UNIVERSITÀ DEGLI STUDI DI PADOVA
Department of Agronomy, Food, Natural resources, Animals and Environment

Second Cycle Degree (MSc)
in Italian Food and Wine

ENTOMOPHAGY:
CULTURAL HISTORY AND FUTURE PERSPECTIVES

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Everything is determined,
the beginning as well as the end,
by forces over which we have no control.
It is determined for the insect,
as well as for the star.
Human beings, vegetables, or cosmic dust,
we all dance to a mysterious tune,
intoned in the distance by an invisible piper.
-Albert Einstein

ABSTRACT

The primary aim of this dissertation is to trace the timeline of entomophagy from the antiquity to present and, in doing so, to individuate the landmarks of insect consumption across cultures and societies. This timeline will prove entomophagy as a very ancient practice which has fallen in disuse over the centuries in some societies for both environmental and anthropological reasons, as Marvin Harris said in one of his most famous books *Good to Eat* (1985).

Once clarified the historical and anthropological vista, I will try to explain how insects and insects-based products could be introduced in the Italian gastronomic background, based on Mediterranean diet pyramidal system: data about consumer behaviour will be analysed, and so believes about "novel foods" introduction on European common market. Further to that, there will be an attempt to investigate which might be the social and cultural limits resulting from this change.

The final part of the dissertation is an economic case-study with the aim of computing the possible price of a cricket-based products line, supposing it will be sold in a closer future in the Italian supermarkets: the assessment will also include a utility analysis.

The dissertation will be introduced by a technical chapter on veterinary and food safety issues, with the objective to give a scientific definition of "insect", to define nutritional aspects and to understand what the advantages and risks of insects re-introduction in contemporary human diet could be.

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INTRODUCTION

The aim of this dissertation is to trace the timeline of entomophagy to understand:

a) which were the turning points of edible insects consumption;
b) the reasons of changes in the implementation of the practice over time;
c) which could be the future of this habit, especially in Italy, a country considered one of the main ambassadors of the Mediterranean diet.

The methodological frame for such an inquiry is provided by historical and cultural anthropology, with particular reference to the core issues debated in the "Food History, Anthropology and Society" classes, where concepts related to Italian food and wine history and sociological background, taste, quality and cultural heritage were presented. It follows that an anthropological analysis, whose primary aim is to understand the various human behaviour facets, becomes the best way to provide an innovative explanation of this controversial dietary practice, something going beyond the mere nutritional or ecological analysis. As for the desire to write about entomophagy, my hope is to contribute the current database with useful material from the anthropological and social point of view.

Entomophagy (from Greek ἔντομον, "insect", and φαγεῖν, "to eat") is the consumption of insects by humans and is practiced in several countries around the world but predominantly in parts of Asia, Africa and Latin America. It is deemed as a dietary regimen which could be obligate or facultative: from the ecological point of view it is a practice of predation, very common in a lot of animals, especially birds, while from the anthropological perspective this practice is common in many populations, based on particular preferences or trends, or even on the necessity of providing a protein supplement in the normal diet.

Yde Jongema of WUR (Wageningen University & Research) conducted a literary review which included Western countries[1] and temperate regions and listed 2,111 edible insect species worldwide as of April 2017. Globally, the most common insects consumed are beetles. This is not surprising, given that such group contains about 40% of all known insect species. The consumption of caterpillars, especially popular in sub-Saharan Africa, is estimated at 18%. Bees, wasps and ants come in third at 14% (such insects are especially common in Latin America). Following these there are grasshoppers, locusts and crickets (13%); cicadas, leafhoppers,

[1] The word "Western" is used for the sake of simplicity: it is for point out European countries, North America countries (USA and Canada) and Oceanian countries (Australia and New Zealand).

planthoppers, scale insects and true bugs (10%); termites (3%); dragonflies (3%); flies (2%); and other orders (Jongema, 2017).

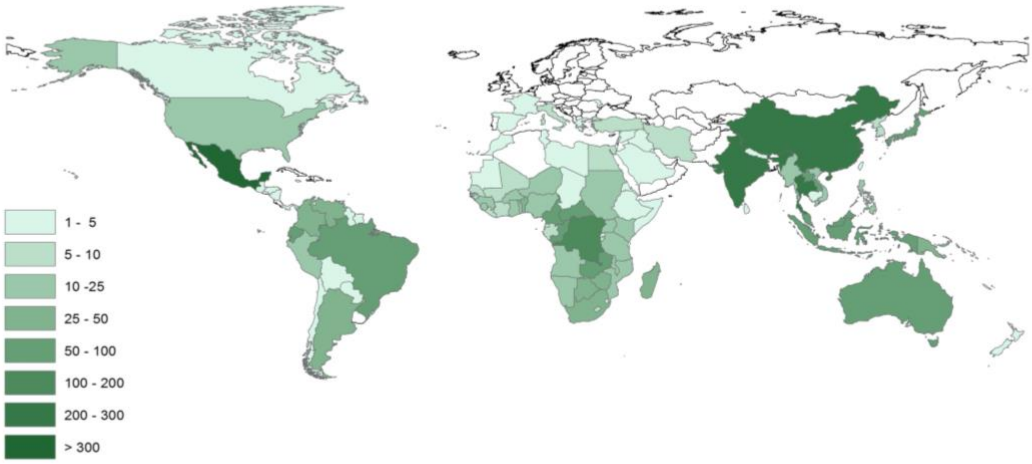

Figure 1: Recorded number of edible insect species, by country (Jongema, 2017)

Insects supplement the diets of approximately 2 billion people and have always been part of human diet. However, it is only recently that entomophagy has captured the attention of the media, research institutions, chefs and other members of the food industry and legislators. Estimations about population growth say that by 2050 there will be over 9 billion people to feed on planet Earth. In view of the current food insecurity situation prevailing in many developing countries, insects have lately received wide attention as a potential alternate major source of proteins (Makkar et al., 2014, pag. 3).

Following increasing income, urbanization, environment and nutritional concerns and other anthropogenic pressures, the global food system is undergoing a profound change. There has been a major shift to diets with increased consumption of animal products, and this change is likely to continue in the coming decades (Makkar et al., 2014, pag. 3). The demand for meat and milk is expected to be 58% and 70% higher in 2050 than their levels in 2010 and a large part of this increase will originate from developing countries (FAO, 2011).

The use of insects as food and feed, according to the Food and Agriculture Organization of the United Nations (FAO), has many environmental, health and social/livelihood benefits:

- insects have a high feed conversion efficiency (the “feed-to-meat” conversion rate is how much feed is needed to produce a 1 kg increase in weight);

- the production of greenhouse gases by most insects is likely to be lower than that of conventional livestock and they use significantly less water;
- insects can feed on bio-waste, such as food and human waste, compost and animal slurry, and can transform this into high-quality protein that can be used for animal feed
- insects farming is less land-dependent than conventional livestock farming;
- insects provide high-quality protein and nutrients comparable with meat and fish; they are also high in fatty acids, fibre and micronutrients such as copper, iron and magnesium;
- insects pose a low risk of transmitting zoonotic diseases (diseases transmitted from animals to humans) such as like H1N1 (bird flu) and BSE (mad cow disease);
- insects can be gathered in the wild, cultivated, processed and sold by the poorest members of society, such as women and landless people in urban and rural areas: these activities can improve diet and provide cash income;
- insect harvesting and farming can provide entrepreneurship opportunities in developed, transitional and developing economies;
- insects can be processed for food and feed relatively easily: some species can be consumed whole.

It is also important to consider the negative aspects about edible insects consumption such as the unhealthy levels of heavy metals, comparable to that of shrimps.

From January 1st, 2018, within the EU it is possible to market edible insects as food, thanks to Reg. (EU) 2283/2015 on "novel foods"[2]. According to this regulation, edible insects fall in the definition of "novel foods" because they are considered "new" compared to ingredients and foodstuffs traditionally used. Other examples of "novel foods" include new sources of vitamin K (menaquinone) or extracts from existing food (Antarctic Krill oil rich in phospholipids from *Euphausia superba*), agricultural products from third countries (e.g. chia seeds, noni fruit juice), or food derived from new production processes (e.g. UV-treated food as milk, bread, mushrooms and yeast). The impact this Regulation had on the market was significant: new specialised firms were born, and supermarkets are now starting to commercialise insect-based

[2] "Novel Food" is defined as food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the first Regulation about it came into force. "Novel Food'" can be newly developed, innovative food, food produced using new technologies and production processes, as well as food which is or has been traditionally eaten outside of the EU.

products to a wide range of consumers. However, in Italy there is still no a clear regulation about edible insects. Although they can be purchased on specific websites from other European and non-European countries, insects cannot be produced and sold as food on the Italian territory, but merely as feed. This drab legislative framework, at the moment, does not permit Italian consumers to interact freely with this gastronomic world, which could be one of the future generations nourishment lifeline.

1. TECHNICAL ASPECTS

1.1 THE *INSECTA* CLASS

The English noun insect derives from Latin *insectum*, a compound made up by the preposition *in* and *sectum*, the neuter perfect passive participle of *secō* ("to cut off; to cleave; to divide"): hence its meaning is "split into sections". Insects are hexapod invertebrates, and the largest group within *Phylum Arthropoda*. They include:

- Subphylum *Trilobitomorpha*
  - Trilobita (extinct)
- Subphylum *Chelicerata*
  - Euchelicerata (arachnids, xiphosurans, etc.)
  - Pycnogonida (sea spiders)
- Subphylum *Myriapoda*
  - Chilopoda (centipedes)
  - Diplopoda (millipedes)
  - Pauropoda (sister group to millipedes)
  - Symphyla (resemble centipedes)
- Subphylum *Crustacea*
  - Branchiopoda (brine shrimps, etc.)
  - Remipedia (blind crustaceans)
  - Cephalocarida (horseshoe shrimps)
  - Maxillopoda (barnacles, copepods, fish lice, etc.)
  - Ostracoda (seed shrimps)
  - Malacostraca (lobsters, crabs, shrimps, etc.)
- Subphylum *Hexapoda*
  - Entognatha (springtails, etc.)
  - Insecta (insects)

Phylum Arthropoda are the largest among clusters of animals that live on earth, including over one million species, equivalent to 5/6 of the entire animal kingdom. The total number of extant species is estimated at between six and ten million, so potentially over 90% of the animal life forms on earth are insects. They are believed to be among the oldest landmass colonisers, since insects fossils have been dated from the Devonian[3]. The leading role insects have in landmass colonisation, including any environment where there is organic matter, from over 300 million years is due to the heterogeneity of their morphology, anatomy, biology and ethology. Consequently, insects are organisms that, in a positive or negative way, have a close relationship with humans and their activities (*vide infra* §1.1.2): they condition, more or less directly, human economy, diet, habits and health.

1.1.1 DISTINGUISHING FEATURES OF INSECTS

The main characteristics of insects are:

- bilateral symmetry;
- chitinous exoskeleton;
- segmented body (a three-part body composed by head, thorax and abdomen);
- three pairs of jointed legs.

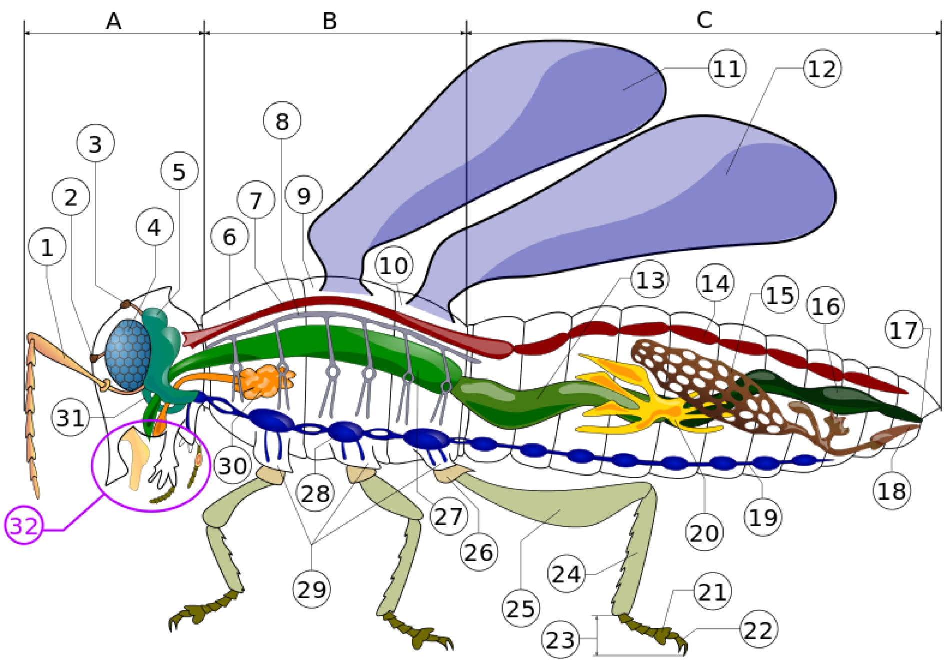

Figure 2: Insect morphology **A** – Head; **B** – Thorax; **C** - Abdomen
1. Antenna 2. Ocelli (lower) 3. Ocelli (upper) 4. Compound eye 5. Brain (cerebral ganglia) 6. Prothorax 7. Dorsal blood vessel 8. Tracheal tubes (trunk with spiracle) 9. Mesothorax 10. Metathorax 11. Forewing 12. Hindwing 13. Mid-gut (stomach) 14. Dorsal tube (Heart) 15. Ovary 16. Hindgut (intestine, rectum & anus) 17. Anus 18. Oviduct 19. Nerve chord (abdominal ganglia) 20. Malpighian tubes 21. Tarsal pads 22. Claws 23. Tarsus 24. Tibia 25. Femur 26. Trochanter 27. Fore gut (crop, gizzard) 28. Thoracic ganglion 29. Coxa 30. Salivary gland 31. Suboesophageal ganglion 32. Mouthparts
(source: www.wikipedia.org, 2005)

[3] The Devonian is a geologic period and system of the Paleozoic, spanning 60 million years from the end of the Silurian, 419.2 million years ago, to the beginning of the Carboniferous, 358.9 million years ago. It is named after Devon, England, where rocks from this period were first studied.

