	d = 0.559
Effect size CI	[0.003;0.21]	[0.25;0.96]	[0.66;1.34]	[0.10;0.39]	[0.25;0.89]
Effect size magnitude	Negligible	Moderate	Large	Small	Moderate

Figure 6-3. Sensory evaluation of insect-based muffin (mean ratings ± standard deviation).

A t-value indicates that a t-test was conducted when the assumptions for parametric analysis were met. A W-value indicates that a Wilcoxon test was conducted when these assumptions were not met. Different superscript letters indicate a significant difference. Bold data indicate significant results. When a significant difference was observed, effect sizes were computed using Cohen's d for t-tests and r for Wilcoxon tests.

4. Discussion

4.1. Attitudes towards entomophagy

The initial attitudes of respondents towards entomophagy were generally positive. Before the activities, respondents were willing to consume, prepare, and purchase insect-based foods. They also expressed a readiness to incorporate entomophagy into their food habits and were willing to recommend it to their loved ones. However, these attitudes did not reflect the prevailing attitudes of the Belgian population due to selection bias. The respondents in the current study could be considered particularly enthusiastic about consuming edible insects, as all had previously declared their acceptance of entomophagy and agreed to participate in a tasting or preparation of insect-based food during the selection process. Consequently, the acceptance rate in the current study was 100%, whereas previous studies in Belgium reported acceptance rates between 43% and 78% (Caparros Megido *et al.*, 2014; Van Thielen *et al.*, 2018; Detilleux *et al.*, 2024a,b).

Following the consumption of the insect-based muffin, no significant changes were observed in any of the five attitudes for either group. In other words, neither tasting nor cooking the insect-based food appeared to influence participants' attitudes toward entomophagy. This lack of change could also be due to a ceiling effect, as participants already exhibited highly positive baseline attitudes, leaving little room for further improvement. Under the conditions examined in the present study, there was therefore insufficient evidence to confirm H1.

Previous research suggests that tasting may enhance negative attitudes, particularly among individuals without prior entomophagy experience (Looy *et al.*, 2006; Caparros Megido *et al.*, 2014, 2016; Lensvelt *et al.*, 2014; Barton *et al.*, 2020; Detilleux *et al.*, 2021; Sogari *et al.*, 2023). In the current study, respondents already exhibited positive attitudes towards insect eating before the tasting, and Detilleux *et al.* (2024b) reported that most had prior experience with entomophagy. Therefore, for a group of participants who are both enthusiastic and experienced, a tasting session is unlikely to enhance attitudes towards entomophagy further.

Similarly, cooking did not change attitudes among the respondents in the current study, who were already characterized by enthusiasm and experience with entomophagy; in contrast, students Saga (2025) who actively participated in preparing insect-based foods reported more positive attitudes towards entomophagy. However, this finding was based on a very small sample of only five students. To better understand the potential impact of cooking on attitudes, the current study's research design should be replicated with respondents who show lower initial acceptance of entomophagy, as no large-scale study has yet examined how cooking insect-based foods influences these five attitudes. However, recruiting respondents with lower enthusiasm or limited experience in entomophagy may be challenging for future studies. The willingness to eat insects could be enhanced by informing people (*e.g.*, about the nutritional and environmental benefits of entomophagy) (Woolf *et al.*, 2019). This approach may also improve their willingness to prepare insect-based foods. One promising strategy would be to highlight the compatibility of insect-based food preparation with participants' existing cooking habits. For example, they could be informed that preparing insect-based food requires no additional culinary skills beyond those required for familiar dishes. Such information is already known to influence long-term insect consumption (House, 2016). Alternatively, offering incentives could facilitate recruiting less enthusiastic participants, as incentives have been shown to increase survey participation and improve sample representativeness, particularly when response rates are low (Singer *et al.*, 2006; Smith *et al.*, 2019). In the present study, participation was relatively low (12.45%), with only 172 respondents completing the activities out of 1382 individuals who took part in the preliminary survey (Detilleux *et al.*, 2024b), and the rate would be even lower if calculated relative to the more than 30,000 members of the University of Liège who were initially invited. Therefore, our findings should not be generalized to Western consumers, but rather to a very specific subset of Belgian participants who had previously accepted the idea of eating insects and voluntarily agreed to take part in a tasting or cooking activity.

4.2. Sensory evaluation

The insect-based muffin was particularly well received, with most respondents rating all sensory attributes positively, including overall liking. This result suggests that the muffin met the main expectations typically reported for Western consumers who are already open to entomophagy, supporting its potential for successful market introduction in this segment. However, a larger-scale test is required to optimize the composition and the recipe. Further attention is also needed on other factors related to insect-based food, such as price, which impact long-term consumption patterns (House, 2016). In this study, the unit cost of the insect-based muffin used was 0.48€, including all ingredients (except mealworms) and the muffin case (excluding delivery charges). The price of mealworms was not included because they were sourced from a non-commercial rearing unit. However, their cost could be estimated using the market price of mealworms sold as animal feed. Including this cost would raise the unit cost of the insect-based muffin to 0.55€. Conversely, a similar muffin without insects, in which the same quantity of wheat flour replaces mealworms, would also cost 0.48€. The addition of insects, therefore, increases the unit cost of the muffin by 14.58%. Previous research suggests that Belgian consumers may be willing to pay slightly more for insect-based foods than for conventional alternatives. Still, this trend should be confirmed specifically for the insect-based muffin used in the current study, as willingness to pay can vary depending on the product carrier (Lombardi *et al.*, 2019; Detilleux *et al.*, 2024a). It should also be noted that the aforementioned costs do not reflect industrial prices, as they exclude labor and energy expenses.

Respondents who prepared the muffin themselves rated it higher than non-preparers on all sensory attributes except appearance, confirming H2. This pattern is in line with Dohle *et al.* (2014), who showed that a self-prepared raspberry milkshake was liked more than an otherwise identical ready-to-drink version, and introduced the "I cooked it myself" effect in parallel with the "IKEA effect", where liking increases with one's own labour (Norton *et al.*, 2012). Building on this, research on DIY and handmade products suggests that consumers often engage in self-production to experience control, accomplishment and identity expression (Williams, 2008; Wolf *et al.*, 2011), and that self-created products can foster more mindful consumption and higher well-being (Brunneder *et al.*, 2018; Birau, 2025). These mechanisms offer a plausible explanation for why our preparers expressed higher sensory liking than non-preparers, and they resonate with the idea that personal involvement in cooking may strengthen psychological attachment to the dish. However, our results also contrast with those of Chow *et al.* (2021), who did not observe an "I cooked it myself" effect when children aged 11–13 prepared insect-based oatmeal balls, suggesting that age or developmental stage might moderate this phenomenon. In addition, differences in insect presentation could play a role: in the present study, preparers used ground mealworms that resembled ordinary flour, with no visible animal characteristics, whereas Chow *et al.* (2021) worked with roasted insects that retained visible features. Visible reminders of "animalness" have been shown to trigger disgust more easily, which may overshadow any positive effect of self-preparation, while less salient forms (such as flours) might allow such an effect to emerge more clearly. Yet, we did not directly measure constructs such as pride, ownership, perceived effort, or disgust in this study, so the psychological processes underlying these patterns remain speculative and should be examined in future research specifically designed to test these mediating mechanisms.

This link between animalness and disgust also helps to explain why both the academic literature and insect companies tend to prioritize insect flours or powders over whole insects when targeting Western consumers (Tan *et al.*, 2015; Caparros Megido *et al.*, 2016, 2025; Mancini *et al.*, 2022). When animal characteristics such as legs or wings are salient, disgust may dominate and potentially dampen any positive "I cooked it myself" effect, whereas less visible forms like ground mealworms may allow this effect to emerge more clearly. Taken together, our results and previous work suggest that the visibility of insects' animal features may play a decisive role in shaping consumer perceptions and in determining whether self-preparation can enhance the liking of insect-based foods. Building on this, future studies should examine the underlying mechanisms of the "I cooked it myself" effect and how it interacts with factors such as perceived risk, disgust, and willingness to consume insect-based products.

Confirming H2 may also have broader implications for promoting entomophagy. From a practical and managerial standpoint, strategies that actively involve consumers in preparing insect-based dishes could help improve both their tasting experience and acceptance. Companies could, for example, develop home-cooking kits or recipe bundles that present insect-based meals as creative, hands-on projects rather than ready-made novelties, while incorporating insects in familiar, low-visibility formats to minimize disgust. Such approaches are consistent with the DIY and handmade literature, which shows that self-production can foster feelings of competence, ownership and meaningful engagement (Williams, 2008; Wolf *et al.*, 2011; Brunneder *et al.*, 2018; Birau, 2025), and with work on DIY valorisation of food by-products in sustainable systems (Comino *et al.*, 2021). Educational stakeholders may likewise leverage cooking activities with insects in schools or youth programs, in line with studies indicating that pedagogical cooking experiences can create enjoyable learning environments and stimulate curiosity and willingness to try insect-based foods (Marquis, 2021, 2023). Beyond entomophagy, fostering cooking skills more generally is known to encourage healthier dietary patterns, suggesting that culinary education can contribute to improved nutrition and more sustainable food practices (Hartmann *et al.*, 2013). However, given the strong self-selection bias and the non-representative nature of our sample, these implications should be interpreted with caution and should primarily be considered for consumers who are already open to eating insects. Therefore, our findings should not be generalized to Western consumers as a whole, but rather to a very specific subset of Belgian participants who had previously accepted the idea of eating insects and voluntarily agreed to take part in a tasting or cooking activity.

5. Limitations of this study

As previously stated, the selection process introduced a bias, as respondents in the current study were more enthusiastic about entomophagy than the general Belgian population.

Although most meals in Belgium are consumed at home, households are rarely used as a setting for tasting insect-based foods (Bel *et al.*, 2015). Conducting a tasting session and a culinary activity in such an environment may introduce several biases due to variability in the physical and social environment, potential non-compliance with instructions and/or recipe, the necessity of recruiting respondents, *etc*. (Boutrolle *et al.*, 2009).