The exoskeleton is a more or less rigid coating which covers insect body, providing defence, isolation and support to internal organs and tissues. It is divided into numerous sclerites, joined by less-sclerotized, membranous regions or sutures, whose guarantee flexibility. It is made up by two layers, one lifeless and one alive: the cuticle and the epidermis. Cuticle is made up by epicuticle, which is a thin and waxy water-resistant outer layer and contains no chitin, and by procuticle, which is chitinous, thicker and itself composed by endocuticle (inner layer) and exocuticle (outer layer). This exocuticle is greatly reduces in many insects during their larval stages; it is also reduced in soft-bodied adult insects. Epidermis is the alive layer whose secretes most of the cuticle components: these substances are carried through small channels, which cross all of the layers area.

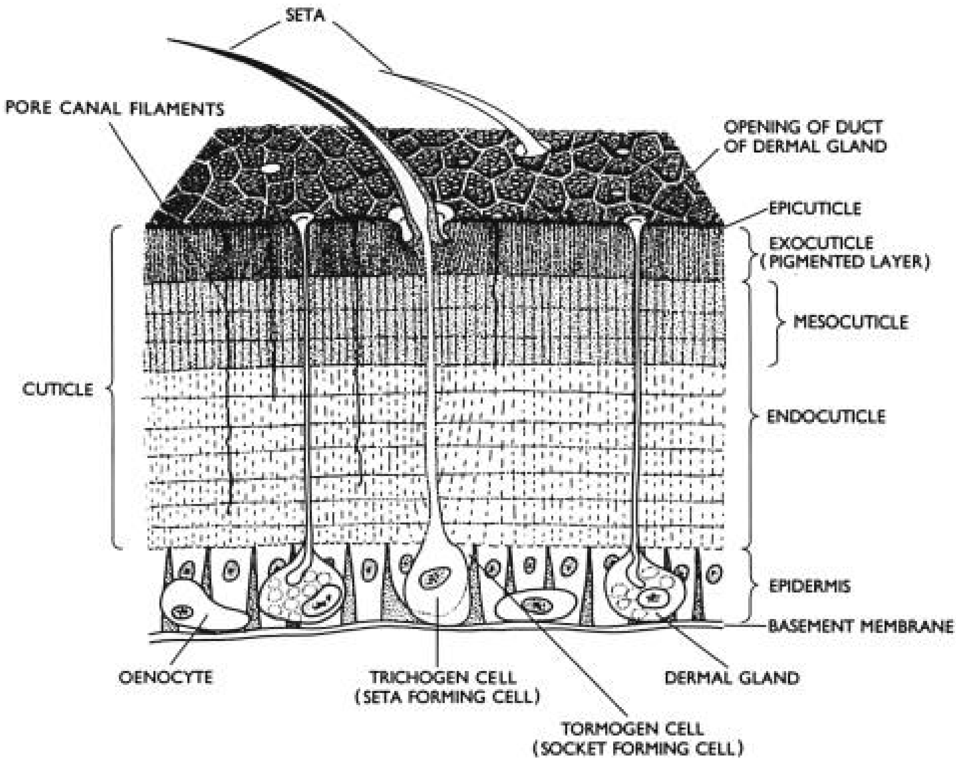

Figure 3: Insect integument section (source: www.sciencedirect.com, 1980)

Insects segmented body is composed by head, thorax and abdomen. The head is enclosed in a hard, heavily sclerotized, unsegmented, exoskeletal head capsule, or epicranium, which contains most of the sensing organs, including antennae, ocellus or eyes, and the mouthparts. The thorax is a tagma composed of three section: prothorax, mesothorax and metathorax. The anterior segment, closest to the head, is the prothorax, with the major features being the first pair of legs and the pronotum. The middle segment is the mesothorax, with the major features being the second pair of legs and the anterior wings. The third and most posterior segment, abutting the abdomen, is the metathorax, which features the third pair of legs and the posterior wings. Each segment is delineated by an intersegmental suture and has four basic regions: the dorsal surface is called the tergum, to distinguish it from the abdominal terga; the two lateral regions are called the pleura and the ventral aspect is called the sternum. The abdomen is the largest tagma of the insect, which typically consists of 11-12 segments and is less strongly sclerotized than the head or thorax. The arthropod leg is a form of jointed appendage of arthropods, usually used for walking. Many of the terms used for arthropod leg segments are of Latin origin: coxa (hip), trochanter, femur, tibia, tarsus and pretarsus. Associated with the leg itself there are various sclerites around its base: their functions are articular and have to do with how the leg attaches to the main exoskeleton of the insect. Such sclerites differ considerably between unrelated insects.

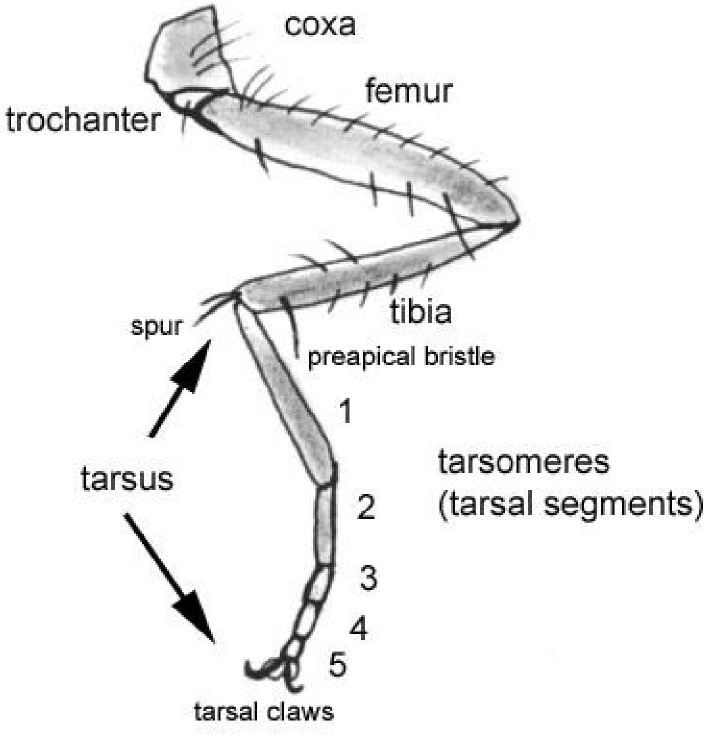

Figure 4: Diagram of a typical insect leg (source: www.buguide.net, 2007)

1.1.2 RELATIONSHIP TO HUMANS

Many insects are considered pests by humans. This classification includes those that are parasitic (e.g. bed bugs), transmit disease (e.g. mosquitos), damage structures (e.g. termites) or destroy agricultural goods (e.g. locusts). Despite the large amount of effort focused at controlling insects, human attempts to kill pests with insecticides can backfire. If used carelessly, the poison can kill all kind of organisms in the area, including insects' natural predators, such as birds, mice and other insectivores. The effects of DDT use exemplify how some insecticides can threaten wildlife beyond intended population of pest insects. Although pest insects attract the most attention, many insects are beneficial to the environment and to humans. Some insects like wasps, bees, butterflies and ants, pollinate[4] flowering plants: this greatly increases plants ability to cross-pollinate, which maintains and possibly even improves their evolutionary fitness. This ultimately affects humans since ensuring healthy crops is a critical to agriculture. In fact, a serious environmental problem is the decline of population of pollinator insects, and several species are now cultured primarily for pollination management in order to have enough pollinators in the field, orchard and greenhouse at bloom time. Insects are also used in medicine, for example fly larvae were formerly used to treat wounds to prevent or stop gangrene, as they would only consume dead flesh. Recently, insects have also gained attention to potential sources of drugs and other medicinal substances.

But the attention for insects received by medical sector is nothing if compared to the one given by the world food sector. In the last few years, indeed, a kind of rediscovery of the practice of eating insects has occurred: the scientific community made a huge effort in order to promote edible insects consumption, supporting it as a sustainable and safe dietary practice. The primary goal, which is carried out by the Food and Agriculture Organization of the United Nations (FAO) above all, is to find an alternative source of nourishment for human beings in anticipation of world population growth, expected for the coming years, and climate changes (*vide infra* §3.1). In some cultures, insects such as deep-fried cicadas, are considered to be delicacies, whereas in other places they are part of the normal diet. Insects have a high protein content for their mass, so they are considered as a potential major source of protein in human nutrition. In most first-world countries, however, entomophagy is taboo (*vide infra* §2.2.1). Since it is impossible to eradicate pest insects from the human food chain, they are inadvertently present in many foods, especially grains. Food safety laws in many countries do not prohibit insects in foods, but rather limit their quantity (*vide infra* §1.3). According to cultural anthropologist Marvin Harris, the eating of insects is taboo in cultures that have other protein sources such as fish or livestock (*vide infra* §2.3.1). Due to the abundance of insects and

[4] Pollination is the transfer of pollen from a male part to a female part of a plant, later enabling fertilization and the production of seeds, most often by an animal or by wind.

a worldwide concern of food shortages, FAO considers that the world may have to regard the prospects of eating insects as a food staple.

1.2 DIETARY ISSUES

As has already been said, entomophagy has countless advantages in terms of sustainability and social welfare: one of the main FAO objectives is to raise awareness about edible insects consumption in first-world countries, in order to let them see this perspective from a different point of view. The purpose is to find alternative solutions to livestock production for human consumption, one of the practices which releases more carbon dioxide and other greenhouse gases in the atmosphere (*vide infra* §3.1). The livestock sector requires a significant amount of natural resources and is responsible for about 14.5% of total anthropogenic greenhouse gas emissions (Grossi et al., 2019, pag. 69). The most important greenhouse gases from animal agriculture are methane and nitrous oxide. Methane, mainly produced by enteric fermentation and manure storage, is a gas impacting on global warming 28 times higher than carbon dioxide. Nitrous oxide, arising from manure storage and the use of organic/inorganic fertilizers, is a molecule with a global warming potential 265 times higher than carbon dioxide (Grossi et al., 2019, pag. 69). Vegan diet too, when compared with other dietary practices as Mediterranean or vegetarian diet, seems to be not associated with significantly lower environmental footprints. A likely explanation might be that, while unprocessed plant-based foodstuffs usually replace animal-based products in hypothetical vegetarian and vegan diet, the real plant-based diets are instead characterized by industrially highly processed plant-based meat and dairy substitutes (e.g. seitan burger and soy yoghurt) (Rosi et al., 2017, pag. 7). From these assumptions, there seems to be a clear need to find alternative dietary patterns, in order to reduce common feeding habits environmental footprints.

1.2.1 NUTRITIONAL VALUES

The nutritional values of edible insects are highly variable, not least because of the wide variety of species: even within the same group of edible insect species, value may differ depending on the metamorphosis stage[5], the habitat and the diet. Like most foods, preparations and

[5] Metamorphosis in insects is the biological process of development all insects must undergo. There are two forms of metamorphosis: incomplete metamorphosis (hemimetabolous insects) and complete metamorphosis (holometabolous insects).

processing methods applied before consumption will also influence nutritional composition. Because of their nutritional value, they are a still highly significant food source in some culinary cultures: FAO is making attempts to compile precise data on their composition, in order to put them in The International Network of Food Data System (INFOODS)[6].

By the late 20th century, scientists started to gather data about insects nutritional values in order to compile the first databases. Ramos Elourduy and his colleagues analysed 78 edible insect species from Oxaca state in Mexico and determined that caloric content was 293-726 kilocalories per 100 g of dry matter. It goes without saying that the actual value varies depending on insect type: the following table presents energy values expressed in kilocalories per 100 g fresh weight of selected wild and farmed insects worldwide.

Location	Common name	Scientific name	Energy content (kcal/100 g fresh weight)
Australia	Australian plague locust, raw	*Chortoicetes terminifera*	499
Australia	Green (weaver) ant, raw	*Oecophylla smaragdina*	1 272
Canada, Quebec	Red-legged grasshopper, whole, raw	*Melanoplus femurrubrum*	160
United States, Illinois	Yellow mealworm, larva, raw	*Tenebrio molitor*	206
United States, Illinois	Yellow mealworm, adult, raw	*Tenebrio molitor*	138
Ivory Coast	Termite, adult, dewinged, dried, flour	*Macrotermes subhyalinus*	535
Mexico, Veracruz State	Leaf-cutter ant, adult, raw	*Atta mexicana*	404
Mexico, Hidalgo State	Honey ant, adult, raw	*Myrmecocystus melliger*	116
Thailand	Field cricket, raw	*Gryllus bimaculatus*	120
Thailand	Giant water bug, raw	*Lethocerus indicus*	165
Thailand	Rice grasshopper, raw	*Oxya japonica*	149
Thailand	Grasshopper, raw	*Cyrtacanthacris tatarica*	89
Thailand	Domesticated silkworm, pupa, raw	*Bombyx mori*	94
The Netherlands	Migratory locust, adult, raw	*Locusta migratoria*	179

Table 1: Energy values (kcal/100 g fresh weight) for edible insects worldwide (source: FAO, 2013)

As for the calories the protein content changes significantly between different orders. Xiaoming et al. (2010) evaluated the protein content of 100 species of insect orders: it was in

[6] In 1984 FAO established the INFOODS with the aim to stimulate and coordinate efforts to improve the quality and worldwide availability of food analysis data and to ensure that all people in different parts of the world can obtain food composition and consumption at many levels.

the range 13-77% of dry matter and there was a large variation between and within insect orders.

Insect order	Stage	Range (% protein)
Coleoptera	Adults and larvae	23 – 66
Lepidoptera	Pupae and larvae	14 – 68
Hemiptera	Adults and larvae	42 – 74
Homoptera	Adults, larvae and eggs	45 – 57
Hymenoptera	Adults, pupae, larvae and eggs	13 – 77
Odonata	Adults and naiad	46 – 65
Orthoptera	Adults and nymph	23 – 65

Table 2: Crude protein content, by insect orders (source: Xiaoming et al., 2010)

The protein content of edible insects also varies strongly by species. Some insects compare favourably with mammals, reptiles and fish. Protein content also depends on the feed (e.g. vegetables, grains or waste). Grasshoppers in Nigeria that are fed with bran, which contains high levels of essential fatty acids, have almost double the protein content of those fed on maize. The protein content of insects also depends on the metamorphosis stage (Ademolu et al. 2010): adults usually have higher protein content than instars.