Homemade insect-based muffins, whether prepared by respondents or stakeholders, may vary in sensory characteristics. Although such variability is inherent to home cooking, the authors mitigated it by providing a detailed preparation protocol (see the recipe in the Supplementary Material) and a standardized consumption protocol (see Materials and Methods), both of which were applied consistently across all respondents.

From a statistical perspective, our approach also has limitations. We relied on multiple pairwise tests to analyze repeated measures without correcting for multiple comparisons, and we did not conduct a formal a priori power analysis. Consequently, the risk of Type I error may be inflated, and non-significant results cannot be interpreted as evidence of no effect. Future research with larger and more diverse samples should employ mixed-effects models that incorporate within- and between-subject factors and relevant covariates, and should report power calculations or equivalence tests to more rigorously assess small effects.

6. Conclusion

Respondents in the current study were particularly enthusiastic about entomophagy throughout. Tasting and cooking the insect-based muffin did not further improve their already positive attitudes, suggesting that such activities may have a limited impact on participants who are both experienced and enthusiastic about entomophagy. For other people, tasting remains a potentially effective strategy for enhancing more negative attitudes, and this effect could be reinforced by incorporating preparatory activities. Indeed, individual preparation of insect-based food led to higher sensory ratings due to the “I cooked it myself” effect. However, this effect requires further investigation, as it was documented in the current study for the first time in Western entomophagy literature. Future studies should aim to confirm the effect across other participant profiles (*e.g.*, respondents with lower enthusiasm for entomophagy), different insect-based foods, and alternative forms of insect-ingredient presentation. They should also explore the underlying mechanisms and their potential influence on factors such as perceived risk and disgust towards entomophagy.

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Supplementary materiel

Recipe for insect-based muffin

Ingredients (4 portions):

- 40 g of wheat flour
- 2 g of instant yeast
- 10 g of ground mealworms
- 30 g of grated cheese (Emmental)
- 4 green olives
- 4 dried tomatoes
- 1 egg
- 4 cl of semi-skimmed milk

Instructions (25-30 minutes):

1. Preheat the oven to 180°C (thermostat 6).
2. In a bowl, mix the flour, yeast, and ground mealworms with the egg. Gradually pour in the milk while continuing to mix until you have a smooth dough.
3. Cut the green olives into two pieces and the dried tomatoes into three. Add them to the dough together with the grated cheese. Mix well. Season with salt and pepper to taste.
4. Evenly distribute the batter among the four muffin cases. The cases should not be filled more than ¾ full.
5. Put in the oven (preheated), to 180°C for 20 minutes.
6. Cool in the fridge before removing from the cases and eating.

Chapter 7

General discussion

1. Introduction

The general discussion provides a conclusion and a critical assessment of the work carried out and the results obtained during this thesis. These aims are addressed in the present chapter, which is structured into two main parts. Each part synthesises the findings highlighted in the five articles, complemented by a review of the most recent literature on the topic, in order to address the research questions of the current thesis. A critical analysis of the work is also provided, highlighting limitations, suggesting possible improvements, and outlining perspectives for future research.

The first part addresses the first objective of the thesis, namely understanding entomophagy in traditional and non-traditional cultural contexts. This section draws on the two case studies: Gabon, to address the existing knowledge gaps on this country, and Belgium, to assess the evolution of trends more than a decade after the introduction of edible insects into the Belgian market and to question youngsters on this food practice. This first part concludes with a reflection on the central role of culture in shaping behaviours towards entomophagy.

The second part focuses on the second objective of the thesis: identifying social determinants and practical strategies for sustainable integration of edible insects into modern diets. It provides an updated profile of Western willing consumers and examines the strategies recommended in Western contexts to promote entomophagy.

Finally, a general conclusion connects both sections to discuss the future of entomophagy on a global scale, highlighting perspectives for research, stakeholders along the value chain, and ultimately consumers.

2. Understanding entomophagy in traditional and non-traditional cultural contexts

2.1. Entomophagy in Gabon

As indicated by broader research on African entomophagy, the consumption of edible insects is prevalent in Gabon (van Huis, 2003; Kelemu *et al.*, 2015). While Omuse *et al.* (2024) suggested that 12 insect species were consumed, our inventory listed 75 species (Detilleux *et al.*, 2021a). However, this number may be underestimated because several species reported in other studies were not recorded in our survey (van Huis, 2003; Kelemu *et al.*, 2015). One reason is that the respondents surveyed did not cover the entire population. Additionally, the inventory was conducted outside the peak period of insect availability, and thus based more on declarations than on direct observation which would provide more reliable data (Detilleux *et al.*, 2021a). Compiling such inventories based on interviews is highly challenging. This difficulty is further compounded by the fact that traditional knowledge is often transmitted orally and at risk of being lost. Local names can also vary for a single species or be shared among multiple species (Nsevolo *et al.*, 2022a).

Regarding the inventory of 75 insect species, a correction must be noted. The insect initially recorded as *Psara* sp. was subsequently identified as *Parotis baldersalis* Walker, 1859 (Lepidoptera: Crambidae) by one of the study's co-authors in a later publication. This misidentification was likely due to the close morphological resemblance between the larvae of these two species from the same family (*i.e.* Crambidae). For a definitive determination, the larvae were returned to the laboratory and reared to adulthood. The host plant identification was also refined, moving from the genus level (Tabernaemontana) to the precise species level [*Tabernaemontana crassa* Benth. (Apocynaceae); (Poligui *et al.*, 2022)]. As with *Psara* sp., *P. baldersalis* was documented for the first time as an edible insect. Among the other insects documented for the first time as edible, most still remain unrecorded as such in Gabon or elsewhere, except for *Bunaelopsis licharbas* Maasen & Weymer, 1886 (Lepidoptera: Saturniidae), which has been recorded in both the Republic of Congo and the Democratic Republic of Congo (DRC) (Latham *et al.*, 2025).

Both of these species belong to Lepidoptera, the order most represented among recorded edible insects in Gabon and across Africa. Lepidoptera species are consumed primarily as caterpillars and, less commonly, as chrysalides. The prominence is reflected in the scientific literature: by 2014, at least 370 publications reported human consumption of Lepidoptera in Africa (Malaisse *et al.*, 2014; Numbi Muya *et al.*, 2022).

With 75 recorded edible insect species, Gabon ranks among the African countries with the highest species diversity. However, this number is lower than the DRC (255 species), and closer to countries such as Cameroon (100), Zambia (78), and the Central African Republic (62). This ranking should be interpreted with caution, as it is based on a review that initially reported only 12 edible insect species in Gabon (Omuse *et al.*, 2024). This finding highlights significant gaps in the documentation of entomophagy in Africa, particularly in understudied countries such as Gabon. To date, research on entomophagy in Gabon remains extremely limited and consists only of the two studies produced as part of the present thesis, along with the publication that refined the identification of *Psara* sp. (Poligui *et al.*, 2022).

Despite the high diversity of edible insects, the two studies conducted for this thesis indicate a relatively low proportion of insect consumers among surveyed participants [62.13% in Detilleux *et al.* (2021a) and 46.84% in Detilleux *et al.* (2024a)] compared to other sub-Saharan countries (ranging from 79.6% to 84.53%) (Nsevolo *et al.*, 2016; Anankware *et al.*, 2017; Manditsera *et al.*, 2018; Ancha *et al.*, 2021). These comparisons should be interpreted cautiously due to methodological differences, including sample size, sample composition, question phrasing, and timing of data collection. Specifically, data from Detilleux *et al.* (2021a, 2024a) were collected outside the peak period of insect availability, potentially underestimating actual consumption. Moreover, some percentages are reported at the national level, even though the data were collected from specific cities or regions, limiting their representativeness.

Beyond methodological considerations, several factors may explain the low consumption observed in Gabon. Rather than reflecting the dominance of a single determinant, consumption patterns appear to result from the interaction between structural transformations (such as urbanisation and economic development), availability constraints, and cultural factors.

Firstly, Gabon's high urbanisation (91% in 2023) and relatively elevated income level [third in Africa by Gross Domestic Product (GDP) per capita] favour a dietary transition. Although income inequality persists, with 33.4% of the population living below the poverty line in 2017, this is lower than neighbouring countries such as the DRC (56.2% in 2020) and the Central African Republic (68.8% in 2021). Urbanisation and rising incomes are associated with a progressive shift away from traditional foods, including edible insects, towards foods perceived as higher value, such as meat, fish, dairy, and processed foods (Vantomme, 2015; Müller, 2019; Glatzel *et al.*, 2024; Central Intelligence Agency (CIA), 2025). This transition can be understood as part of a broader dietary shift in which traditional practices gradually lose their centrality, not necessarily because of their limitations, but because of changing social representations of what constitutes desirable food.

Secondly, in some African countries, seasonal scarcity of certain animal protein sources encourages reliance on alternatives such as edible insects (Dürr *et al.*, 2021). In Gabon, commonly consumed animal proteins (*i.e.* poultry, fish, beef, pork, and bushmeat) are available throughout the year, reducing dependence on alternative protein sources (Bachand *et al.*, 2015). National data support this idea: in 2023, Gabon had roughly two to three times more meat and fish available per capita per day than the sub-Saharan African average (*i.e.* ≈ 170 g of meat and 75 g of fish per capita per day, versus 65 g and 33 g, respectively) (The Global Alliance for Improved Nutrition (GAIN), 2025).