Insect stage	Gram protein/100 g fresh weight
Instar:	
First	18.3
Second	14.4
Third	16.8
Fourth	15.5
Fifth	14.6
Sixth	16.1
Adult	21.4

Table 3: Variation in insect protein along subsequent metamorphosis phases of the variegated grasshopper, *Zonocerus variegatus* (raw), Ogun state, Nigeria (source: Ademolu et al., 2010)

In some insect species, amino acids like lysine, tryptophan and threonine, which lack in some cereal proteins which are key staples in diets around the world, are instead very well represented. Several caterpillars of the *Saturniidae* family, palm weevil larvae and aquatic insects have amino acid scores for lysine higher than 100 mg amino acid per 100 g crude protein. Yet in order to make recommendations regarding the use of edible insects as food enrichments in diets, it is important to look at traditional diets in their entirely, and in particular at staple foods, and to compare their nutritional quality of edible insects locally available in the region.

Edible insects are a considerable source of fat too. They frequently contain the essential linoleic and α-linoleic acids. Given that in recent times greater attention has been paid to the potential deficient intake of omega-3 and omega-6 fatty acids[7], it turned out that insects could play an important role, in particular in landlocked developing countries with lower access to fish food sources, by suppling these essential fatty acids to local diets. The fatty acid composition of insects appears to be influenced by the plants on which they feed (Bukkens, 2005), but the presence of unsaturated fatty acids will also give rise to rapid oxidation of insect food products during processing, causing them to go rancid quickly.

Edible insect species	Fat content (% of dry matter)	Composition of main fatty acids (% of oil content)	SFA, MUFA or PUFA1
African palm weevil (*Rhynchophorus phoenicis*)	54%	Palmitoleic acid (38%)	MUFA
		Linoleic acid (45%)	PUFA
Edible grasshopper (*Ruspolia differens*)	67%	Palmitoleic acid (28%)	MUFA
		Linoleic acid (46%)	PUFA
		α-Linolenic acid (16%)	PUFA
Variegated grasshopper (*Zonocerus variegates*)	9%	Palmitoleic acid (24%)	MUFA
		Oleic acid (11%)	MUFA
		Linoleic acid (21%)	PUFA
		α-Linolenic acid (15%)	PUFA
		γ-Linolenic acid (23%)	PUFA
Termites (*Macrotermes* sp.)	49%	Palmitic acid (30%)	SFA
		Oleic acid (48%)	MUFA
		Stearic acid (9%)	SFA
Saturniid caterpillar (*Imbrasia* sp.)	24%	Palmitic acid (8%)	SFA
		Oleic acid (9%)	MUFA
		Linoleic acid (7%)	PUFA
		α-Linolenic acid (38%)	PUFA

Table 4: Fat content and randomly selected fatty acids of several edible insect species consumed in Cameroon (source: Womeni et al., 2009)

As mentioned above, in insects, metamorphic stage and diet influence nutritional values: the mineral and vitamin contents of edible insects described in the literature are highly variable

[7] Fatty acids are categorised in saturated fatty acids (often found in animal products and tropical oils), unsaturated fatty acids (mostly present in vegetable oils, nuts and seafood) and essential fatty acids which cannot be synthesized in human body, so they must be obtained from the diet.

across species and orders. Usually, consumption of the entire insect body generally elevates nutritional content: studies on small fishes suggested that consuming the whole organism – including all tissues – is a better source of minerals and vitamins than the consumption of fish fillets; in much the same way, consuming the entire insect is expected to provide higher micronutrient content than eating individual insect parts. Edible insects are undeniably rich sources of iron and zinc: most of them boast equal or higher iron[8] and zinc[9] contents than beef (Bukkens, 2005). Vitamins essential for stimulating metabolic processes and enhancing immune system functions are present in most edible insects: thiamine (vitamin B1) ranges from 0,1 mg to 4 mg per 100 g of dry matter and riboflavin (vitamin B2) ranges from 0,11 mg to 8,9 mg per 100g of dry matter. Vitamin B12 occurs only in food of animal origin and is well represented in mealworm larvae, *Tenebrio molitor* (LINNAEUS, 1748) (0,47 µg per 100 g) and house crickets, *Acheta domesticus* (LINNAEUS, 1758) (5,4 µg per 100 g in adults and 8,7 µg per 100 g in nymphs). Retinol and β-carotene (vitamin A) have been detected in some caterpillars, but their levels are less than 20 µg per 100 g and less than 100 µg per 100 g in some species as mealworm larvae, super worms and house crickets, so we can conclude that generally insects are not the best source of vitamin A. The vitamin E content in some species is also relatively high.

Insects contain significant amounts of fibre, as measured by crude fibre, acid detergent fibre and neutral detergent fibre. The most common form of fibre in insects is chitin[10], an insoluble fibre derived from their exoskeleton. Finke (2007) estimated the chitin content of insect species raised commercially as food for insectivores and found it to range from 2,7 mg to 49,8 mg per kg (fresh) and from 11,6 mg to 137,2 mg per kg (dry matter).

1.2.2 COMMON DIETARY PRACTICES AROUND THE WORLD

To people living in Europe and North America, edible insects are mostly perceived as disgusting, and entomophagy is considered a curiosity at best. Yet, for these same people, other invertebrate animals, such as oysters, snails, crayfish and lobsters (even these belonging to

[8] Beef has an iron content of 6 mg per 100 g of dry weight, while the iron content of the mopane caterpillar, for example, is 31–77 mg per 100 g. The iron content of locusts (*Locusta migratoria* LINNAEUS, 1758) varies between 8 and 20 mg per 100 g of dry weight, depending on their diet (Oonincx et al., 2010).

[9] Beef averages 12,5 mg per 100g of dry weight, while the palm weevil larvae (*Rhynchophorus phoenicis* FABRICIUS, 1801) contains 26,5 mg per 100g. (Bukkens, 2005).

[10] Chitin, the main component of the exoskeleton of an insect, is a long-chain polymer of N-acetyl glucosamine, a derivative of glucose: it is much like the polysaccharide cellulose found in plants. Chitin has also been associated with defense against parasitic infections and some allergic conditions.

Phylum Arthropoda), are not only accepted as food but even viewed as delicacies. The prohibition against eating insects among many contemporary North Americans can probably be traced in Europe: European colonists who settled in North America also had strong taboos against consuming insects (e.g. they classified lobster as an insect and refused to eat it). Native Americans, however, did not have the same prejudices against insects as food: they usually consumed large caterpillars found in certain pine tree species, grasshoppers, crickets and shore flies (*vide infra* §2.4.3).

In many other parts of the world, however, insects are considered "good to eat", as Marvin Harris said in his eponymous book, and are appreciated for their taste as well as nutritional value. In Mexico, for example, have been documented 101 species of insects[11] regularly consumed fresh, roasted, or fried, at various stages of development. An example of culinary preparation is the *ahauatle*, a mixture of hemiptera eggs, which is then fried witch chicken eggs. In Colombia, the giant queen ants of the genus *Atta* are praised as a gastronomic delicacy (*vide infra* §2.4.3). Among the African states we see a quite widespread consumption of edible insects: caterpillars have become something of a trend on menus around Africa and also locusts play a significant role in African diets, especially *Schistocerca gregaria* (FORSKÅL, 1775), the desert locust (*vide infra* §2.4.4). We have to make a separate discussion for Asia, whose customs change depending on the area taking into account. In the Middle East and South Asia, with the exception of locusts, there is not a strong entomophagy culture, but in Southeast and East Asia the situation is clearly different (*vide infra* §2.4.1). Thailand currently exports frozen steamed ants, larvae, pupae and cricket-based products all around the world as specialty foodstuffs, and in the North of the country a bee brood is prepared for consumption by steaming entire honeycombs wrapped in banana leaves. The consumption of beetles has ever been popular throughout Southeast Asia, with 24 species in six families listed by the entomologist Bodenheimer in 1951. Insect consumption is still quite common in some parts of East Asia. The most well-known insect eaten is the pupae of the silkworm *Bombyx mori* (LINNAEUS, 1758): these pupae are exported from Korea to United States and are also eaten commonly in China (*vide infra* §2.4.1). A mention for Australia: many restaurants in the country usually include in their menu insects-based dishes, made by black honey ants, witchetty grubs

[11] They include dragonflies, grasshoppers, bugs, lice, treehoppers, cicadas, caddis flies, butterflies, moths, flies, ants, bees and wasps.

(the larvae of a Cossid moth), bardi grubs (the larvae of a Cerambycid beetle) and *Trigona* bees (*vide infra* §2.4.5).

1.3 LEGISLATIVE FRAMEWORK

Food law, generally, does not define foodstuffs as based on their nutritional characteristics, but based on their consumption reasonableness, which is associated to each foodstuff human health and safety requirements. Currently, food safety legislators experience a peculiar situation: on one hand, they recognise the need for scientific proofs demonstrating potential edible risks associated with insect consumption; on the other hand, edible insects market actors and potential consumers are pushing for new regulations in order to legalise a practice which is considered healthy, ecologic and already widespread in the world (*vide infra* §3.3). Assessing the potential risks of entomophagy is essential to ensure both food safety and either the possibility for producers to work in a normative framework, which guarantees the fairness of their activities. At most, legislative reference to insects in the context of food prescribe maximum limits of insects traces in foodstuffs, where this is unavoidable. For example, according to the Unites States Food and Drug Administration's (FDA) booklet, Food Defect Action Levels, average contamination levels below 150 insect fragments per 100g of what flour pose no inherent health hazard.

Product	Type of insect contamination	Maximum permissible level
Canned sweet corn	Insect larvae (corn ear worms or corn borers)	Two or more 3 mm or longer larvae, cast skins, larval or cast skin fragments, the aggregate length of insects or insect parts exceeds 12 mm in 24 pounds
Canned citrus fruit juices	Insects and insect eggs	Five or more Drosophila and other fly eggs per 250 ml or 1 or more maggots per 250 ml
Frozen broccoli	Insects and mites	Average of 60 or more aphids and/or thrips and/or mites per 100 grams
Hops	Insects	Average of more than 2 500 aphids per 10 grams
Ground thyme	Insect filth	Average of 925 or more insect fragments per 10 grams
Ground nutmeg	Insect filth	Average of 100 or more insect fragments per 10 grams

Table 5: Maximum permissible levels of insect contamination in food products (source: UFSDA, 2011)

According to some producers of insects for food and feed, the barriers to establishing markets for insects and the implications for trade are a result of the following factors:

- unclear regulations and legislation on farming and selling insects for human consumption and feed are an obstacle;

- difficulty in understanding relevant national and international information regarding processing and quality, little networking among producers and a lack of demand for large quantities for human consumption in developed countries represent additional obstacles;
- the lack of awareness among consumers and buyers about existing markets leads to low demand;
- it is difficult to market insects for human consumption because they are perceived to be inherently unsanitary.

In Europe, but not only, the concept of "novel food" is guiding the development of rules and standards for insects as human food: this term refers to food products that do not have a history of human consumption in the region or country in question. Examples of definition of novel foods contained in national legislations, besides European Union, are:

- "a food that does not have a history of human consumption in Australia or New Zealand" (Australia New Zealand Food Standards Code – Standard 1.5.1);
- "a substance, including microorganisms, that does not have a history of safe use as food (Canada's Food and Drug Regulations (C.R.C., c870) – B.28.001).

According to the definitions mentioned below, in some places such as Canada, USA and European member countries, insect species may require a premarket safety evaluation and authorization for sale as a novel food or ingredient. Regulation (EC) No. 258/97 of the European Parliament concerning novel food ingredients considers foods and food ingredients that have not been used for human consumption to a significant degree in the EU before 15 May 1997 to be "novel foods ingredients". According to this regulation, such novel foods and novel food ingredients must be, among other things, safe for consumers and properly labelled to not mislead consumers. From 1st, January 2018, within the EU, it is possible to market edible insects as food, thanks to the enter in force of Regulation (EC) No. 2283/2015[12] on novel foods: this regulation modifies the Regulation (EC) No. 1169/2011 and repeals the Regulation (EC) No. 258/97.

In Italy, the Ministry of Agriculture (MIPAAF) does not provide a clear regulation about edible insects and novel foods, which can be purchased on specific websites from other European and non-European countries, although they cannot be produced and sold as food on

[12] https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX%3A32015R2283

the Italian territory, but merely as feed. This drab legislative framework, at the moment, does not permit Italian consumers to interact freely with this gastronomic world, which seems to be one of the future generations nourishment lifeline.

1.4 SAFETY ISSUES

Food safety, processing and preservation are closely related. Insects, like many meat products, are rich in nutrients and moisture, providing a favourable environment for microbial survival and growth (Klunder et al., 2012). The Hazard Analysis Critical Control Points (HACCP) system, a science-based and systematic tool, identifies specific hazards and establishes control systems to ensure the safety of food: the adoption of HACCP throughout the insect supply chain will be a determining factor in the success and development of the edible insects sector. Although it has been stated that no significant health problems have arisen from the consumption of edible insects (Banjo et al., 2006), consumer confidence is arguably strongly correlated with the perceived safety of a give product. This is why in modern and cosmopolitan societies, where we can purchase mostly all kind of products whenever we desire, edible insects may begin to be perceived as safe, rather than "good to eat" (*vide infra* §3.2).

1.4.1 EFSA RECOMMENDATIONS

In accordance with Article 29 of the Regulation (EC) No 178/2004, the European Commission asked the European Food Safety Authority (EFSA[13]) to assess the microbiological, chemical and environmental risks arising from the production and consumption of insects as food and feed. The assessment of those risks should cover the main steps from production chain up to consumption:

1. production (farming of insects): production process including substrates (feedstock) for the insects;
2. processing: manufacturing of insects to insect products;
3. consumption of the products by pets, food producing animals and humans considering the composition of the products and potential microbial and chemical contamination.

EFSA has also made a list of insects which were reported to have the biggest potential to be used as food and feed in the EU. They are:

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[13] EFSA is an EU association that provides scientific advice and communicates on existing and emerging risks associated with the food chain. It is located in Parma (Italy).

- *Musca domestica* (LINNAEUS, 1758): common housefly;
- *Hermetia illucens* (LINNAEUS, 1758): black soldier fly;
- *Tenebrio molitor* (LINNAEUS, 1748): mealworm;
- *Zophobas atratus* (BLANCHARD, 1845): giant mealworm;
- *Alphitobus diaperinus* (PANZER, 1797): lesser mealworm;
- *Galleria mellonella* (LINNAEUS, 1758): greater wax moth;
- *Achroia grisella* (FABRICIUS, 1794): lesser wax moth;
- *Bombyx mori* (LINNAEUS, 1758): silkworm;
- *Acheta domesticus* (LINNAEUS, 1758): house cricket;
- *Gryllodes sigillatus* (WALKER, 1869): banded cricket;
- *Locusta migratoria migratorioides* (LINNAEUS, 1758): African migratory locust;
- *Schistocerca Americana* (DRURY, 1770): American grasshopper.

This opinion has the format of a risk profile that identifies hazards. Specific risk assessments should be taking into account the whole production chain from farming to consumption including the species and substrate to be used as well as methods for farming and processing.

According to EFSA, pathogenic bacteria (such as *Salmonella*, *Campylobacter* and verotoxigenic *E. coli*) may be present in non-processed insects depending on the substrate[14] used and the rearing conditions. Most likely the prevalence of some pathogens (e.g. *Campylobacter*) will be lower compared to other non-processed sources of animal protein, since active replication of the pathogens in the intestinal tract does not seem to occur in insects (EFSA, 2015). Despite the documented occurrence of parasites in insects and the linkage between sporadic human parasitic disease and insect consumption, a properly managed closed farm environment would lack all the hosts necessary for the completion of parasite life cycles and proper management before consumption, relying on freezing and cooking, can eliminate risks. Production methods, substrate, stage of harvest and insect species in insect rearing will all have an impact on the presence of chemical contaminants in insect food and feed products:

[14] A wide range of organic materials can be used as source of nutrients or as substrates for rearing of insects; substrate is the overall term that will be applied for these materials as insect feed throughout the opinion. The substrates that will be included in the production will depend on the legislative framework, availability, the applicability in the specific farming system and the cost. Due to the different requirements, the substrate preference will differ among the different insect species.

the expected occurrence of hazards in non-processed insects is different for each substrate groups analysed.

Several cases have been documented in which the consumption of insects has caused an allergenic reaction and even anaphylactic shock in humans. Although allergies occur in pet and farm animals, no information of allergy caused by consumption of insect-derived feed are reported in pet and farm animals in the literature. In case of allergenic proteins, or in case of proteins cross reacting with allergens such as tropomyosin or arginine kinase from crustaceans or mites, a potential measure may be to indicate presence of the insect protein and the possible allergenicity or cross reactivity on the label of the product (EFSA, 2015).

In conclusion, since there are no substantial hazards to human health related to entomophagy, it is desirable this practice can be reintroduced in common dietary patterns (*vide infra* §2.5.1). If we are to succeed in this attempt, it is necessary to understand the reasons which, over time, have made sure that this source of food has become outmoded. In the next chapter, a timeline will be followed along the dissertation, in order to cover all the historical and sociological aspects of entomophagy from the antiquity to our days.

2. CULTURAL HISTORY

2.1 THE TIMELINE OF ENTOMOPHAGY

Eating patterns do not simply stem from nutritional requirements or environmental conditions. They also depend on cultural identity, politics, religious beliefs and individual preferences. As Italian food historian Massimo Montanari says in his book *Il cibo come cultura*, the idea of food is related to the idea of nature, but the connection between them is ambiguous and overall inappropriate. Among human experiences, eating core values are not defined in terms of "naturality" but as the outcome of cultural processes involving the domestication, the transformation and the reinterpretation of nature. *Res non naturales*, meaning things that do not happen naturally, is the definition given by ancient physicians (i.e. Hippocrates) and philosophers to food: they include it in factors making up life which do not belong to the natural order of things, but rather to the man-made field. Basically, this is culture which man himself builds up and manages: a result of work, techniques and knowledges transmitted from generation to generation. It represents the interface between human beings and the world where they live.

The easiest way to discuss about historical processes is to put them on a timeline. In this way case, the timeline of entomophagy presented below has the purpose of clarifying key issues, events and changes in the evolution of this dietary practice in the same way as it would be done in order to explain the evolution of a society or the events related to wars or great discoveries. Among the sources used for this historical dissertation there are medical, religious and legislative texts. Since dietary practices have always been related to permissions, prohibitions and recommendations, the use of these sources has helped to understand better the reasons why edible insects consumption is such as controversial food habit. Scholars who handled the topic of entomophagy so far focused on aspects connected to nutrition, climate and eating habits, with the intent to explain dietary behaviours opposed to traditional eating patterns (e.g. European food habits) and to suggest an alternative opportunity for human nourishment. However, entomophagy is not a new trend. It is deeply rooted in the culture of early humans, when the African continent was populated mostly by *Australopithecus africanus*[15] species.

[15] Australopithecus, from Latin *australis*, meaning "southern", and Greek πίθηκος (pithekos), meaning "ape", is a genus of hominis that existed in Africa from around 4,2 to 1,9 million years ago and from which the Homo genus, including modern humans, is considered to be descended.

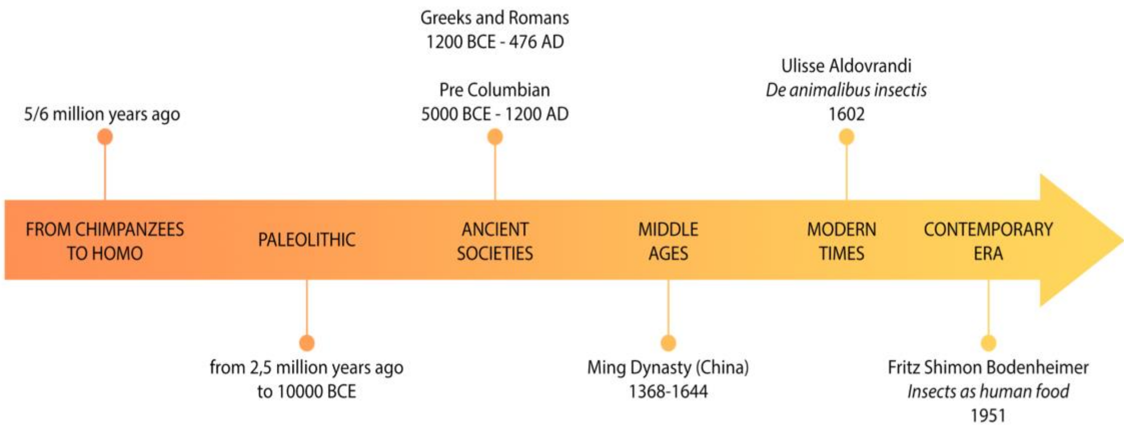

Figure 5: The timeline of entomophagy

"But one thing I'm sure of is that none of us has an instinctive aversion to eating small invertebrates, be they insects, spiders or earthworms" (Harris, 1985, pag. 153): this quote from Marvin Harris' *Good to eat* (*vide infra* §2.3.1) serves as starting point in order to analyse the timeline above. Moving from the examination of the behaviour of chimpanzees and apes, Harris affirms that the genus *Homo* descends from a long line of insects eaters. In fact, most great apes and monkeys eat significantly quantities of insects. Chimpanzees, considered to be our closest relatives among the great apes, pursue insect game using a special tool, a strong and supple twig stripped of leaves. To catch termites, they insert the twig into the ventilation shafts of termite mound. They wait a few seconds for the residents to swarm over the twig, then they pull it out and lick off the prey with their tongue (Harris, 1985, pag. 154). This is a clear example of skills development, which are then transmitted in the evolution of the species. In shaping humankind primate ancestry, natural selection favoured precisely those traits which were useful for the pursuit and the capture of food such as insects and other small invertebrates in tropical arboreal habitats. These traits were a keen stereoscopic vision rather than a keen sense of smell, an agile body, fingers that can grasp and pick up bits and bring them close to eyes for an accurate inspection and, above all, a complex, alert mind capable of monitoring the movements of arboreal canopy. In this way, insectivores laid the basis for the further evolution of manual dexterity, differentiation of hands from feet and the extra braininess that defines *Homo*'s distinct place in the great chain of being (Harris, 1985).

To introduce the discussion on early humans' entomophagous habits it is reasonable to provide a short line-up of human prehistory. This line-up comprises the time from the first appearance of *Homo sapiens* in Africa 300,000 years ago to the invention of writing and the beginning of history, 5,000 years ago. It thus covers the time from the Middle Palaeolithic (Old Stone Age) to the very beginning of world history:

- Middle Palaeolithic: from 315,000 years ago, the approximate date of appearance of *Homo sapiens* to 45,000 – 43,000 years ago, the colonisation of Europe by early modern humans;
- Upper Palaeolithic: from 45,000 – 40,000 years ago, with the Châtelperronian cultures in France, to 12,000 years ago, the earliest dates suggested for the domestication of the goat;
- Holocene: the last part of human prehistory, including Mesolithic and Neolithic, from 11,600 years ago to 4,600 years ago (2600 BCE) when writing was developed in Sumer and Egypt.

According to Bodenheimer's studies about on Palaeolithic men eating habits, eating insects was the instinctive response to the physiological need for animal proteins, fats or other substances in case that hunting for small mammals did not succeed. Although he insists upon the exceptionality of Palaeolithic entomophagy, it should be remembered that at certain latitudes very few insects are available throughout the year. As we are talking about small groups of food-gatherers, neither insects nor any other food was ever stored by them. However, insects represented an important source of nourishment for Palaeolithic men, who found in termites and locusts the primary products of consumption. The link between primitive men and insects is well documented in cave paintings and totems[16] used as symbols for fortune and prosperity: the representation below portray the honey-hunting event, where the community and its animals are involved in the gathering of honey from bee's nest.

Figure 6: A Palaeolithic cave drawing at Araña of honey-hunting (Hernandez-Pacheco, 1921, pag. 14)

[16] A totem is a spirit being, sacred object, or a symbol that serves as an emblem of a group of people, such as a family, clan, lineage, or tribe.

In the Neolithic, around 10,000 BCE, when human communities started the breeding practice, there were in Eurasia 13 of 14 tameable animals. Big mammals, both omnivorous and herbivorous, provided our Neolithic ancestors not only a considerable amount of meat, but also heat, milk, pelts, wool and transports. Therefore, the identification of breeding as an actual economic benefit has, probably, to be collocated in this period (*vide infra* §2.5). Consequently, edible insects consumption, as much as it was widespread in both the Palaeolithic and the Neolithic, became gradually something reserved for a few.

The habit of entomophagy was not completely lost among Eurasian populations, so much so that in ancient Greece the philosopher Aristoteles (384-322 BCE), in his *Historia Animalium*, wrote about grasshopper maggot flavour, which is better at the last stage of development (HA, V.30). He also reported how female goslings are finest after copulation, because they are full of eggs. These are evidences of how entomophagy was still common while he was alive. Greeks and Romans wrote abundantly about edible insects within and beyond their borders. The Greek historian Herodotus reports that in IV century BCE the Budini nomadic tribes from central Asia are the only people in the area who eat "parasites" (*Historia*, IV.109). According to the French naturalist Malcom Burr, the word used by Herodotus means "cootie-eaters". Herodotus in *Historia* counts among insects consumers also the Nasamoni, who haunt locusts and make them dry under the sun, later they powder and eat them mixed with milk (ivi. 172). Again, Bodenheimer reports that Aristophanes wrote about markets where locusts were being sold at a low price, so they were consumed by lower social classes. Pliny the Elder, first author of romans natural history, says that grasshoppers were eaten in the East, and he also reports that his contemporaries considered the *Cossus* (i.e. a red longhorn beetle larva) as a delicacy: to increase its flavour this larva was fattened with flour and wine, in other words, they fried it.
Meanwhile, from across the Atlantic, the Amerindian people (*vide infra* §2.4.3) were particularly greedy of various type of larvae, namely of bees, wasps, ants, crane flies and moths (it must be said that they lacked agriculture or domesticated animals other than dogs). In the late summer the pupae of a small fly (*Ephydra hians* Say, 1830) washed ashore along the beaches of California and Nevada's brackish lakes, forming windrows which made it easy for the Indians to harvest huge numbers at a time (Harris, 1985, pag. 156). They also caught copious quantities of locusts and Pandora moth caterpillars, who were left to dry and set aside for winter months when even insects became scares. In the south part of the continent, it is well-known that many indigenous people of the Amazon basin seem to be especially keen on

insect fare: that is why since ancient times indigenous knew about 20 different species of insects to consume as a food. Of those, almost 75% were consumed in their fat larval stage and the rest were divided between winged sexual plus the soldier castes of ants and termites whose large heads make tempting titbits, as Marvin Harris explains (ivi, pag. 156).

During the Middle Ages, entomophagy slowly disappeared from Europe due to the diffusion of an agrarian economy supported by single self-sufficiency breeding approaches, whereas in Asia the practice remained widespread. Li Shizhen's *Compendium of Materia Medica*, one of the largest and most comprehensive books on Chinese medicine during the Ming Dynasty in China (1368 – 1644), displays an impressive record of all foods, including a large number of insects, and it also highlights the medical benefits of the them used as food (Li et Liang, 2015). It is possible to identify in this timeframe one of the reasons why, currently, entomophagy is widespread in Asia, especially in South-East: entomophagy has been maintained simultaneously with the food economic system and edible insects were not completely replaced by other products, as it happened instead in Europe with the spreading, albeit slow, of bovine and swine meat among all the population (*vide infra* §2.4.2).