Thirdly, edible insect consumption depends on actual availability. Although around 75 edible species have been identified, they cannot contribute to diets if access is limited (House, 2016). Field observations during Detilleux *et al.* (2024a) showed that edible insects were difficult to obtain, particularly in supermarkets, which are widely developed in Gabon (The Global Alliance for Improved Nutrition (GAIN), 2025). Only traditional markets offered some availability. This limited accessibility suggests that, despite their diversity, edible insects remain marginal within formal food distribution systems. As supply and demand are interdependent, limited supply may also reflect limited consumer interest. In this respect, availability should not be understood solely as a logistical constraint, but also as the outcome of broader market dynamics shaped by consumer preferences and cultural acceptance. In many African countries, wild harvesting is a common procurement method, and respondents in Detilleux *et al.* (2024a) similarly identified collection in nature as the primary source of supply (Ebenebe *et al.*, 2020). Strengthening knowledge of harvesting techniques, seasonality and species distribution could reinforce this supply channel (Ishara *et al.*, 2023). However, insect farming could also contribute to increasing supply and reducing seasonal constraints, particularly in the context of developing more structured value chains. This approach raises new questions regarding consumer acceptance, as it remains unknown whether farmed insects would be as well accepted as wild-harvested insects in regions where insect collection may represent an important source of supply. While farmed insects may benefit from perceptions of safety and quality control, wild insects may be associated with naturalness and authenticity. To date, this aspect has not been investigated for edible insects, although similar differences in consumer perceptions according to production origin have been reported for other foods such as fish (Verbeke *et al.*, 2007; Claret *et al.*, 2014; Barhoumi *et al.*, 2025).

Finally, cultural differences between Gabon and other African countries may also explain the lower consumption of edible insects. This factor, already introduced in previous chapters, will be examined in greater depth in Section 2.3 (Entomophagy and culture).

Cultural differences within Gabon also contribute to variation in insect consumption. Notably, consumption practices differ among ethnic groups: some are more accustomed to eating insects than others. According to Ghosh *et al.* (2018), ethnic affiliation is one of the strongest predictors of food preferences and shapes both the selection of insect species and the culinary methods used to prepare them. Similar ethnic-based differences have been documented in several other African countries, including Benin (Hongbété *et al.*, 2017; Ghosh *et al.*, 2021; Anagonou *et al.*, 2023), the DRC (Bomolo *et al.*, 2017), Kenya (Kusia *et al.*, 2021), Nigeria (Alamu *et al.*, 2013), and Uganda (Alaroker *et al.*, 2025). In Gabon, the Teke appear to be the ethnic group that consumes edible insects most frequently. Located in the eastern regions of the country, particularly in the Haut-Ogooué Province, the Teke are also present in parts of the Republic of Congo and the DRC. They have consumed edible insects for thousands of years, using their ancestral knowledge of the relationships between insects and their host plants to guide harvesting practices. These food habits have also been transmitted beyond Central Africa, as members of the Teke diaspora in countries such as Benin and France continue to incorporate edible insects into their diets (Tchibozo, 2018; Poligui *et al.*, 2022). In Gabon in 2021, the Teke represented only 5.6% of the total population, while the Fang and the Punu were the largest ethnic groups (Central Intelligence Agency (CIA), 2025). These two groups were also the least entomophagous in the two studies conducted for this thesis (Detilleux *et al.*, 2021a, 2024a).

In both studies included in this thesis, the Teke were overrepresented, accounting for 17.16% of participants in Detilleux *et al.* (2021a) and 10.9% in Detilleux *et al.* (2024a), potentially overestimating national insect consumption levels. Given the strong influence of ethnic affiliation on attitudes and practices related to insect consumption, ensuring proportional representation of ethnic groups would therefore be advisable in future studies to provide a more accurate assessment of entomophagy in Gabon.

Furthermore, although the rural population constitutes a relatively small share of Gabon's total population, including rural participants could potentially increase observed consumption rates. Nevertheless, it remains to be determined whether the general trend of differences between urban and rural populations reported in other countries also applies in Gabon (Vantomme, 2015; Müller, 2019; Glatzel *et al.*, 2024). Dedicated research on entomophagy in rural Gabonese contexts is therefore needed to assess whether similar patterns exist and to document practices that may not be captured in urban-focused surveys. Future studies should therefore aim to achieve both ethnic and rural-urban representativeness to better capture the diversity of insect consumption practices.

In Gabon, as in several countries across Central Africa, entomophagy has the potential to contribute to reducing malnutrition and food insecurity (Niassy *et al.*, 2016; Payne *et al.*, 2016; FAO, 2021). By introducing an additional resource into local food systems, it enhances dietary diversity and can therefore increase the resilience of populations to food-related shocks (Nsevolo *et al.*, 2022b). Beyond its nutritional benefits, entomophagy also has the potential to generate economic opportunities and to contribute to climate-change mitigation efforts (see Chapter 1). Furthermore, the valorisation of a naturally abundant resource could support Gabon in reducing its considerable reliance on imported food products (FAO, 2013). In this context, advancing the use of edible insects in Gabon and in neighbouring countries is especially relevant.

However, promoting this practice remains essential if it is to become more widely adopted across the population. The main reasons reported in Detilleux *et al.* (2024a) for not consuming insects (*i.e.* primarily disgust and cultural considerations) are similar to those observed in many other countries. Taking inspiration from promotion strategies implemented elsewhere may therefore be relevant for encouraging the development of entomophagy in Gabon. However, the effectiveness of such strategies cannot be assumed and should be empirically evaluated in the Gabonese context. Nsevolo *et al.* (2022a) also highlight several limitations in the edible insect sector in the DRC that likely apply to many sub-Saharan African countries, including Gabon: the need for a dedicated legal framework for insects and insect-derived products, risk assessments for insects harvested from the wild, and the development of species-specific guidelines covering the entire value chain. Achieving these objectives will require coordinated efforts among government authorities, researchers, private enterprises and rural communities (Nsevolo *et al.*, 2022a).

In summary, these findings provide a first overview of edible insect diversity and consumption patterns in Gabon, offering a baseline for future research. While the present thesis initially positioned Gabon as a country with widespread traditional insect consumption, the relatively low levels of reported consumption suggest a more nuanced reality. The results highlight the importance of cultural and ethnic factors in shaping insect consumption and point to the need for more representative and temporally extended studies to better understand these dynamics. This work represents an important contribution, as no previous studies have systematically investigated entomophagy in Gabon. In an exploratory way, these findings contribute to addressing the first two research questions of this thesis, which aimed to investigate both the supply of edible insects and their consumption patterns in Gabon.

2.2. Entomophagy in Belgium

The main insights derived from the articles included in this thesis suggest that Belgian consumers appear generally open to the idea of eating insects. In particular, a high level of awareness of entomophagy was reported among Belgian consumers in 2022, reaching 98.8% (Detilleux *et al.*, 2024a). This finding is consistent with earlier and more recent studies conducted in Belgium, which document a steady increase in awareness over time: from 61.9–71.5% in 2013 (Caparros Megido *et al.*, 2014; Verbeke, 2015), to 72.3–78.7% in 2017 (Barsics *et al.*, 2017; Van Thielen *et al.*, 2018), and up to 95.6% in 2022 (Mancini *et al.*, 2024).

However, one Belgian study reports markedly lower awareness levels. Caparros Megido *et al.* (2016) found that only 49.4% of respondents were familiar with entomophagy in 2014. The authors suggested that this difference may be due to the use of the term "entomophagy" in the survey question, which may not have been understood by all respondents, leading to an underestimation of awareness. In line with this explanation, all articles included in the present thesis assessed awareness using more explicit formulations (*e.g.*, "Have you already heard about edible insects?" or "Do you know that some insects can be eaten by humans?").

This overall increase in awareness may partly be explained by the growing presence of entomophagy in the media, both as informational content (*e.g.*, press and television) and as entertainment (*e.g.*, Top Chef, Koh-Lanta). However, in the latter context, entomophagy is often framed as a challenge to be overcome, which may not necessarily contribute to a positive image of the practice (Payne *et al.*, 2019).

Beyond awareness, the articles included in this thesis also report relatively high levels of acceptance of insect consumption, ranging from 67.4% to 68.2%, as well as a notable proportion of respondents with prior experience of eating insects, ranging from 46.2% to 47.6% (Detilleux *et al.*, 2024a,b). Comparable results have been reported in some studies conducted in Belgium, including high acceptance levels [77.7% in Caparros Megido *et al.* (2014)] and similar levels of prior experience [51.7% in Delicato *et al.* (2020)]. However, these findings are not consistently observed across the entire literature. Other surveys conducted in Belgium report lower acceptance rates, such as 55.0% (IPIFF, 2024), 43.0% (Van Thielen *et al.*, 2018), and 28.3% for whole insects versus 51.8% for insects incorporated into foods (Tzompa-Sosa *et al.*, 2023a). Similarly, lower levels of prior experience have been documented in other studies, including 32.9% (Caparros Megido *et al.*, 2016), 30.0% (IPIFF, 2024), and 24.0% (Sogari *et al.*, 2023).

Such differences suggest that, unlike awareness, which appears to be widely established, acceptance and actual experience of insect consumption remain more heterogeneous within the Belgian population. This variability may reflect differences in study design (*e.g.*, data collection methods, sampling strategies, and question wording) or differences in sample characteristics (*e.g.*, age, gender, and study level) (Ardoin *et al.*, 2021). For example, in the studies included in this thesis, participants were informed in advance that the research focused on edible insects. Individuals who are strongly disinterested in, or opposed to, entomophagy may therefore have been less inclined to participate, potentially leading to an under-representation of more negative attitudes. This may partly explain why studies based on consumer panels, such as those conducted by IPIFF (2024) or Sogari *et al.* (2023), report higher levels of reluctance and lower levels of prior experience, as participation in such surveys is less dependent on prior interest in the topic.

Similarly, attitudes towards entomophagy are reported as generally positive in the articles included in this thesis. In particular, attitudes observed in Detilleux *et al.* (2026) were markedly positive. However, as noted in that study, these results cannot be generalised to the Belgian population as a whole due to the presence of selection bias. Nevertheless, they indicate that a segment of the population, albeit limited, appears sincerely enthusiastic about entomophagy, suggesting that the practice has potential for further development among one part of the population.