The New Age of entomophagy begins with the appearance of the compendious *De Animalibus Insectis Libri Septmen, cum singulorum iconibus and viuum expressis* (1602) by the Italian entomologist Ulisse Aldovrandi (1522-1605). He reports about various insects used as a food, quoting previous sources that refer about the consumption of locusts and grasshoppers. Moreover, he talks about the consumption of bees from Cumaná inhabitants and fried silkworm in Italy. From his travel experiences, he reports about ants used as food in some parts of India and Genusucian Islands. We can consider Ulisse Aldovrandi as the forefather of modern times entomology science: after his dissertation many other entomologists discussed about edible insects consumption in their writings. Bodenheimer quotes the entomologist De Reaumur:

> in one of his superb *Memoires pour server a l'Histoire des Insectes* (1737, vol. 2, pp. 113-120) discusses the edibility of insects, while dealing with the enormous ravages produced in France by *Plusia gamma*. During that period some people who had eaten these caterpillars with salad or in soup claimed that they were poisonous. Yet, as with all other smooth caterpillars, they are actually harmless. However, the prejudice against this insect has been so great that when one of its caterpillars has been swallowed, it has been immediately held responsible for any symptoms of poisoning.

As regards the unpleasant symptoms reported by diners, De Reaumur says this caterpillar is safe, and it is possible to eat it without dangerous injuries for human stomach.

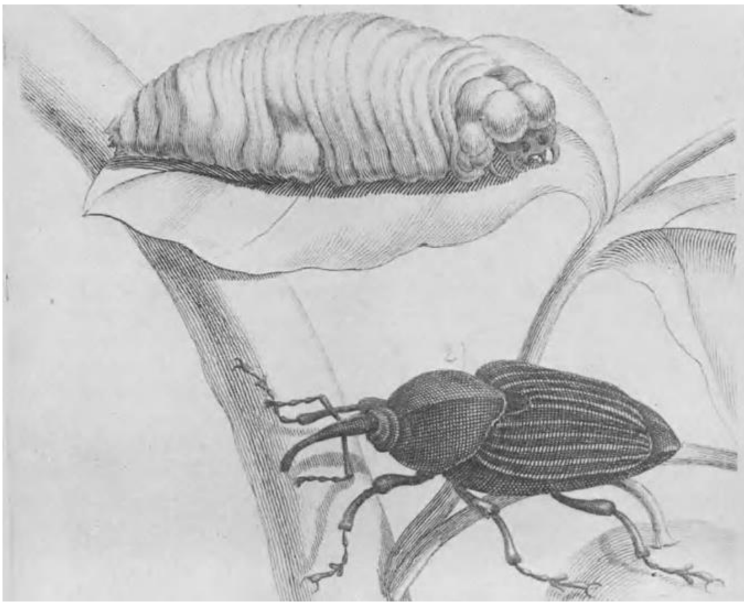

Figure 7: The palmworm (*Rhynchophorus palmarum* LINNAEUS, 1758) as drawn by Maria Sibylla Merian in her *Insects of Surinam* (Bodenheimer, 1951, pag. 47)

Before we get to Bodenheimer's work, which marks the beginning of current entomophagy studies, it is necessary to mention the authors who connect first modern writings to the most recent ones. Foucher D'Obsonville, in 1783, wrote *Philosophic Essays on the Manners* of *Various Foreign Animals*, a book in which he says locusts are eaten tastefully by most of Africans, some Asians and furthermore Arabs. Immanuel Kant in his *Physical Geography* (1802) devoted a paragraph to talk about the consumption of locusts in Africa. The French naturalist Georges Cuvier (1769 – 1832) tells how southern French children love locust fleshy thighs, and he also reported how these, pickled, are a trading commodity. Malcom Burr, an entomologist and geologist member of the Royal Society, proposes the use of insects as food and medicine, harking back to medieval China habits explained before. The last of this latter area is Vincent Holt, with his book *Why not eat insects?* (1885), in which is clearly established the theory reported earlier in this chapter: what we eat is affected by religion, traditions and trends; in one simple word, by culture. According to Holt, this is the reason why in Europe, insects are not consumed as a food despite they are safe and rich in nutrients.

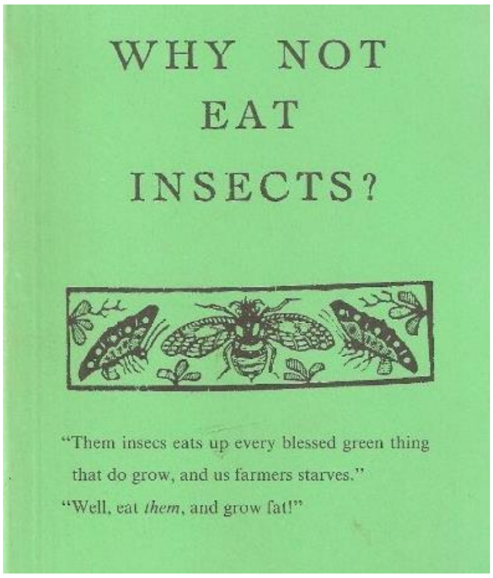

Figure 8: Vincent Holt's *Why not eat insects?* cover of 1992 edition (source: www.abebooks.it)

Through his work from 1951, Bodenheimer marks the beginning of current era dissertations about entomophagy. The real turning point is in 1985, with Marvin Harris' *Good to eat*, where it is said that "food must nourish collective stomach before it can feed a collective mind". Or in other words, there is a costs-benefits association for whom, whether foods are good or bed to think depends on whether they are good or bad to eat (*vide infra* §2.3.1). Consequently, with Marvin Harris we make the leap over the primary mentally association Food-Culture, and we speak of food in mathematical terms. It is currently just so hard for Europeans or North Americans to accept FAO recommendations on edible insects, because they do not think at them as a good thing to deal with, and so they do not eat them: to destroy this stigma, at first, and after to tip the scale in flavour of benefits, are the only ways to accept entomophagy as a common dietary practice all over the world.

2.2 THE ROLE OF RELIGION

The majority of religions, generally, assume a regulatory role in the life of people who practice them: the rules to follow do not only establish prohibitions on certain foods, but also offer guidelines and regulations about their ritual consumption. As a matter of fact, the Latin word *religio*, from which the English word "religion" derives, counts among its possible semantic explanations that of *obligatio,* i.e. "duty". Within the framework of food as part of *res non naturales*, the concept of culture as understood by Massimo Montanari, we should include precepts given by the religious authorities of different peoples.

Nourishment is part of the complex set of symbols that makes up for the cultural system of a community: such system establishes a dietary code of practice that not just favours some foods and bans other, but also separates what is permissible from what is not. Accordingly, it can be stated that religions not only value human nutrition from a cultural point of view, but they also consecrated it in different ways, since they have determined, beyond dietary bans, the circumstances itself whereby some foods can be eaten or can be used during rituals. Individually, food becomes an actual part of the person himself, helping in the formation of a group identity, with common dietary rules.

This is how taboos[17] were born. They are an implicit prohibition on something, usually against an utterance or behaviour, based on cultural sense that is excessively repulsive or, perhaps, too sacred for ordinary people. Such prohibitions are present in virtually all societies. On a comparative basis taboos related to food items seem to make no sense at all: as what may be declared unfit for one group by custom or religion, may be perfectly acceptable to another. The meaning of the word "taboo" has been somewhat expanded in the social sciences to strong prohibitions relating to any area of human activity or custom that is sacred or forbidden based on moral judgment, religious beliefs or cultural norms.

2.2.1 ARE INSECTS REALLY A RELIGIOUS TABOO?

Given the major role played by religious beliefs in the evolution of human civilisation, one might think that some people reject the idea of eating insects as reminiscence of rules imposed by their religious authority. After all, dietary taboos related to worships are presents in quite every cultural pattern in the world: Hindu do not eat cows because they are considered holy animals (*vide infra* §2.4.1); following prescriptions originally presented in the Torah, pork (*vide infra* §2.3.1) is forbidden for both Jewish and Muslims as well as some Christian movements, such as the Adventists; crustaceans consumption is forbidden in Judaism and a certain number of people refuse to eat crabs in Europe and Africa. Even though humans are omnivorous, they treat some edible foods as inedible. In this last category we distinguish:

- rejected foods, including anything that is considered disgusting, even though such foods can be eaten if necessary (e.g. famine foods);

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[17] The term "taboo" comes from the Tongan *tapu* or Fijian *tabu* ("prohibited", "disallowed", "forbidden"), related among others to the Maori *tapu* and Hawaiian *kapu*. Its English use dates to 1777 when the British explorer James Cook visited Tonga and referred to the Tongans' use of the term "taboo" for "anything is forbidden to be eaten".

- forbidden foods, including what is polluting and therefore taboo.

The sacrificial and ritual exchange of food between humans, gods and spirits is entirely based on notions of purity and pollution, which in turn shape social hierarchies. Thereby, the sacrificial and dietary fields join in one single practice, including both rules from religion and from nutrition. In the *Deuteronomy*, it is said "you shall not eat any abominable things" (XIV.3) whereas in *Leviticus* "eatable animals" (*kashér*) are discussed. Among these, there are "winged insects that walk on all four and have jointed legs above their feet, with which to leap on the ground: the locust, the cricket and the grasshopper" (XI.20). The Gospel reports that John the Baptist[18] ate locusts in the desert (*Matthew* III.4): this biblical episode reminds us that locusts were part of desert people dietary regimen since thousands of years. Locusts consumption is similarly recognized by Arabic-Islamic tradition (*vide infra* §2.4.1). In the rest of religions diffused worldwide, entomophagy is not clearly banned and considered a taboo. Consequently, it is incorrect to think that in Europe and North America, where Christianism is the main practiced religion and most people show repulsion towards edible insects, the religious sphere had an influence on the dietary practice in this regard. Rather, Marvin Harris' cultural materialist anthropological theory, which will be explained later, clarifies better why entomophagy became a "food disuse".

2.3 THE ANTHROPOLOGICAL THEORY OF CULTURAL MATERIALISM

Cultural materialism is one of the major anthropological perspectives for analysing human societies. Coined by Marvin Harris in his 1968 text, *The Rise of Anthropological Theory*, it embraces three anthropological schools of thought: cultural materialism, cultural evolution and cultural ecology. Cultural materialism emerges as an expansion of Marxism (*vide infra* fig. 9): the work of Karl Marx and Friedrich Engels presented an evolutionary model of societies based on the materialist perspective. They argued that societies go through several stages, from tribalism to feudalism, to capitalism to communism. Since the late 1920s, anthropologists have increasingly come to depend on materialist explanations for analysing societal development and some inherent problems of capitalist societies. They contend that the physical world

[18] John the Baptist is mentioned by the Hebrew historian Josephus and revered as a major religious figure in Christianity, Islam and Mandaeism. He is called a prophet by all of these faiths and is honoured as a saint in many Christian traditions.

impacts and sets constrains on human behaviour, which is part of nature and therefore, it can be understood by using the methods of natural science. Materialist do not necessarily assume that material reality is more important than mental reality. However, they give priority to the material world over the world of the mind when they explain human societies. The theory of cultural materialism explains cultural similarities and difference as well as models for cultural change within a societal framework consisting of three distinct levels: (i) infrastructure, (ii) structure and (iii) superstructure. Infrastructure is the basis for all other levels and includes how basic needs are met and how it interacts with the local environment. Structure refers to a society economic, social and political organization, while superstructure is related to ideology and symbolism. Cultural materialists contend that the infrastructure is the most critical aspect as it is here where the interaction between culture and environment occurs. All the levels are interrelated so that changes in the infrastructure result in changes in the structure and superstructure, although the changes might not be immediate. While this appears to be environmental determinism, cultural materialists do not disclaim that change in the structure and superstructure cannot occur without first change in the infrastructure. They do however claim that if change in those structures is not compatible with the existing infrastructure the change is not likely to become set within the culture.

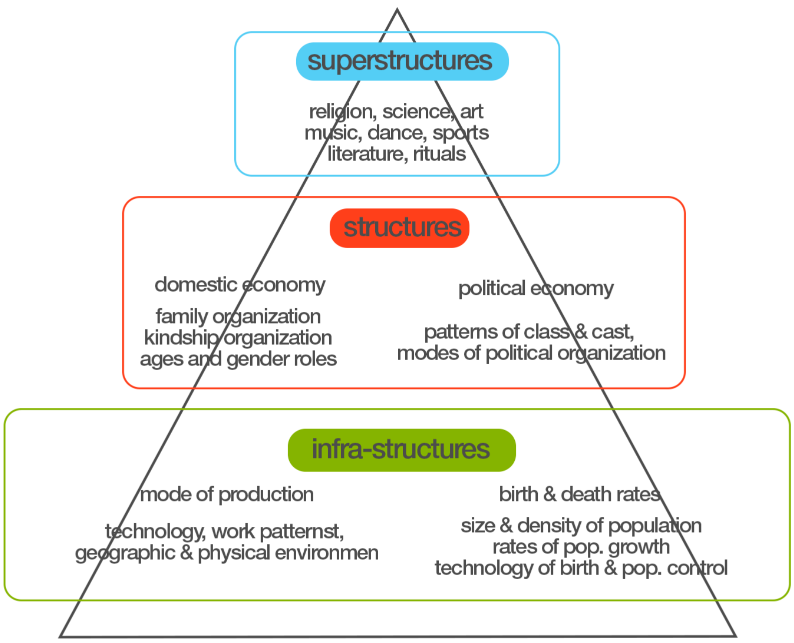

Figure 9: Cultural materialism pyramidal model (source: www.pinterest.com)

The main objective of cultural materialism is to understand the effects of technological, economic and demographic factors on moulding societal structure and superstructure through strictly scientific methods. As stated by Harris, cultural materialism strives to "create a pan-human science of society whose findings can be accepted on logical and evidentiary grounds by the pan-human community" (Harris, 1979, pag. 8). It can be stated that this theory is an expansion of Marxist materialism, because cultural materialism views both economic and demographic forces as the primary factors that shape society. Therefore, cultural materialism explains the structural features of a society in terms of production within the infrastructure only (Harris, 1996). As such, demographic, environmental and technological changes are invoked to explain cultural variation.

2.3.1 *GOOD TO EAT: RIDDLES OF FOOD AND CULTURE* (1985)

As the first representative member of cultural materialism, Marvin Harris stated that is mostly environment which affects food choices: he made one of his principal statements by antagonizing Mary Douglas' theory of "purity and pollution". Her study is based on the comparative analysis of religions and symbolic systems, throughout the examination of "impurity" and "purity" concepts uses. Her fundamental assumption is that these symbolic definitions are necessary to extant social structurers almost in every kind of society: "either the rules are meaningless, arbitrary because their intent is disciplinary and not doctrinal, or they are allegories of virtues and vices" (Douglas, 1966). One of the leading instances presented by Mary Douglas is that of pork is a proscribed food in the Jewish tradition because swines have cloven hooves but are not ruminants. The pig thus becomes hardly classifiable in a rigorous structure, which provides the idea of "completeness" is associated to that of holiness. This implies that to be holy is to be "whole", and consequently only the animals considered as "whole" can be eaten. But that is not Marvin Harris' feeling. About Jewish dietary regulation he said:

> by raising animals that could 'chew the cud', the Israelites and their neighbours were able to obtain meat and milk without having to share with their livestock the crops destined for human consumption. […] Rather than compete with humans for food, the ruminants further enhanced agricultural productivity by providing dung for fertilizer and traction for pulling ploughs. And they were also a source of fibre and felt for clothing, and of leather for shoes and harnesses (Harris, 1985, pp. 65-66).

In this perspective, Mary Douglas' theory does not justify the low status of pig in the Middle East: the real problem, as Marvin Harris explains, is the danger pig-rearing posed to husbandry. First of all, pigs compete with humans for environmental edible resources, unlike ruminants; secondly, they are not adapted to hot climates, because they cannot sweat as they have no functional sweat glands; last but not least, raising them in the Middle East was and still is a lot costlier than raising ruminants. For a pastoral nomadic people like the Israelites during their years of wandering in search of lands suitable for agriculture, swineherding was out of the question.

The prohibition on eating pork in the Middle East makes perfectly clear the relationship between costs and benefits underlying all the *Good to Eat* dissertation. Foods that are better to eat are those that tip the scale towards pragmatic benefits, in contrast to what happens for abominable and prohibited foods, which tip the scale towards costs. This occurs in pig consumption as well as edible insects consumption: insects are eaten where benefits overcome supply costs, e.g. in areas where meat is not enough compared to the number of inhabitants. In the Middle Ages, as it was mentioned above, this assumption permitted the diffusion of entomophagy in Asia, Southeast Asia and South America, rather than Europe and North America, where, currently, meat consumption is the primary source of nourishment for the population.

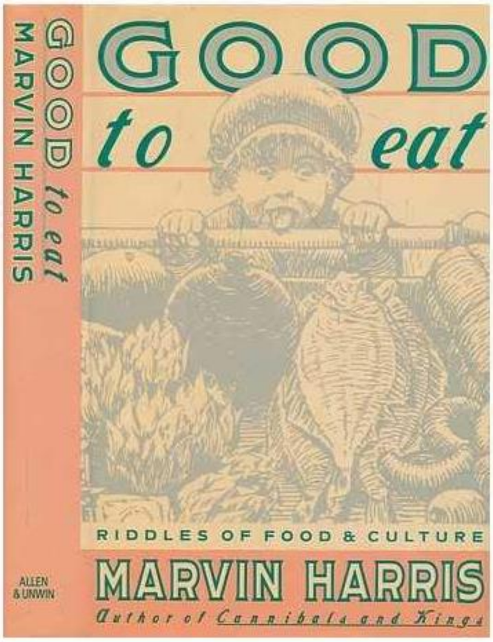

Figure 10: Marvin Harris' *Good to eat* cover from 1985 edition (source: www.amazon.it)

2.4 THE FOCUS OF ENTOMOPHAGY HISTORY IN THE FIVE CONTINENTS

After the chronological approach, it seems now appropriate to go deeper into the above-mentioned cultures. In this case, however, a geographic approach will be used, in an effort to provide an overview even on those places and backgrounds not mentioned before. The main benchmark remains F.S. Bodenheimer's 1951 *Insects as Human Food*.

2.4.1 ASIA

The territory of Asia may be divided into three main sectors. The Middle East, a zoogeographical heterogenous region, is a very old centre of highly specialised agriculture[19] and animal husbandry neither in its historical development nor in its present condition much inducement to entomophagy. Moreover, Middle East is the cradle of the three main monotheistic religions: Judaism, Christianism and Islam. Even if we cannot properly regard to insects as a religious taboo (*vide supra* §2.2.1), there are some prohibitions referred to them in the Old Testament, followed by both Christians and Jewish. It is prohibited to eat "winged insects" (*Deuteronomy* XIV.19): they are, consequently, considered as impure. As regards to Islam, despite in the *Qur'an* there are two chapters (*surah*) dedicated to, respectively, bee and ant, there is no real references to entomophagy. In fact, such details should be looked for in Muhammad's sayings (*ahādīth*), where he observed that flies and cooties are forbidden as food. However, insects as locusts can be considered permissible to eat since the occasional locust swarms are acclaimed by the nomads (e.g. Bedouins[20]), but certainly not by the *fellahs* (Bodenheimer, 1951). Bodenheimer mentions again wild honey (*vide supra* fig. 6), which is used wherever available, and beekeeping itself has been long stablished. The mannas are more a curiosity than a source of food: the most widely accepted view in textbooks is that the lichen *Lecanora esculenta* (LINNAEUS, 1810) is probably the manna of the Bible. This lichen grows on rocks and produces fructifications in the form of pea-sized globules which Irano-Turanian natives collected for their sweetness. In more recent times, this manna was regarded as a secretion of the tamarisk, that

[19] Middle East is a Vavilov Centre of Diversity, a region of the world first indicated by Nikolai Vavilov to be an original centre for the domestication of plants. They are all over twelve: Chinese, Indian, Indo-Malayan, Central Asiatic, Persian, Mediterranean, Abyssinian, South American, Central American, Chilean, Brazilian-Paraguayan and North American centre.

[20] The Bedouins are a grouping of nomadic Arab people who have historically inhabited the desert regions in North Africa, the Arabian Peninsula, Iraq and the Levant. They are traditionally divided into tribes, or clans and share a common culture of herding camels and goats.

is sucked by the insects living on the plant, and from these sucking holes or punctures oozed the manna.

The Indian sub-continent is a natural physical landmass in South Asia, geologically the dry-land portion of the Indian Plate, which has been relatively isolated from the rest of Eurasia. Given the difficulty of passage through the Himalayas, the sociocultural, religious and political interaction of the Indian sub-continent has largely been through the valleys of Afghanistan in its northwest, the valleys of Manipur in its east and by maritime routes. More difficult but historically important interaction has also occurred through passages pioneered by the Tibetans. These routes and interactions have led to the spread of Buddhism out of the Indian sub-continent into the other parts of Asia. Further, the Islamic expansion arrived into the Indian sub-continent in two ways, through Afghanistan on land and to Indian coast through the maritime routes on the Arabian Sea. Hinduism, however, remains the main religion followed in the area. This includes a diversity of ideas on spirituality and traditions, but has no ecclesiastical order, no unquestionable religious authorities, no governing body, no prophet(s) nor any binding holy book. Most rules are listed in the *Dharmaśāstra*, a genre of Sanskrit normative texts (*śāstras*) on *dharma* (personal, social, religious duty). In the *Dharmaśāstra* there are no direct references to entomophagy practice or to its ban, but there is a verse saying:

> leftover food from anyone other than one's teacher is unfit to be eaten, as also one's own leftovers, and food that has come into contact with leftovers or with a garment, hair, or insects. If he wants, however, he may eat it after removing the hair or the insect from it, sprinkling it with water, strewing some ash over it, and getting it verbally declared as suitable (*Vaśiṣṭhadharmasūtra* XIV.20).

Even if the prohibition of eating insects is not directly highlighted, they are considered as unclean, enough to avoid eating something which has come in contact with them. Entomophagy, in this area, has always remained confined to indigenous populations as, for example, the Veddas[21].

In China, Japan and Southeast Asia, the third area remained, the eating of insects, from silkworm pupae to water beetles, is instead widely accepted. With the development of highly

[21] Entomophagy can be found in India among some *ādivāsī*s (indigenous tribes) such as the Veddas, a minority group of Sri Lanka. The Vedda minority in Sri Lanka is an endangered community at risk of being completely assimilated. Most speak *Sinhala* instead of their indigenous languages which are nearing extinction. It has been hypothesized that the Veddas were probably the earliest inhabitants of Sri Lanka and have lived on the islands since before the arrival of other ethnic groups in India.

specialized agriculture this is no longer of basic importance, but certain insects are everywhere sold in special shops in the towns and gathered by the peasants as prized delicacies.

2.4.2 EUROPE

With regard to Europe, a distinction is necessary between the pre-Christian period, namely the Greco-Roman world, and the Middle Ages, with the spread of Christianism. Indeed, in 380 A.D. the emperor Theodosius made Christianism the only religion in the empire with the Edict of Thessalonica. Consequently, at the time of the fall of Western Roman Empire in 476 A.D., Christianism was already widespread in Europe. As already explained, the entomophagous habits of the Greco-Roman world were several and the disappearance of entomophagy during Middle Ages cannot be ascribed only to Christian prescriptions (*vide supra* p.24). Actually, the dissemination and implementation of an agrarian economy among the territory, supported by single self-sufficiency breeding approaches, remains the most common cause attributed its disuse.

In fact, the eating of insects as a common habit ceased long ago, apart from the collection of wild honey[22], which is still practiced in forest regions, especially among the Slavic people. However, Georges Cuvier pointed out that in Spain and Portugal the beggars had been reported to eat cooties, referring to this practice as “disgusting”[23]. Other than Cuvier’s reference on the consumption of locust fleshy thighs, French children were being told by Dr. Trouessart catching grasshoppers, crickets and locusts on the River Loire, pulling off their wings and cracking their hindlegs with evident pleasure (Bodenheimer, 1951). While in Russia, Oktawiusz Radoszkowski, one of the founding members of the Russian Entomological Society, mentioned that locusts were extensively uses as food in Southern Russia, either salted or smoked. Similar information has been repeatedly reported of the Tartars of Crimea. In some parts of Sweden ants were distilled together with rye, to give a flavour to their inferior kinds of brandy: apparently even today ant-pupae are used there for the production of good gin. Still on the subject of spirits production, cochineal extract was used as dye[24] in the production of some famous Italian spirits as Aperol and Campari: nowadays, it has been substituted with artificial dyes because of allergic

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[22] S.F. Bodenheimer considers the practice of collecting wild honey as an actual part of entomophagy, since eating honey means to feed directly with the secretion from bee pollination work.

[23] It should not be regarded as a real part of entomophagy practice, but as fruit of social exacerbation.

[24] The additive E120 is carminic acid aluminium salt extracted by insects, especially by cochineal.

reactions. Talking again about Italy, in Sardinia a very particular cheese is still manufactured, and it is called *casu marzu* (i.e. rotten cheese): that is a pecorino cheese colonized by fly cheese larvae, who is recognized as "cheese skippers" (*Piophila casei* LINNAEUS, 1758).

2.4.3 THE AMERICAS

America is another continent which by its geographical position, stretching from the Arctic to the Antarctic seas, embraces all the diversity conditions which terrestrial ecology can offer (Bodenheimer, 1951). Information about the northern Arctic areas are little: their natives, Eskimos[25], are most eager for fatty food, because of the climate conditions and insects are rare. Is reported that they did not know flies before the arrival of white men. The same is for the areas of South America and south of Amazonia: as in North America, insect feeding habits were more common in the arid areas to the west of the Andes than in the pampas of the east. Some North American Indian tribes were in the habit of consuming large quantities of Rocky Mountain locusts. De Smet mentions that the Assiniboine idea of luxury was an immense dish of pulverized ants, as well as locusts and grasshoppers dried in the sun. The Shoshocos liked crickets and grasshoppers and stored bags of roasted ants for future use. About caterpillars, they were eaten in great quantities by the Paiute Indians[26], while in Mexico caterpillars of *Hesperia sp*. burrowing the leaves of *Agave Americana* are cut out of the leaves and sold as a delicacy. In this area, many authors have reported on the large-scale consumption of the 17-year cicada, *Magicicada septendecim* (LINNAEUS, 1758), which is much relished when dried and pounded, fried or roasted, or as a soup. Otomite Indians in Mexico ate maggots of ant: these ants lived in oven-like hills; even a caterpillar, about 5 cm long, which abounded in July and belonged apparently to a Noctuid moth was eaten, either raw or cooked by the Mexican Indians.

[25] Eskimos are the indigenous circumpolar peoples who have traditionally inhabited the northern circumpolar region from the eastern Siberia to Alaska, Canada and Greenland. The two main peoples known as "Eskimo" are the Inuit and the Yupik.

[26] The Northern Paiute people are a Numic tribe that has traditionally live in the Great Basin region of the United States in what is now eastern California, western Nevada and southeast Oregon.

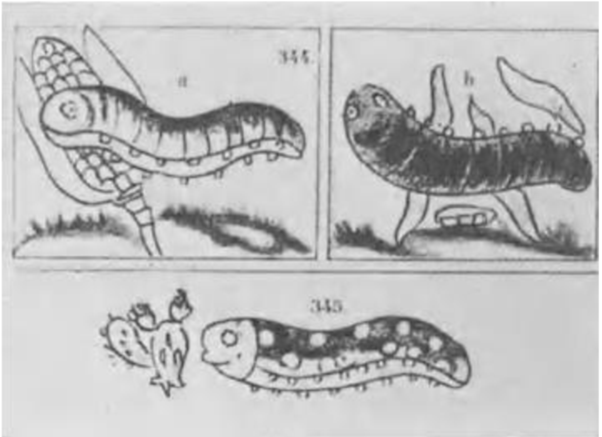

Figure 11: Different species of caterpillars drawing by the Incas (Bodenheimer, 1951, pag. 294)

2.4.4 AFRICA

With the spread of Islam across African territories, even its usages and costumes were disseminated. In the Sub-Saharan Africa, however, people are largely Christian, or they practice traditional animistic religions, which often come into conflict with Islamic groups. With reference to the food prescriptions of such religions, the consumption of locust in Africa is widespread in the continent and it has already been discussed previously. So, now other various types of insects used as food will be mentioned: since in Africa there have never been well-established farming and breeding systems, entomophagy has remained an important source of nourishment for African people.