At the same time, positive attitudes primarily reflect a willingness or openness to consume insects rather than established and routine consumption practices. Even when insect consumption occurs, it often remains confined to specific contexts, such as tastings at events, experimental trials, social challenges among peers, or during travel (Tan *et al.*, 2015). This highlights the gap that may exist between favourable attitudes towards entomophagy or one-time consumption experiences and the actual integration of insect-based foods into regular food habits, as reported in several articles of this thesis (Detilleux *et al.*, 2021b, 2024a,b), as well as numerous other authors (House, 2016; Dupont *et al.*, 2020; Ardoin *et al.*, 2021; Modlinska *et al.*, 2021; Rehman *et al.*, 2024b). This attitude–behaviour gap appears to be a central challenge in Western contexts, suggesting that positive perceptions alone are insufficient to drive sustained dietary change. Several practical barriers may contribute to this gap, including limited product availability, higher prices compared with conventional foods, and a lack of familiarity with preparation methods or recipes. Taken together, these factors may hinder the transition from perceived readiness to the actual adoption of insect-based foods as part of regular consumption habits (House, 2016). However, beyond these practical constraints, emotional responses (particularly disgust) and the absence of culturally embedded consumption norms appear to constitute more persistent barriers to regular consumption (see further details below).

One of the articles included in this thesis also focused on young Belgians aged 9 to 17 (Detilleux *et al.*, 2021b). As in the other Belgian studies discussed in this thesis, respondents were relatively open to entomophagy: 90.1% had heard of the concept, 70.9% had already consumed insects, and 84.1% participated in a tasting of an insect-based falafel. Although no other Belgian studies specifically targeting children are available, European studies and the Belgian study by Caparros Megido *et al.* (2014), which included participants aged 0–18, provide points of comparison. In Belgium, awareness of entomophagy among young people increased markedly over time, from 26.7% in 2013 (Caparros Megido *et al.*, 2014) to 90.1% in the study included in this thesis, mirroring trends previously observed among adults. Recent studies also report high levels of awareness among children in other European countries, reaching up to 98.9% in Denmark (Erhard *et al.*, 2023), while similarly high awareness has been reported in France (Hémar-Nicolas *et al.*, 2022).

By contrast, reported experience of insect consumption was higher in Detilleux *et al.* (2021b) than in recent studies conducted in Denmark and France (ranging from 7.0% to 49.7%). These comparisons should nevertheless be interpreted with caution due to substantial differences in age ranges across studies: 9–17 years in (Detilleux *et al.*, 2021b); 9–13 years in (Erhard *et al.*, 2023); 7–10 years in (Guichard *et al.*, 2025);

8–13 years in (Hémar-Nicolas *et al.*, 2022); and 12–18 years in (Gallen *et al.*, 2025b). Age is known to influence acceptance of entomophagy and is therefore likely to explain part of the observed differences (see Chapter 1). As previously observed among adults, other sample characteristics, as well as differences in study design, are also likely to contribute to these variations (Ardoin *et al.*, 2021). Among these factors, national context appears to be particularly influential: even when restricting the sample in Detilleux *et al.* (2021b) to children aged 9–13, reported experience remained notably high (73.8%), still largely exceeding levels observed in Denmark for the same age group (49.7%) (Erhard *et al.*, 2023). In this respect, as already discussed throughout this thesis, Belgium can be considered a European pioneer in terms of the commercialisation of insect-based food products. Consequently, Belgian children have likely been more frequently exposed to such products than their Danish counterparts.

Beyond these quantitative findings, Detilleux *et al.* (2021b) and the existing literature suggest that children's reactions to entomophagy largely mirror those observed among adults. Initial responses are typically characterised by the perception of insects as inedible, with rejection grounded in reasons similar to those reported by adults (see below). Under these conditions, one of the recommendations formulated in Detilleux *et al.* (2021b) was that strategies aimed at promoting entomophagy could, in principle, be broadly similar for children and adults, although this assumption requires empirical validation. However, the study by Guichard *et al.* (2025) introduces important nuance to this observation. Although rejection is present in children, it appears to be less deeply rooted. Children often oscillate between curiosity and fear, with food neophilia and food neophobia coexisting simultaneously. As a result, their curiosity can be more easily stimulated, and they may be encouraged to taste insect-based foods (Guichard *et al.*, 2025).

It should also be noted that children are still in the process of developing their taste preferences and food-related reference points. This developmental stage likely makes them more receptive than adults to novel foods, such as edible insects, and consequently more likely to adopt new eating patterns (Guichard *et al.*, 2025).

Taken together, these findings underscore the importance of not overlooking younger populations in future research on entomophagy, as well as in the development of marketing and communication strategies aimed at promoting edible insects. In particular, children's openness to entomophagy appears especially relevant, as it may generate a dual impact: not only in the short term, by influencing their immediate social environment and encouraging family members to engage with insect-based foods, but also in the long term, by shaping future consumption patterns, given that dietary practices adopted during childhood are more likely to persist into adulthood (Kelder *et al.*, 1994; Thomson *et al.*, 2007; Sogari, 2015; Baldassarre *et al.*, 2016; Sogari *et al.*, 2017; Hémar-Nicolas *et al.*, 2022; Dubois *et al.*, 2025).

Since the beginning of this discussion section, the focus has primarily been on Belgian consumers who are positively disposed towards entomophagy, reflecting the dominant trend observed in the articles included in this thesis. However, consumer reluctance to eat insects is also evident in Belgium. Although such consumers were less represented in the studies included in this thesis, they appear far more frequently in other Belgian studies discussed above (Van Thielen *et al.*, 2018; Tzompa-Sosa *et al.*, 2023a; IPIFF, 2024). In the articles included in this thesis, such respondents mainly refused to eat insects because they considered this practice disgusting and not part of their culture (Detilleux *et al.*, 2024a,b). While the cultural dimension will be discussed more extensively in the following section, disgust is very frequently reported as a reason for refusing to consume insects in other Belgian studies (Van Thielen *et al.*, 2018; Tzompa-Sosa *et al.*, 2023b), as well as among European and non-European populations (Ruby *et al.*, 2015, 2019; Tan *et al.*, 2015; Sogari *et al.*, 2017, 2023; Menozzi *et al.*, 2017a; Orsi *et al.*, 2019; Castro *et al.*, 2019a; Lammers *et al.*, 2019; Barton *et al.*, 2020; Orkusz *et al.*, 2020; Videbæk *et al.*, 2020; Naranjo-Guevara *et al.*, 2020; Ribeiro *et al.*, 2022; Hémar-Nicolas *et al.*, 2022; Tzompa-Sosa *et al.*, 2023b; Zugravu *et al.*, 2023; Peksever *et al.*, 2024; Ranga *et al.*, 2024; Buongiovanni *et al.*, 2025; Park *et al.*, 2025; Sikora *et al.*, 2025; Tolve *et al.*, 2025; Gatzemeier *et al.*, 2025; Mariscal-Moreno *et al.*, 2025; Niimi *et al.*, 2025; Velchovska *et al.*, 2026).

From a theoretical perspective, food-related disgust has been conceptualised by Rozin *et al.* (1987) as a basic emotion characterised by revulsion at the prospect of orally incorporating an offensive object, particularly one perceived as contaminating. In this context, disgust can be understood as a form of food rejection driven by the "offensive properties" of an item, which lead individuals to anticipate that it will either taste unpleasant or potentially cause illness (Hamerman, 2016). Such objects are considered capable of rendering otherwise acceptable food unsuitable for consumption, even following minimal contact. As a basic emotion, disgust is associated with a characteristic facial expression, an action tendency involving distancing from the offensive object, a distinctive physiological manifestation (notably nausea), and a typical state of intense repulsion (Rozin *et al.*, 1987).

Beyond its immediate emotional expression, disgust sensitivity can be understood as a protective mechanism that generally serves to prevent the ingestion of potentially harmful substances, such as toxins or pathogens. This response is often triggered not only by the sensory properties of a food, but also by knowledge regarding its nature or history. In Western contexts in particular, insects are frequently associated with representations of dirt, death, disease, and contamination. Such associations may contribute to their cognitive categorisation as offensive objects, thereby eliciting disgust and reinforcing reluctance to consume them (Sogari *et al.*, 2023).

In the articles included in this thesis, disgust was assessed using a single-item ("Eating insects is disgusting"), as is common in other studies. However, disgust can also be evaluated using scales, including one specifically developed for entomophagy by La Barbera *et al.* (2020): the disgust subscale of the Entomophagy Attitude Questionnaire (Kröger *et al.*, 2022; Sogari *et al.*, 2023). Using such scales in Belgian studies would allow for a more nuanced investigation of disgust in this country, facilitating a better understanding and more effective strategies to promote the acceptance of edible insects.

In summary, the findings of this thesis provide an updated overview of awareness, attitudes, and consumption patterns regarding edible insects in Belgium, complementing previous studies of the general population. In addition, this work specifically examines youngsters, thereby contributing to the third and the sixth research questions of the thesis. The studies show that awareness is generally high, while acceptance and prior experience are more variable. Disgust and cultural considerations were identified as the main reasons for reluctance to consume insects, consistent with observations among adults in Belgium and in other contexts. Beyond addressing the research questions on Western youngsters, the results also open the way to the second objective discussed later in this discussion, highlighting the need to explore strategies to promote the adoption of insect-based foods and support their wider integration into Western diets.

2.3. Entomophagy and culture

As discussed in the previous sections relating to Gabon and Belgium, culture emerges as a central determinant in explaining variations in consumption patterns, not only between countries but also within a single national context (see the ethnic differences discussed above). The cross-cultural study conducted as part of this thesis is consistent with this perspective, showing that practices, assessed through reported experience of edible insect consumption, differed markedly between Gabon and Belgium. The study also revealed additional cross-national differences in knowledge and attitudes, notably in levels of acceptance and willingness-to-pay (WTP) (Detilleux *et al.*, 2024a).

Such differences have been widely documented in the cross-cultural literature on entomophagy reviewed in the Introduction (see **Table 1-3**). In particular, cultural variation in acceptance has received the greatest attention in the literature (Ruby *et al.*, 2015, 2019; Tan *et al.*, 2015; Cunha *et al.*, 2015; Hartmann *et al.*, 2015; Menozzi *et al.*, 2017b; Castro *et al.*, 2019b; Grasso *et al.*, 2019; Ghosh *et al.*, 2020; Ribeiro *et al.*, 2022; Tzompa-Sosa *et al.*, 2023a,b; Guiné *et al.*, 2024a,c; IPIFF, 2024; Mancini *et al.*, 2024; Cho *et al.*, 2025; Mara *et al.*, 2025; Park *et al.*, 2025; Ranga *et al.*, 2025). However, cross-cultural differences have also been identified with regard to knowledge (Tan *et al.*, 2015; Ghosh *et al.*, 2020; Hénault-Ethier *et al.*, 2020; Guiné *et al.*, 2022, 2023, 2024b; Rehman *et al.*, 2024a; Mara *et al.*, 2025) and practices (Hartmann *et al.*, 2015; Tan *et al.*, 2015; Ruby *et al.*, 2019; Sogari *et al.*, 2023; Guiné *et al.*, 2024c; IPIFF, 2024; Rehman *et al.*, 2024a; Mara *et al.*, 2025; Mariscal-Moreno *et al.*, 2025).

With respect to WTP, the cross-cultural study conducted as part of this thesis appears to be the first to examine this parameter comparatively across countries (Detilleux *et al.*, 2024a). Existing intercultural research has more commonly focused on willingness-to-buy (WTB), likewise identifying a cultural influence on purchase intention (Piha *et al.*, 2016; Gómez-Luciano *et al.*, 2019; Yaxin *et al.*, 2020; Ranga *et al.*, 2025). Nevertheless, these two factors are conceptually distinct, although both are related to attitudinal dispositions. WTP refers to the maximum monetary amount an individual is prepared to pay for a given good or service, thereby capturing a valuation threshold. By contrast, WTB reflects a stated readiness to purchase, without explicitly indicating a maximum price (Breidert, 2005; Bigliardi *et al.*, 2020).

Beyond knowledge, attitudes, and practices, cultural factors emerge as a key driver of the refusal to consume insects, as observed in both Gabon and Belgium and in other studies in the literature (Menozzi *et al.*, 2017a; Van Thielen *et al.*, 2018; Hémar-Nicolas *et al.*, 2022; Detilleux *et al.*, 2024a,b; Guichard *et al.*, 2025).

These findings underscore that culture not only plays a central role but also shapes multiple dimensions of the relationship between consumers and edible insects. As emphasised by Jayasinghe *et al.* (2025), culture can be understood as a set of shared meanings, norms and practices that are shaped and reshaped through social interaction. It includes both tangible and intangible components, such as ways of interacting, communicating and perceiving the world, as well as language, religion, cuisine and other practices transmitted across generations. Although dynamic and evolving, culture remains rooted in everyday life and influences what food is produced, considered appropriate and ultimately consumed (Jayasinghe *et al.*, 2025). In this respect, food cannot be reduced to a purely nutritional or economic good but is also an expression of identity, values and lifestyle (Enriquez *et al.*, 2022). The cross-cultural differences observed in knowledge, attitudes, and practices may therefore reflect deeper differences in how food is represented and understood within cultural identity.

Cultures establish implicit classificatory systems that define what is edible and what is not. Edibility is therefore not an intrinsic property of a food item but a socially constructed status, shaped by formal or informal prohibitions and food-related norms (Guichard *et al.*, 2025). In this perspective, the acceptance or rejection of edible insects cannot be fully explained by their objective characteristics, but must instead be understood as the outcome of culturally embedded classification systems. Insects occupy different positions within these cultural systems: integrated into traditional diets in some contexts, positioned outside accepted food boundaries in others. Cultural environments thus shape shared beliefs, moral values and ideas about what is considered acceptable cuisine, influencing attitudes and consumption patterns regarding edible insects (Phonthanukitithaworn *et al.*, 2023).

Among the various components of culture, religion may influence food acceptance by shaping dietary norms and perceptions of what is considered appropriate for consumption. Religious beliefs and practices can contribute to defining food-related classifications and taboos, although their content and significance vary across societies (Wormley *et al.*, 2022). However, despite its potential relevance, the role of religion in entomophagy acceptance remains relatively understudied. As discussed in Section 2.2 (Sociodemographic determinants), available evidence from Western countries generally indicates no significant effect of religious beliefs on the acceptance of insect-based foods, although the limited number of studies prevents definitive conclusions (Kröger *et al.*, 2022). In contrast, religion appears to play a more important role in some non-Western contexts, where dietary principles and religious interpretations may influence perceptions of insect consumption. For example, vegetarian practices associated with Hindu beliefs may contribute to the avoidance of animal-derived foods, including insects, whereas among Muslim populations, perceptions of insect consumption may vary depending on interpretations of religious rules and knowledge regarding their halal status. Indeed, interpretations of Islamic dietary rules regarding edible insects are not uniform (Kröger *et al.*, 2022; Anagonou *et al.*, 2023; Khatun et *al.*, 2025). Overall, these findings suggest that the influence of religion is not universal but depends on cultural context, religious interpretation and the extent to which religious norms are integrated into everyday food practices.

The relative influence of culture and individual-level determinants may depend on the degree of cultural acceptance. When a product is broadly accepted within a society, individual beliefs tend to guide consumption decisions. In contrast, where strong societal norms discourage consumption, refusal is more likely to be culturally anchored and relatively homogeneous (Castro *et al.*, 2019a).

Taken together, the different elements discussed above highlight the multidimensional role of culture in shaping the relationship between consumers and edible insects. **Figure 7-1** summarises the conceptual framework proposed in this thesis, illustrating how collective cultural factors contribute to shaping shared food classification systems, which in turn influence individual knowledge, attitudes and food practices related to insect consumption.

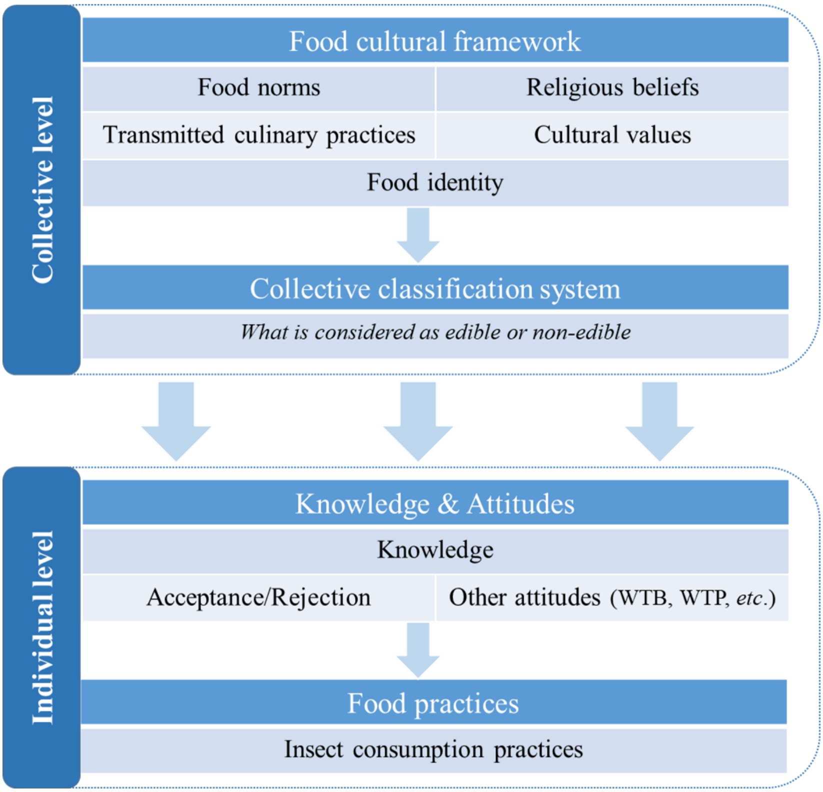

Figure 7-1. Multilevel conceptual framework of cultural influences on entomophagy.

Overall, culture can be understood as a framework that shapes how food is perceived, evaluated and consumed. It influences not only practices but also knowledge and attitudes towards edible insects. The cross-cultural differences identified in this thesis should therefore be interpreted as the result of broader cultural influences rather than isolated behavioural differences.

Surprisingly, in Detilleux *et al.* (2024a), the country considered non-traditional (Belgium) generally showed higher levels for most of the assessed parameters (*e.g.*, knowledge, acceptance) than the country identified as traditional (Gabon). This contrasts with patterns generally reported in the scientific literature on cross-cultural studies of edible insects (Hartmann *et al.*, 2015; Tan *et al.*, 2015; Castro *et al.*, 2019b; Sogari *et al.*, 2023; Tzompa-Sosa *et al.*, 2023a,b; Guiné *et al.*, 2024c; Mancini *et al.*, 2024; Yan *et al.*, 2024; Mariscal-Moreno *et al.*, 2025). However, this finding should be interpreted cautiously. As discussed earlier in this Discussion, it may reflect a need to reconsider the classification of Gabon as a traditional context, and it could also be influenced by the possibility that participants recruited in Belgium were somewhat more enthusiastic than the average population.

It should also be noted that a significant portion of the literature, including the present thesis, treats Western countries as a single, homogeneous cultural bloc (Ardoin *et al.*, 2021). However, this assumption is misleading, as significant differences exist between Western countries, even within Europe. Several studies have already highlighted such variations, showing that attitudes, knowledge and practices regarding edible insects can differ markedly from one European country to another (Piha *et al.*, 2016; Verneau *et al.*, 2016; Menozzi *et al.*, 2017b; Ribeiro *et al.*, 2022; Rehman *et al.*, 2024a; Ranga *et al.*, 2025).

To illustrate, Verneau *et al.* (2016) found that Danish consumers were more willing to consume edible insects than Italian consumers. The authors suggested that this contrast may be linked to differences in the strength and stability of national food cultures. Danish food culture has undergone considerable change in recent decades and is often described as relatively flexible in its culinary traditions. By contrast, Italian food culture is widely regarded as one of the most established in Europe, with a long-standing reputation for gastronomic and nutritional excellence. Individuals raised within a highly valued and deeply rooted food culture may therefore be less inclined to adopt novel or unconventional food products, including edible insects (Verneau *et al.*, 2016).