Of the large number of beetles which are eaten, usually as roasted larvae, only a limited number has so far been identified, and the main reason is that most of them and especially their larvae are not available in large quantities. Bodenheimer lists the following species: *Scarabaeidae. Angosoma spp.* (larvae), *Goliathus sp.* (larvae delicacy in Congo), *Platygenia spp.* (sold living or fried in oil on almost all native markets of tropical Africa), *Cerambycidae*, *Ancylonotus tribulus* (larvae eaten in Senegal and Gabon) and *Macrotoma edulis* (larvae fried in palm oil on St. Thome Island, Gulf of Guinea).

Although some studies from the early 1990s indicated that 10% of the animal protein in the diet of local people in Congo came from insects, the general trend in Africa was and is still toward a reduction in entomophagy. This is probably due to an increased use of pesticides as well as to exploitation of new habitats in order to accommodate growing populations, both of which have reduced the number of insects to which populations have access.

2.4.5 OCEANIA

Entomophagy is common all over Australia. The Aborigines, who have always practiced entomophagy, have now disappeared or have become "civilized", but researchers have been able to collect information about the practice before it was too late. The black honey ant (*Camponotus inflatus* LUBBOCK, 1880) has an enlarged body the size of a grape filled with nectar: it was highly sought by Aborigines and even considered as a totem animal by some clans. Other species of ants were also important food resources for Aborigines (Bodenheimer, 1951): Tasmanians had a number of words for the various ants that they identified, and traditional feasts were held during the periods that ant pupae could be obtained. Witchetty grubs were also an important food: the name refers to several types of grubs and probably includes the larvae of the Cossid moth (*Xyleutes leuchomochla* TURNER, 1915), the giant ghost moth and the longicorn beetle.

2.5 THE CONTEMPORARY PERIOD

Nowadays, the practice of eating edible insects is relegated to a curiosity, something mostly considered "exotic". But, to define entomophagy as "exotic" is not completely wrong: generally, insects consumption is commonplace in the tropics, while in temperate zones it is often absent. There are, however, some exceptions of countries partially or fully in temperate zones, such as China, Japan and Mexico, where edible insects are commonly eaten. And even between and within countries in the tropical zone, there can be large differences among ethnic groups on which insects are considered edible (Meyer-Rochow, 2005). A number of trends in favour of entomophagy are recognised in the tropics, although some are admittedly hard to support with literature (FAO, 2013). These are:

- insects tend to be larger in the tropics, which facilitates harvesting;
- in the tropics, insects often congregate in significant numbers, so large quantities can be collected during a single harvest;
- a variety of edible insect species can be found year-round in the tropics;
- for many insect species in the tropics, harvests are predictable;
- location: palm and bamboo trees are generally preferred by insects to live in;
- time of abundance: this may be seasonal (often depending on rains) or a preferred time of day.

So, why were insects, even in the tropical areas, never domesticated for food before? The domestication of animals and plants took place thousands of years ago, in the previously mentioned Neolithic period, with different forms springing up independently in different parts of the world at different times. There are 148 species of large terrestrial mammalian herbivores and omnivores weighing at least 45 kg. The fact that a mere 14 of these have been domesticated is due neither to human ignorance nor human incapacity but is a direct result of the intrinsic biological features of the animals (FAO, 2013). Jared Diamond, in his *Guns, germs and steel: a short history of everybody for the last 13 000 years* (2005), identified 6 characteristics that a species must have to allow for domestication:

1. adequate diet (herbivores are easiest and most efficient to keep as a source of food);
2. high growth rate (it is cheaper and more worthwhile to invest in fast-growing animals);
3. capacity to breed in captivity (some animals simply refuse to do so);
4. a domesticable disposition (e.g. the domestication of horses succeeded but the domestication of zebras failed because of their aggressiveness and tendency to bite relentlessly);
5. relatively calm behaviour (animals with tendencies to panic create dangerous situations);
6. a clear hierarchical social structure (allowing human to assume the role of leader).

The domestication of large animals gave Europeans a considerable advantage over other regions, as evidence by their worldwide conquests (Diamond, 2005). The conquests enabled Europeans to exert a major influence on food production, with habits, knowledge, techniques and organisms exported worldwide: perhaps, the aforementioned negative attitudes to eating insects formed part of this package, as in more recent times (*vide supra* p.24).

As with mammals, not all edible insect species render themselves to domestication. Most edible insects are harvested in the wild, but a few insect species have been domesticated because of their commercially valuable products: the best-known examples are silkworms and bees. Sericulture[27] domesticated silkworm form has increased cocoon size, growth rate and efficiency of digestion, and is accustomed to living in crowded conditions (FAO, 2013). Both bee larvae and silkworm pupae are eaten as by-products of fibre production system in Colombia, India, Madagascar and Kenya. But the best example of rearing insects for human consumption

[27] Sericulture, the practice of rearing silkworms for the production of raw silk, has its origins in China and dates back 5 000 years.

is cricket farming in Thailand, where two species are produced: the native cricket (*Gryllus bimaculatus* De Geer, 1773) and the house cricket (*Acheta domesticus* Linnaeus, 1758). At the moment, Thailand is one of the first countries in cricket-based products manufacturing and selling: it exports quite all over the world, spreading entomophagy even in more reluctant places as North America and Europe.

2.5.1 RISKS AND ISSUES RELATED TO MODERN ENTOMOPHAGY

The nutritional and environmental advantages of entomophagy have already been discussed in this dissertation, mostly relying on FAO researches and studies. The foremost interest of the organization is to promote the advantages of this dietary practice, with a view to future generations relationship with environment and food resources. There are, however, some issues related to entomophagy that should be analysed more in details. Indeed, what one finds is that the scientific narrative on edible insects tends to highlight the advantages of this dietary practice. But, as for any activity related to food consumption, there are issues which I will attempt to resume briefly in this paragraph.

Insects may have associated micro-organisms that can influence their safety as food. Both insects collected in nature and insects raised on farms may be infected with pathogenic micro-organisms, including bacteria, virus, fungi, protozoa and others (Vega and Kaya, 2012). Such infections can be common but, in general, insect pathogens are taxonomically separate from vertebrate pathogens and can be regarded as harmless to humans. According to FAO researchers, these organisms should not be seen as potential human pathogens, but as microbial contaminants for final product and, so, they must be treated as such. Insect-based products hygienic handling and correct storage should be strongly addressed, in order to avoid potential risk following their consumption (Belluco et al., 2013, pag. 304).

Harmful metals from the environment have been found in the cells of several insect body parts – such as the, exoskeleton, reproductive organs and digestive tracts – where they bio-accumulate. Insects accumulate cadmium and lead in their bodies when they feed on organic matter in soils that contain these metals (Vijver et al., 2003). Recent studies have demonstrated the accumulation of cadmium in black soldier fly and of arsenic in yellow mealworm, species with the potential to be used as food or feed (Schrögel and Wätjen, 2019). The tendency to accumulate heavy metals in their bodies is associated to the one of fishes and crustaceans, whose accumulate cadmium, lead and mercury if sea areas where they live are polluted. Insect consumption is expected to be low, at least in an early stage of reintroduction, compared to that of shrimps and, in general, crustaceans: for this reason, the high level of heavy metals[28] accumulated does not represent a significant danger for human health.

Like most protein-containing food, arthropods can induce allergic reactions in sensitive humans. These allergens may cause eczema, dermatitis, rhinitis, conjunctivitis, congestion, angioedema and bronchial asthma (FAO, 2013). Allergic reactions to bee and wasp venom (injectant allergens) are well known. Some studies suggest that people frequently in contact with larvae of *Tenebrio molitor* (LINNAEUS, 1758) run the risk of developing certain allergic reactions, and the same was found for closely related species *Alphitobius diaperinus* (PANZER, 1797). The amount of evidences about allergies raises the question of the potential of developing sensitivity caused by ingesting edible insects and by handling while cooking and eating. For the great majority of people eating to insects do not pose significant risk of causing allergenic reactions, even because processes such as boiling, and cooking will destroy allergenic components. However, the risk of food allergy after insect consumption needs further investigation and greater attention is required in distinguishing between toxic and allergic symptoms.

In conclusion, after having proved that entomophagy has accompanied human evolution since its earliest days and there are nowadays the conditions for reintroducing it safely, the next chapter will try to explain both environmental, social and economic implications of this process.

[28] The Reg. (EC) 1181/06 sets maximum levels for certain contaminants in foodstuffs, including heavy metals.

3. FUTURE PERSPECTIVES

3.1 EDIBLE INSECTS AND MEDITERRANEAN DIET: A POSSIBLE COMBINATION

It has been calculated that by 2050 food production alone will reach the global objectives of greenhouse gases emissions. Typically, when this topic comes up, we tend to focus on coal-fired power stations energy production or on fracking, but food production has a decisive impact on climate change progress. Several studies argue that taking action on global food system is crucial in order to slow down climate change and to ensure, generally, food supplies for everyone.

We are now conscious that the best path we have as individuals to reduce the impact food production has on the planet is to change our dietary habits. This change does not open to a generalised scenario, but rather suggests submitting to a healthier diet in the most classic sense of food pyramid. In fact, the healthiest diets tend to be more functional along the productive cycle too, which means they lead to less land use and to chop down less trees, whose absorb greenhouse gases. The Mediterranean diet is the best example so far of what a sustainable diet means. Sustainable diets are defined as those with low environmental impacts that contribute to food and nutritional security and to healthy lives for present and future generations (Burlingame et Dernini, 2010). These kinds of dietary patterns could be graphically represented with the system of "double food pyramid": at the bottom there are plant-based foods rich in nutrients and protective substances with low energy density, while progressively going down to top there are food with higher energy density, which should be eaten less frequently both for their environmental impact and health effects.

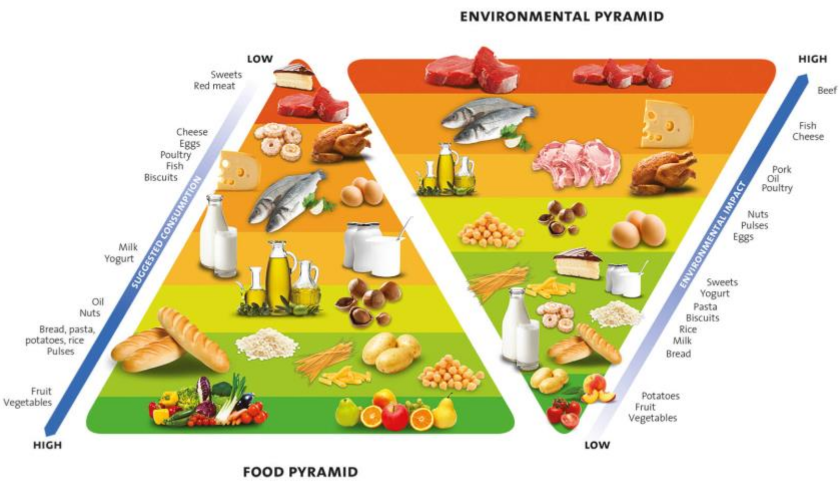

Figure 12: Double food pyramid for Mediterranean diet (source: www.barillacfn.com)

As the double food pyramid shows, the environmental impact of our food varies depending on what we put on our plate. To examine this idea further, the BCFN Foundation[29] analysed the impact of the weekly diets, which are balanced from a nutritional viewpoint and with the same calorie content. The menus analysed are:

- sustainable menu: includes both meat (with a preference for white meat) and fish, focusing on achieving the right balance between plant and animal protein;
- vegetarian menu: excludes meat and fish, protein sources are plant-based (legumes) and animal-origin protein is provided by cheese, other dairy foods and eggs;
- meat-based menu: it includes a higher consumption of protein from animal origins.

Sustainable menu and vegetarian menu both have a lower environmental impact compared to the meat-based menu. In practice, if over the course of a year a person avoids eating meat two days a week, they would save 310 kg of CO_2 per year. And if all Italians stopped eating meat for one day a week, we would achieve an overall saving of 198,000 tonnes of CO_2, equivalent to the annual electricity consumption of almost 105,000 families or 1.5 billion kilometres of car journeys. In short, one less meat dish a week would be as beneficial as 3.5 million fewer cars on the road for one year (BCFN Foundation, 2016).

If we were to place edible insects on the Mediterranean diet double pyramid system they should be put together with fish, crustaceans and dairy products, in the orange area, for both nutritional and environmental pyramid. Within this framework, edible insects would mean to be an innovative protein source that is configured as a meat and fish substitute. In fact, the most common edible insect species farmed (crickets, locusts and mealworms) seem to have greater environmental benefits than traditional breeding animals. FAO data shows how green-house gas emissions of insects are lower than domestic animals with an average of 1 g/kg of weight gain compared to the 2,850 g of cattle and 1,300 g of pigs. The soil used to produce 1 kg of protein is usually 20 square meters compared to the 45-70 of pigs. Furthermore, insects have a nutritional conversion efficiency rate significantly greater than beef; they might be fed with organic waste streams and use less quantity of water (Sogari, 2015, pag. 313). Regarding nutritional aspects, besides proteins, edible insects provide energy, amino acids and essential fatty acids which are beneficial for human health; while the fat content can vary widely

[29] The Barilla Center for Food & Nutrition Foundation (BCFN) was founded in 2009 with the aim of analysing the major issues related to food and nutrition in the world.

between 7 and 77g/100g based on dry weight. Also, the fiber and micronutrients content are very high. However, their expected intake levels, at least for the first stage of introduction process, need to remain quite low in order to define their exact heavy metals contents and in what terms this could be harmful for human health (*vide supra* §2.5.1).