Such differences are also observed between regions within the same Western country. Several Italian studies have shown that consumers from southern Italy tend to be less willing to consume edible insects than those from other parts of the country, further illustrating that food cultures are not uniform even within national borders (Sogari *et al.*, 2019; Buongiovanni *et al.*, 2025).

Future research should therefore pay greater attention to these intra-Western differences rather than assuming cultural uniformity, in order to better capture the diversity of acceptance and consumption patterns across contexts (Kröger *et al.*, 2022).

In summary, the results of this thesis confirm the presence of cross-cultural differences in knowledge, attitudes, and practices related to edible insects, in line with the broader literature. In addition, the study identified a novel cross-national difference in WTP, whereas previous intercultural research has more commonly focused on differences in WTB. Taken together, these findings provide a clear response to the fourth research question of this thesis concerning the role of culture. They demonstrate that culture is a complex and multidimensional construct that substantially shapes the relationship between consumers and edible insects. Its influence operates across cognitive, attitudinal and behavioural dimensions, and varies not only between countries but also between regions within the same country. These findings thus reinforce the need to approach entomophagy not merely as a nutritional or sustainability issue, but as a practice shaped by cultural contexts.

3. Identifying social determinants and practical strategies for sustainable integration of edible insects into modern diets

3.1. Profile of Western willing consumers

In the introduction of this thesis, the profile of the Western willing consumer was described as a young, educated male (see **Figure 1-3**). Several recent studies have also identified this profile in Western countries (Buongiovanni *et al.*, 2025; Mara *et al.*, 2025; Tolve *et al.*, 2025), although some only confirmed certain aspects of it (Gallè *et al.*, 2025; Velchovska *et al.*, 2026). However, this profile was derived from trends observed in the majority of studies. Other research, including more recent studies, highlights different consumer profiles (Kröger *et al.*, 2022; Alhujaili *et al.*, 2023). For instance, Platta *et al.* (2025) found that gender had no impact on the acceptance of insects among Polish consumers. As their sample consisted of adults enrolled in higher education institutions in Poland, this absence of gender differences may reflect the influence of higher education in attenuating gender-based reluctance towards edible insects, as suggested by Velchovska *et al.* (2026). In contrast, Fountouli *et al.* (2025) reported that gender was the only demographic factor (among age, education level, and place of residence) influencing the acceptance of edible insects in Greece, with women being more willing to consume them than men. This finding, however, is based on a relatively small sample of 70 participants and should therefore be interpreted with caution.

In the research included in this thesis (Detilleux *et al.*, 2024b), gender emerged as a significant determinant of consumer acceptance. In this case, men appeared more willing to consume edible insects than women, which aligns with the dominant trends reported in Western literature. Conversely, age did not have a significant effect, contrasting with the general tendency in the literature to associate younger age groups with higher levels of acceptance (Detilleux *et al.*, 2024b). Although younger consumers are often portrayed as more open to entomophagy, an increasing number of studies point to the inconsistent role of age in shaping attitudes towards insect consumption. Such variability may be attributed to cultural context, generational perceptions of sustainability, and differences in food-related behaviours such as neophobia or novelty-seeking. For instance, younger individuals are often more curious and motivated by sustainability concerns, whereas older consumers may prioritise food safety, familiarity, and adherence to traditional food practices. Differences in values and risk perceptions are therefore likely to shape the effect of age on acceptance, contributing to the heterogeneity observed across studies (Velchovska *et al.*, 2026).

The study also identified the field of work as a factor influencing consumer acceptance, with respondents from Science and Technology disciplines being generally the most inclined to accept entomophagy (Detilleux *et al.*, 2024b). This notion of field of work, relatively uncommon in the literature, was conceptualised as a broad construct including both the current occupational sector of workers and the field of study of students, the latter reflecting their prospective professional domain. In the literature, research focusing on field of study typically examine potential differences between academic disciplines within a single occupational group, namely students (*e.g.*, medicine, sciences or humanities) (Menozzi *et al.*, 2017a; Platta *et al.*, 2025). In contrast, studies investigating occupation generally consider broader employment categories, such as students, office workers or self-employed, without distinguishing between specific fields within these groups (Woolf *et al.*, 2019; Lee *et al.*, 2023). By combining these perspectives, the concept of field of work makes it possible to analyse differences across domains within multiple occupational groups, including both students and workers, within a unified analytical framework.

As with other sociodemographic factors, results related to field of study and occupation are heterogeneous. With regard to field of study, a study conducted among Polish students found no significant effect of this variable on the acceptance of edible insects, whereas research carried out among students at the University of Parma in Italy reported a significant influence (Menozzi *et al.*, 2017a; Platta *et al.*, 2025). Beyond potential cultural differences, the way in which educational categories are defined may partly explain these contrasting results. In the Polish study, broad categories were used, with Natural sciences grouping together students from medical and health sciences, agricultural sciences, and natural and physical sciences. While such grouping may be justified as “fields unified by their empirical orientation and practical application”, it may also mask potential differences between subgroups (Platta *et al.*, 2025). In particular, students in agricultural and health-related fields may be more likely to have been exposed to information on entomophagy and its benefits, which is associated with more favourable attitudes (Detilleux *et al.*, 2024b). They may also be more engaged in health-conscious and sustainable dietary behaviours, as suggested by Menozzi *et al.* (2017a). As a result, their potentially more positive attitudes may be diluted when combined with other disciplines, thereby limiting the detection of significant differences. These findings highlight the importance of how educational categories are constructed when examining their relationship with food acceptance.

A similar methodological consideration applies to respondents’ occupation and may help explain contrasting findings. Woolf *et al.* (2019) found no effect of occupation, while Lee *et al.* (2023) reported a significant influence. In Woolf *et al.* (2019), the use of only two broad categories (*i.e.* students and others) may have hindered the detection of differences between subgroups. In addition, studies focusing on occupation typically rely on general employment categories, within which individuals from very different professional domains may be grouped together. For example, individuals classified as professionals may include both lawyers and agricultural engineers, despite potentially differing levels of exposure to information related to sustainability or food innovation. Consequently, these broad occupational categories may reflect underlying characteristics such as education level or income. This may limit their ability to capture the specific influence of professional activity on attitudes towards entomophagy.

In summary, establishing a profile of the Western willing consumer remains challenging, as sociodemographic factors often reflect a range of underlying determinants. For example, age may be associated with food neophobia or varying levels of concern for sustainability, while cultural context further shapes consumer attitudes, adding another layer of complexity. Nevertheless, some consistent patterns emerge from this thesis. Western willing consumers appear more likely to be male. In addition, and specifically addressing the fifth research question of this thesis, the findings suggest that consumers studying or working in fields where entomophagy or sustainable food alternatives are discussed are generally more willing to accept edible insects. The inclusion of field of work represents a novel contribution to the literature, capturing an intermediate dimension between field of study and occupation. Further research is needed to clarify its role and assess its relevance relative to other work-related factors. Although defining a consistent profile remains difficult, these insights provide valuable guidance for targeted communication strategies and may ultimately contribute to the development of an initial market base for edible insects.

3.2. Promotion strategies in Western countries

Strategies to promote the consumption of edible insects in Western countries, as summarised in **Table 1-4**, continue to be widely recommended in recent literature (Schomaker *et al.*, 2025). In particular, recent studies emphasise both informing consumers about entomophagy and its benefits (Barbosa *et al.*, 2025; Buongiovanni *et al.*, 2025; Gallen *et al.*, 2025a; Killough *et al.*, 2025; Nikravech *et al.*, 2025; Platta *et al.*, 2025; Sikora *et al.*, 2025; Willeke *et al.*, 2025) and promoting the use of insects in the form of flour (Buongiovanni *et al.*, 2025; Sikora *et al.*, 2025; Willeke *et al.*, 2025; Velchovska *et al.*, 2026).

However, evidence regarding the effectiveness of these strategies is inconsistent. For instance, Gatzemeier *et al.* (2025) observed no significant impact of providing information on the nutritional or environmental benefits of insect-based burgers on participants' willingness to try or purchase such products. A similar finding was reported by Brunner *et al.* (2025), where different types of information (nutritional, environmental, and taste-related) did not significantly influence interest in insect-based foods.

These contrasting findings suggest that the mere presentation of nutritional or environmental facts is often insufficient to alter negative perceptions of entomophagy. Emotional and sensory reactions also need to be addressed, while deeply rooted attitudes and real-life food experiences may exert a stronger influence than short-term informational efforts. In this context, strategies appear to be most effective when they are personalised, culturally sensitive, and implemented over the long term, particularly when supported by education and awareness campaigns highlighting health and environmental benefits (Brunner *et al.*, 2025; Velchovska *et al.*, 2026). This includes adapting both the communication approach and the type of information to consumers' psychological profiles and dietary patterns (*i.e.* omnivores, flexitarians and vegetarians) (Puteri *et al.*, 2023; Gallen *et al.*, 2025a; Platta *et al.*, 2025). Taken together, these findings indicate that information can facilitate the acceptance of insect-based foods, but only when it is targeted, contextualised, and delivered repeatedly (Puteri *et al.*, 2023; Brunner *et al.*, 2025; Gallen *et al.*, 2025a; Platta *et al.*, 2025; Velchovska *et al.*, 2026).

Overall, the effectiveness of promotion strategies therefore depends strongly on both context and implementation. Consequently, in Western countries, where anchored disgust and scepticism towards insects persist, isolated and uncoordinated efforts remain insufficient to promote insect-based foods (Sikora *et al.*, 2025).

The studies included in this thesis provide further empirical support for several of the approaches previously outlined in **Table 1-4**, while also offering important nuances regarding their scope and limitations.

More specifically, the results reported in Detilleux *et al.* (2024b) reinforce the relevance of positioning insect-based products within snack contexts, as participants identified this format as the most appropriate for consumption. Converging evidence from Detilleux *et al.* (2021b) among Belgian youngsters further supports this observation and also highlights the importance of savoury sensory profiles. In this study, insects were predominantly associated with salty foods, suggesting that such positioning is consistent with existing consumer expectations.

In addition, the findings from Detilleux *et al.* (2021b) support the importance of product form, as older participants (*i.e.* adolescents) expressed a preference for processed insect-based products, thereby reinforcing the relevance of incorporating insects in non-visible, transformed formats. The same study also highlights the effectiveness of tasting experiences as a means of influencing attitudes towards entomophagy.

However, the results from Detilleux *et al.* (2026) indicate that the impact of tasting varies across consumer segments. While beneficial for individuals with initially neutral or negative attitudes, tasting appears to have little additional impact on those who already hold positive perceptions of insect consumption. This finding underscores the importance of considering consumers' initial attitudinal profiles when implementing such approaches and further supports the idea that no single strategy is effective across all segments.

Beyond reinforcing several of the approaches identified in **Table 1-4**, the studies included in this thesis also relied on these approaches to interpret findings and to inform methodological design. For instance, in Detilleux *et al.* (2026), the selection of the insect-based food was guided by these considerations: a savoury muffin was chosen as a familiar snack product, aligned with expected flavour profiles, and designed to contain no visible insect cues. This illustrates how the approaches identified in the literature were not only examined empirically but also used as a basis for structuring the research and making sense of the observed results.

Taken together, these findings confirm the relevance of several approaches highlighted in **Table 1-4**, while also emphasising their conditional nature. They support the view that their effectiveness depends on factors such as consumer characteristics, prior attitudes, and product design, thereby reinforcing the need for targeted and context-sensitive implementation.

With regard to **Table 1-4**, two additional strategies were also investigated in the articles included in this thesis. The first aimed to identify the most appropriate time of day for the consumption of insect-based foods among Western consumers. Belgian respondents in Detilleux *et al.* (2024b) did not identify a specific moment as particularly suitable (among breakfast, lunch, dinner, and between meals), but rather identified breakfast as the least appropriate occasion for insect consumption.

As discussed in the study, this result likely reflects both the general perception of insects as salty foods and the Belgian context, where breakfast is typically associated with sweet foods, while other eating occasions are more commonly linked to salty foods (Detilleux *et al.*, 2024b).

However, this result remains highly context-dependent and is difficult to generalise across all Western countries. For instance, in the United Kingdom, salty breakfasts are far more common, and different results might therefore be expected. By contrast, in countries with similar consumption habits, such as France, generalisation may be more plausible, although replication studies remain necessary to confirm this.

Nevertheless, these findings provide valuable insights into the positioning of insect-based products. Based on the results of Detilleux *et al.* (2024b), avoiding breakfast as a target occasion appears particularly relevant in the Belgian context. More broadly, the time of day seems to act more as a constraint than as a lever for promoting insect consumption.

However, this interpretation remains hypothetical. To isolate the effect of time of day from that of the sweet–salty dimension, future research could involve offering both sweet and salty insect-based products at different times of the day. Such an approach would help determine whether the rejection of breakfast observed in Detilleux *et al.* (2024b) is driven by the temporal context itself or by associated flavour expectations.

The second additional strategy examined in this thesis was investigated in the study conducted by Detilleux *et al.* (2026). This study aimed to assess whether greater consumer involvement (through the preparation of an insect-based product) could influence attitudes towards entomophagy and sensory evaluations. Specifically, the study compared respondents who prepared and subsequently consumed an insect-based muffin with those who only consumed it.

Regarding its impact on attitudes, the results indicate that individual preparation did not have a significant effect (Detilleux *et al.*, 2026). This finding contrasts with the results reported by Saga (2025), in which Japanese higher education students who prepared pumpkin croquettes containing cricket powder reported more positive attitudes towards insects following the cooking experience.

One possible explanation for this difference lies in the initial attitudinal profiles of the participants. In Detilleux *et al.* (2026), respondents already held relatively positive attitudes towards edible insects, whereas participants in Saga (2025) initially exhibited less favourable perceptions. This suggests that preparation, similarly to tasting, may not further enhance already positive attitudes, but may instead be more effective for individuals with initially neutral or negative perceptions.

Taken together, these results suggest that the effectiveness of preparation as a strategy may depend strongly on consumers' initial attitudes, and further research involving more diverse attitudinal profiles is needed to confirm this effect.

However, the findings reported by Saga (2025) should be interpreted with caution. First, the observed positive effect of preparation was based on a very small sample (n = 5), which substantially limits the robustness of the conclusions. Second, the study was conducted in Japan, a context that differs from Western countries in terms of cultural familiarity with entomophagy. Although contemporary Japanese diets largely exclude insects, entomophagy has historical roots and remains present in some regions, which may have influenced participants' responses.

With regard to sensory evaluation, the study conducted as part of this thesis showed that individual preparation had a positive impact on participants' evaluations. As is the case for many other types of food, preparing insect-based products appears to elicit the "I cooked it myself" effect, described as the tendency for food preparation itself to enhance product evaluation (Dohle *et al.*, 2014; Detilleux *et al.*, 2026).

To the best of the author's knowledge, no additional studies have examined this effect in the context of edible insects since the writing of Detilleux *et al.* (2026). The only point of comparison therefore remains the study by Chow *et al.* (2021), which did not observe any significant impact of preparation on sensory evaluation.

As discussed in Detilleux *et al.* (2026), the absence of the "I cooked it myself" effect in Chow *et al.* (2021) may be explained by two main factors: the characteristics of the participants and the way in which the insects were presented [see Detilleux *et al.* (2026) for further details].

The preparation of insect-based foods therefore appears to represent an additional strategy that could complement those outlined in **Table 1.4**. As with these existing strategies, its effectiveness is likely to depend on the characteristics of the target audience, but also on other factors, such as how insects are incorporated and presented within recipes. However, given the very limited number of studies on this topic, further research under varying conditions is required to confirm these initial trends and hypotheses.

Another study also examined the preparation of insect-based foods in a domestic context, although participants were not provided with specific recipes or instructions. In this research, ten Norwegian households received a range of commercially available insect-based products (including whole insects, insect powders, and processed products) and were asked to incorporate them freely into their daily eating practices over a two-week period. The results indicate that, while insects could be relatively easily added to existing dishes, participants found it more difficult to use them as a central ingredient. Processed products, due to their similarity to familiar foods, were more readily integrated into existing eating routines. By contrast, participants were unable to clearly assign a culinary role to other forms of insects. For example, whole insects were mainly used as toppings, with their crunchy texture making them comparable to foods such as nuts, seeds, or croutons (Volden, 2026).

These findings suggest that, in cultural contexts where entomophagy is not traditionally embedded, consumers may find it challenging to position insects as a central component of meals, particularly in the absence of clear culinary references. This perspective complements the findings discussed above regarding the role of preparation and consumer involvement, while also highlighting the practical challenges associated with integrating insect-based foods into everyday eating practices.

Other innovative strategies have also been investigated in recent scientific literature and could potentially be integrated into those outlined in **Table 1-4**. These include sensory-based approaches (*e.g.*, auditory stimuli and multisensory experiences) (Marquis *et al.*, 2025), increased direct exposure to insects in their natural environment (Shiozawa *et al.*, 2025), the reframing of entomophagy through social media and influential role models (Acheampong *et al.*, 2025; Guichard *et al.*, 2025; Schomaker *et al.*, 2025), *etc*. Among these emerging approaches, the latter deserves particular attention given the growing influence of digital media on consumer behaviour, including food-related behaviours. Social media platforms may contribute to normalising edible insects by facilitating the dissemination of recipes, cooking demonstrations and positive consumption experiences through influencers and content creators, particularly among younger consumers (Acheampong *et al.*, 2025). Given the global reach of these platforms, similar approaches could also be relevant beyond Western contexts. In countries where entomophagy is already part of traditional food practices, such as Gabon, social media could contribute not only to promoting consumption but also to revalorising local practices, supporting knowledge transmission and presenting edible insects through more contemporary representations. However, evidence regarding their effectiveness remains mixed (Schomaker *et al.*, 2025). These contrasting findings reinforce the central idea developed throughout this section that the effectiveness of promotion strategies depends strongly on both context and implementation, including the credibility of the messenger, the target audience, and the way edible insects are presented.

In summary, the strategies presented in the introduction of this thesis are not exhaustive, and the literature continues to refine existing approaches while exploring new ones. Among these, the present thesis highlights two complementary insights.

First, positioning insect-based foods for breakfast appears less appropriate in the Belgian context, and potentially in other cultures with similar food habits. Second, encouraging consumers to prepare insect-based foods themselves emerges as a promising approach, particularly for enhancing sensory evaluation. These findings contribute to the identification of additional strategies addressing the seventh and eighth research questions of this thesis. However, the current evidence base remains limited, and further research across diverse contexts is needed to confirm their relevance and better define their conditions of effectiveness. More broadly, this section reinforces that no single strategy is universally effective. Their impact depends on multiple interacting factors, including cultural context, consumer characteristics, and implementation. Consequently, maximising effectiveness likely requires integrated and coordinated approaches combining multiple strategies and stakeholders.

4. General conclusion

Overall, this thesis contributed to advancing current knowledge on entomophagy in both traditional and non-traditional cultural contexts. It provided one of the first detailed insights into the consumption of edible insects in Gabon, documenting the diversity of edible species available to consumers and highlighting the characteristics of the current demand. This overview demonstrated that Gabon possesses a rich diversity of edible insects within its environment. However, despite this abundance, entomophagy does not appear to be as widespread as in certain neighbouring African countries. The potential for further development of this practice is therefore present, but additional research is required to better understand current practices, consumer perceptions and the opportunities and constraints associated with the development of the sector. At the same time, the thesis improved the understanding of consumer acceptance of edible insects in Western settings, particularly in Belgium, and explored the perceptions of Western youngsters towards edible insects, a population that remains under-investigated in the literature on entomophagy. At the beginning of this research project, edible insects were frequently presented as a food of the future. However, despite increasing visibility in Europe, they remain largely absent from everyday diets. For many Western consumers, insects are either a novelty consumed once as a challenge or a food category that is firmly rejected. This thesis confirms that acceptance is strongly constrained by cultural representations, food habits, and perceptions of appropriateness. Even when environmental or nutritional benefits are acknowledged, they are often insufficient to overcome disgust, neophobia, and the symbolic role of meat in Western diets. The transition towards insect consumption is therefore far more complex than the introduction of a new food product. As suggested by Rudy Caparros Megido in an interview with a Belgian media outlet, the European acceptance of sushi already took nearly a decade despite using familiar ingredients, whereas edible insects may require 20–25 years before reaching comparable social acceptability (Canal Zoom, 2025).

The current global context may also partly explain this slow development. Recent crises, including the COVID-19 pandemic, economic instability, and international conflicts, have shifted public priorities towards issues such as purchasing power, security and geopolitical uncertainty. In this context, environmental concerns, which constitute one of the main arguments used to promote entomophagy in Western countries, may temporarily play a less prominent role in public debate. Nevertheless, the thesis also identified a smaller but enthusiastic consumer segment that may constitute an initial market niche in the following years.

From a regulatory perspective, considerable progress has been achieved during the course of this thesis, particularly within the European Union, where new authorisations for edible insects have progressively been implemented under the Novel Foods framework. Similar developments are emerging in other parts of the world, including several African and Asian countries. However, important challenges remain. Regulatory frameworks still differ substantially between countries, creating barriers for international trade, slowing industrial development and potentially weakening consumer confidence. The establishment of clearer and more harmonised international standards concerning farming practices, processing methods, safety assessment and labelling would therefore represent an important step for the future development of the sector (Acheampong *et al.*, 2025; Gautam *et al.*, 2025; Pastrana-Pastrana *et al.*, 2026). Furthermore, current European legislation still limits some of the potential environmental advantages of insects, notably regarding the valorisation of organic side streams and food waste as rearing substrates within a circular economy approach. In this context, emerging regulatory approaches such as regulatory sandboxes could also offer interesting opportunities for the edible insect sector. By allowing controlled experimentation under regulatory supervision, such frameworks may facilitate the evaluation of innovative farming practices, circular economy models and environmental management strategies before broader regulatory implementation (Spranghers, 2025).

At the industrial level, the development of edible insect production also remains uncertain. Although important investments have been made in recent years, particularly in Western countries, the initial enthusiasm surrounding industrial insect farming has progressively been challenged by economic and technical constraints. Several major companies (*e.g.*, Agronutris and Ynsect in France, Enorm Biofactory in Denmark, Aspira Food Group in Canada, Inseco in South Africa, and Beta Hatch in the United States of America) have encountered significant economic difficulties or ceased their activities (RTBF, 2026). These developments illustrate the difficulty of translating the theoretical advantages of insect production into economically viable industrial models. Moreover, the highly vertically integrated business models adopted by some insect companies may have increased technological and operational complexity. Greater specialisation across the value chain, with companies focusing on farming, processing or final products, has been proposed as a potentially more resilient strategy (Dossey *et al.*, 2016). Nevertheless, high production costs, difficulties related to industrial scaling, limited market opportunities, regulatory constraints and uncertain consumer demand continue to hinder the development of the sector. Beyond economic viability, the alignment between current insect farming models and circular economy principles remains debated. Although insects are often promoted for their ability to convert organic waste into valuable biomass, Western industrial farms still make limited use of food waste as rearing substrates, relying instead on commercial feed or agricultural co-products that may also be suitable for direct consumption by other animals or humans. Consequently, when insects intended for human consumption are reared on conventional feed ingredients rather than waste streams, the potential contribution of insect farming to resource circularity may be substantially reduced. This limitation results from regulatory, nutritional, logistical and economic constraints. Nevertheless, insect farming could still contribute to more sustainable food systems under specific conditions. Environmental performance strongly depends on production parameters, including the insect species, rearing substrate, energy sources, production scale and technological optimisation. The use of waste-based substrates, regionalised circular feed supply chains, co-location of insect farms near industries generating suitable by-products, waste heat recovery and renewable energy sources have been identified as promising strategies to reduce environmental impacts. Similarly, valorisation of insect frass through biogas production could contribute to circular energy systems by generating heat that could be redirected to insect-rearing facilities. However, these conditions are not yet widely implemented in current Western industrial production systems, thereby limiting the environmental benefits often associated with insect farming (Biteau *et al.*, 2026; Ribeiro *et al.*, 2026). In addition, most investments within the insect sector are currently directed towards feed rather than food applications, reflecting the fact that insects are generally more easily accepted as feed ingredients than as direct food for humans (Ribeiro *et al.*, 2022; Biteau *et al.*, 2025). In comparison with edible insects, other alternative protein products, especially plant-based meat substitutes, currently appear to be more easily accepted by Western consumers (de Koning *et al.*, 2020; Wang *et al.*, 2024; Biteau *et al.*, 2025). Their resemblance to familiar foods and their compatibility with existing culinary practices may reduce the psychological and cultural barriers commonly associated with insect consumption. In this context, the integration of insects into Western diets remains a long-term challenge rather than an immediate transformation of food systems.

By studying Gabon and Belgium, this thesis confirmed the major role of culture in shaping knowledge, attitudes and practices related to insect-based foods, whilst also emphasising the influence of several sociodemographic factors, including gender and professional background. However, although culture emerged as a central determinant, the ways in which cultural norms, traditions and social representations influence food behaviour remain only partially understood. Likewise, the effects of sociodemographic determinants were not always consistent across populations and contexts, suggesting that consumer acceptance does not depend on a single factor, but rather on the interaction of multiple interconnected variables. Consequently, transferring conclusions from one cultural setting to another remains difficult, reinforcing the need for context-specific approaches in both research and market development.

Regarding strategies to promote entomophagy in Western contexts, research continues to explore new approaches and perspectives. Within the framework of this thesis, the findings highlighted the importance of contextual appropriateness and individual involvement in food preparation, showing that the acceptance of insect-based foods is closely linked to the broader social and situational environment in which consumption takes place. More broadly, this thesis reinforces the idea that no single strategy is universally effective, as their impact depends on multiple interacting factors, including cultural context, consumer characteristics and implementation. In addition, recent studies suggest that partial substitution strategies, such as incorporating insect-based ingredients into familiar products, may not necessarily lead to a real displacement of meat consumption, as insect products are often consumed as supplements or "add-ons" rather than central meal components (Volden, 2026). This issue may be particularly relevant when insect ingredients are incorporated into foods that are not traditionally meat-based, such as muffins or falafels, as explored in the tasting sessions conducted within this thesis, as well as in most currently available insect-based foods. In such cases, insect-based foods may be consumed in addition to existing animal protein intake rather than as genuine substitutes for meat, potentially limiting their expected environmental benefits. Moreover, these benefits depend on the products they replace. Although comparisons with meat are frequently used to highlight their sustainability potential, their greatest contribution is expected when they effectively substitute high-impact animal products rather than being consumed as additional protein sources. Furthermore, evidence indicates that technological substitution alone is insufficient, as meat consumption remains strongly embedded in sensory preferences, social norms, cultural identity and perceptions of nutritional necessity. Consequently, although such strategies may facilitate initial acceptance and willingness to try insect-based foods, they do not fundamentally challenge the dominant role of meat within Western diets. Broader societal changes involving education, food culture, public policies and social norms are therefore likely to be required, alongside measures addressing price structures, consumption norms and culinary practices (Siegrist *et al.*, 2023; Biteau *et al.*, 2025, 2026).

Finally, beyond the scope of this thesis, several important gaps remain in the edible insect sector, including long-term health effects, allergenicity, nutrient bioavailability, and microbiological safety. Further research is also needed on insect welfare and on the environmental sustainability of intensive insect farming systems. At the same time, technological developments such as automation, vertical farming, and improved processing may enhance efficiency and sustainability (Acheampong *et al.*, 2025; Gautam *et al.*, 2025). The future of edible insects in Western countries will therefore depend not only on consumer acceptance, but also on coordinated efforts between research institutions, industry stakeholders, and policymakers to build safe, viable, and coherent food systems (Acheampong *et al.*, 2025; Pastrana-Pastrana *et al.*, 2026).

At the same time, edible insects may still represent a relevant component of future food systems in both Western and non-Western contexts. In Western countries, they could contribute to reducing dependence on conventional livestock production and support current efforts to strengthen protein sovereignty and diversify protein sources. In other regions of the world, edible insects may also provide accessible sources of animal protein, create economic opportunities and contribute to local livelihoods.

However, as highlighted in the foreword of this thesis, edible insects should not be considered a universal solution to food-related challenges, but rather as one potential component of broader and more diversified strategies. In this context, it will remain essential to ensure that the development of the sector does not generate environmental, social or economic externalities that outweigh its expected benefits.

Ultimately, however, the future of edible insects will depend less on technical feasibility, nutritional value or environmental potential than on the capacity of food systems to redefine what is culturally acceptable as food.

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Chapter 8

Scientific communications

1. Publications

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2. Oral Communications

Detilleux L., Andres L. & Lebailly P., 2018. Les sources protéiques en aquaculture au Laos : cas des fermes modèles de vers de terre, XXXIVèmes Journées du Développement de l’ATM : L’émergence en question. Marqueurs et dynamiques du développement, Grenoble (France).

Detilleux L. & Occhetti F., 2022. Bugs on my plate: a journey between Belgium and Gabon, Terra Innovation Day 2022, Gembloux (Belgium).

3. Poster Communciations

Detilleux L., Le Luc A., Andres L., Dogot T., Francis F. & Caparros Megido R., 2021. In what context do you want to eat edible insects?, Insecta 2021, Magdeburg (Germany).

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Detilleux L., Le Luc A., Andres L., Dogot T., Francis F. & Caparros Megido R., 2022. Quality of edible insects seen by Belgian academics, Insects to Feed the World 2022, Québec City (Canada).

4. Master's thesis

Detilleux L., 2016. Comparative study of edible insect acceptance between Vietnam and Belgium and potentiality of cricket breeding in Southern Vietnam (Ho Chi Minh City).