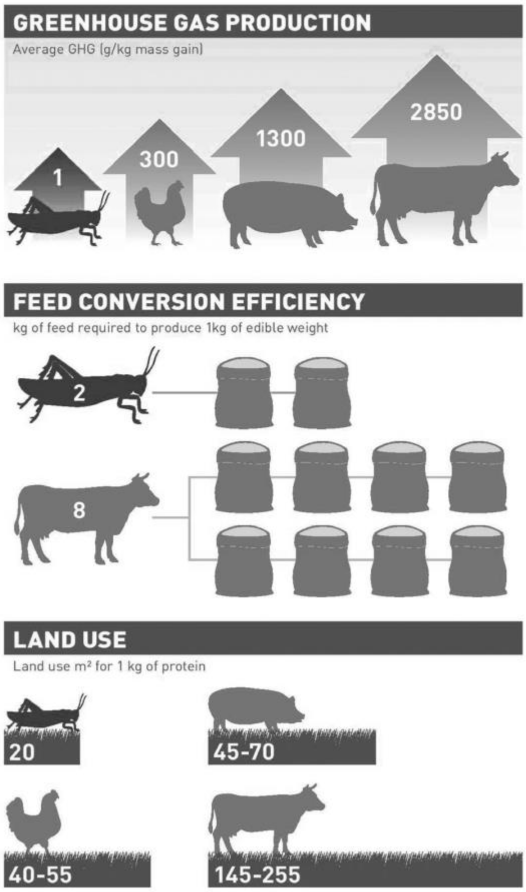

Figure 13: Environmental benefits for farmed insects (source: FAO, 2013)

The assumption is to gradually introduce insect-based products in the framework of Mediterranean diet, those could in part relieve the environmental impact of meat and fish products and be also a healthier alternative source of proteins. This process may sound complicated if we consider the impact Mediterranean diet has on the people who practice it, since it is not only regarded to nutritive aspects, but also to the social sphere. Vegetables, fruits and wheat products underlying the pyramid are linked to the rural tradition distinctive of those who live the Mediterranean basin. At this juncture, insect-based products introduction would place alongside with fish and meat consumption, already in itself products consumed less frequently in this dietary regimen. As for insect by-products like flours or powders, they still need to be mixed with common flours in order to be used, so they are considered complementary and not substitutes. For these reasons, insect-based products introduction in Mediterranean people's diets is set up as a draft of change towards a broader vision of food resources and sustainability.

In doing this should be taken into account several factors, starting from consumer behaviour and preferences to economic considerations about demand and offer. In the next paragraphs we will try to analyse data about the Italian panorama of edible insects, to see how we stand and what are the chances for the coming years.

3.2 CONSUMER BEHAVIOUR RELATED TO ENTOMOPHAGY

In the previous chapter it has been discussed about the anthropological and historical reasons why entomophagy is still considered a controversial dietary practice in the Western countries. Reasons are mostly related to culture: it has been amply demonstrated how our food choices are influenced by the society where we live and so by physiological and psychological factors. Some authors have tried to explain factors responsible for the aversion of edible insects: from the sensory properties (unpleasant taste and texture) to the perception of health risks (Sogari, 2015, pag. 312). However, food preferences are not permanent and may change over time: the acceptance of Japanese sushi in the Western world is a prime example.

Therefore, as suggested by Martins and Pliner (2007) in order to motivate the consumer's willingness to eat a new product (e.g. edible insects), the perception of disgust, especially for sensory characteristics, need to be reduced (Sogari, 2015, pag. 312). But literature about this topic is still little and few experimental studies associated with a tasting session have been identified. Only after the entry into force of Reg. (EU) 2283/2015 on "novel foods", some Italian researches started to analyse the topic on a trial basis. The study outlined by G. Sogari (2015), *Entomophagy and Italian consumers: an exploratory analysis*, was one of the first in this field.

3.2.1 ENTOMOPHAGY AND ITALIAN CONSUMERS: AN EXPLORATORY ANALYSIS

Data have been collected in Italy in April 2015, involving 46 individuals mixed by age and gender. They answered a questionnaire with semi-structured open-ended responses. The sample was recruited among the participants at a "bug banquet" event, where the nutritional and the environmental benefits of entomophagy were explained, followed by a tasting experiment. Before starting the tasting session, the participants were informed about the safety aspects and the potential allergenic risks of eating an arthropod.

The species of insects used in the experiment were house cricket (*Acheta domesticus*, LINNAEUS 1758), wax moth larvae (*Galleria mellonella*, LINNAEUS 1758) and grasshoppers (*Calliptamus italicus*, LINNAEUS 1758). All insects were cooked by roasting process in the oven and only salt was added during the preparation. This choice was taken in order to avoid the alteration of the taste and to permit the participants to better judge sensory characteristics of the insects (Sogari, 2015, pag. 313). Afterwards, the respondents had to answer a number of questions about which species were being preferred, their sensory characteristics and general expectation about the introduction of entomophagy. The second part of the questionnaire was constituted by a battery of items[30] used to understand the reasons which might influence the decision to consume insects in the future (Sogari, 2015, pag. 313).

Results outlined that more than half of the sample preferred wax moth larvae (63%), followed by grasshoppers (19%) and crickets (12%). Only a small part of the sample (6%) indicated that none of the three species above indicated was preferred. Despite the description of the insects given by the participants, one of the most interesting result is focused on family members and friends' opinion regards the introduction of this kind of product in the diet. More than half of the sample has indicated that this practice would not be approved and supported, while only few respondents believe that would receive consensus. This result clearly underlines how the importance of our relatives' opinions, especially about a negative attitude, is configured as a strong barrier to approach and to introduce entomophagy in the Western diet. Whereas, the most important factor to trigger the consumption of insects in the future is curiosity, followed by environmental and nutritional benefits (Sogari, 2015, pag. 314).

3.2.2 THE DISGUST FACTOR

As we saw, the new trend represented by entomophagy could be jeopardized by the aversion that people show for insects as food. The grounds of this are the significance and power of the effect of food neo-phobia and disgust on the intention to eat insect-based products, and the relationship between disgust and implicit attitude towards insects.

[30] Likert scale from one to five was used.

Food neo-phobia is the tendency to avoid unfamiliar food: it is hence a universal construct, but what is unfamiliar is of course culturally dependent. The Food Neo-phobia Scale (FNS) is the instrument developed and validated by Pliner and Hobden (1992) to quantify this individual characteristic. More specifically, the FNS examines the neophobia/neophilia continuum in humans. (La Barbera et al., 2017, pag. 121). Encouraging consumption of insect-based food implies making insect-based food more familiar. This will be a gradual process, which involves that more insect-based food products are introduced on the market, these products are discussed in public and private arenas, and more and more less neophobic people start eating them.

Disgust has been traditionally considered as a basic emotion, which is universal for all humans (Darwin, 1872) and protects individuals from any potential source of disease. Although disgust is a universal emotion, it is important to note that the factors eliciting disgust can be different across individuals and cultures. This is very clear in the case of entomophagy, because this practice is not disgusting for at least two billion people in South and East Asia and in several African, South, and Central American countries, whereas it elicits disgust in many others (FAO, 2013). Disgust is a primary emotion: its elicitation is culture specific and must be based on some kind of learned associations between the stimulus eliciting disgust and something else that is a more basic source of disgust. For Western people, insects have always been associated to disgusting item (e.g. faeces, decaying matter) and often with the idea of disease transmitters. Therefore, the implicit attitude deriving from implicit associations with insects could affect whether the exposure to insects or insect-related items – such as insect-based food – would elicit at disgust or not.

The key to adequate change is trying to reduce the basis for the elicitation of disgust by eating insects: being related to implicit attitudes, to reduce disgust reaction of Western people requires changes in those implicit attitudes. The dominant paradigm for analysing the formation and change of implicit attitudes has been evaluative conditioning[31]: it has been shown to be related to sensory perception of the food but can be achieved also just by pairing

[31] Evaluative conditioning is defined as a change in the valence of a stimulus that is due to the pairing of that stimulus with another positive or negative stimulus. The first stimulus is often referred to as the conditioned stimulus and the second stimulus as the unconditioned stimulus. A conditioned stimulus becomes more positive when it has been paired with a positive unconditioned stimulus and more negative when it has been paired with a negative unconditioned stimulus.

with images. This suggests that a more positive implicit attitude to eating insects and hence a lower incidence of disgust reactions could be achieved by developing insect-based products that are tasty, by embedding them in positive gastronomic experiences, and also by just pairing them with image and verbal stimuli that are known to be positively valued (La Barbera et al., 2017, pag. 124). In economic terms, this means turning some form of disutility[32], in this case the disgust, in utility (*vide infra* §3.3.4). Reducing the disgust factor implies making insect-based products more appealing and palatable. If it does not happen, market development for these new products cannot be possible. This transition from disgust to appeal justifies, somehow, the high costs of insect-based products production and distribution: at the moment, this is not cost-effectively sustainable, but there is also the hope for a decrease in costs with an increasing demand, given by a better awareness of this market in the next few years.

Though in recent years the scientific research on entomophagy has brought to a higher acceptance of the practice in the Western world, I believe it could suffer a stop in the growth of acceptance due to the pandemic caused by Covid-19[33].

3.3 EDIBLE INSECTS MARKET

The objective of the following economic analysis is to make an estimation of the possible price of a cricket-based line, supposing it will be sold in a closer future in the Italian supermarkets. The assessment also includes a qualitative utility analysis. After having explained the historical and social implications of entomophagy, I believe that to show the results obtained from this analysis could be useful in order to make an idea about future perspectives in more practical terms.

The global edible insects market size was valued at USD 0.41 billion in 2018 (Grand View Research, 2019) and it is expected to reach about USD 8 billion by 2030, supported by a CAGR[34] of 24.4% (period 2019 – 2030) (Meticulus Research, 2019). This growth could be justified by an increase in population which, along with scarcity of food resources, high demand for protein-

[32] If consumers demand for a product, it means they can afford its price (budget constraint) and they have a preference for it (utility): in the case of insect-based products disgust is a form of disutility which affects the formation of demand.
[33] Covid-19 was initially presented as a virus caused by eating uncommon animals (i.e. bat).
[34] Compound annual growth rate (CAGR) is a business and investing specific term for the geometric progression ratio that provides a constant rate of return over the time period.

rich food and environmental sustainability concern, is pushing consumption toward new kinds of products. The market appears segmented according to:

- product type (whole insect, animal feed, insect powder, insect protein bars, baked products, snacks, confectioneries, beverages, etc.);
- insect type;
- end use (human nutrition or animal consumption).

Moreover, it is characterised by the presence of many small and medium-sized firms, operating mainly at the local and regional levels.

In this scenario, Italy accounts for around 6% of total edible insect market in Europe, and the market revenue is forecasted to capture the value of $4.70 million by 2023, at a CAGR of 9.6% (2018-2023) (Hypercube Insights, 2018). Despite the expected growth, the national market still relies on imports, with very few small-sized firms located in the northern part of the country.

3.3.1 TACKLING THE ECONOMIC PROBLEM

The objective of this analysis is two-fold. First, to empirically estimate the possible price of a cricket-based line, under the hypothesis it will be put, in a closer future, on the shelves of Italian supermarkets. Second, to identify the characteristics, for each category of product, that mainly impact on consumers utility, trying to elicit information about buyers' preferences. According to a research carried out by *Doxa*[35] in 2018, 40% of Italian people consider insect-based products as one of the future foods and they are ready to taste them, at least for curiosity (*vide supra* §3.2.1). Here the hypothesis of supermarkets as possible future retailers, considering also the interest shown, in the last years, by some large-scale chains (i.e. *Pam* and *Coop*) toward this kind of novel foods.

The choice to focus on crickets, instead, takes into account both that this segment dominated the global edible-insects market in 2019 (Meticulus Research, 2019), and that cricket-based products, sold online, involve lot of different foods from baked products, to aperitif, sweet products and protein bars.

[35] www.bva-doxa.com

3.3.2 CREATION OF DATABASES

This descriptive analysis was carried out collecting data about 34 cricket-based products, prices of 90 common products sold at physical stores and 68 sold online[36].

The research was conducted by digitising, in the Google research bar, simple Italian words and sentences (e.g. "prodotti a base di insetti shop online"; "acquistare insetti online") to find the more visited web sites that trade insect products also in Italy. The internet platforms used as source were:

- www.multivores.com/it/
- www.21bites.it
- www.insetticommestibili.it
- www.bugsolutely.com
- www.futurefoodshop.com
- www.cricketfood.com
- www.exoprotein.com
- www.tibiona.it

Data about cricket-based foods have been collected on 10th January and 2nd February 2020. The observations have been divided by type of product[37] and information about brand, price/kilo, price per portion, portion size, percentage of crickets used, claims and certifications applied have been reached. As regard normal products data on price/kilo, price/portion and portion size have been collected in two ways: visiting the more common Italian web platforms to shop online (i.e. www.supermercato24.it and www.prontospesa.it) as well as doing surveys at supermarkets[38]. So as to check if there was a price difference between the two-selling channels.

Hence, products that can be substituted with crickets ones from the utilisation point of view (e.g. wheat pasta – cricket pasta) have been taken into analysis, choosing as reference basic foods, without any particular feature: wheat flour, durum wheat pasta, wheat salted crackers, salted peanuts, protein bars and pralines. Each one of these could be substituted by a cricket product in exception of flour: cricket powder needs to be paired with normal flour in

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[36] *Vide infra* Annex 1, Annex 2 and Annex 3.

[37] Cricket powder, cricket pasta, cricket crackers, whole crickets for aperitif, pralines of crickets and cricket protein bars.

[38] Auchan, Carrefour, Alì, Crai and Esselunga.

order to be used, so it can be defined as a complementary good. It is important to note that prices from websites do not consider shipment costs neither for crickets nor for normal products.

3.3.3 PRICE DETERMINATION

The calculations included arithmetic average and standard deviation of prices per kilo both for cricket products and for common products sold online and at supermarkets. In order to evaluate the difference between online and physical retailers, the average price per kilo of common products at the two-selling channels have been compared, through this formula:

$$\frac{P_{supermarket} - P_{online}}{P_{online}}$$

The obtained percentage difference was the applied to the average price per kilo of cricket products.

From the collected data it emerges that prices remained quite stable in the considered period, except for few reductions registered on websites *Thailand Unique* and *21bites*, which have been taken into account in determining the average price of products. Moreover, given that on the website *Future Food Shop*, prices are reported in GBP, the correspondent prices in € are affected by the currency conversion of the period when the purchase occurs. Also, in this case, it has been decided to include them in the calculation.

Another important aspect to be underlined is the exclusion of shipment costs from the estimation. In fact, different companies choose different shipment policies: some of them provide for costs that are function of the amount of product bought, other apply fixed costs and the last ones adopt free shipment for orders over certain monetary values. Therefore, the impacts of these costs per unit of good depends significantly on the size of the final expenditure. Given the absence of data about the real volume of orders from Italy, it was not possible to estimate a final price that included also shipment costs.

In Table 6 are reported average prices ($\bar{x}$) and standard deviation (σ) for each category, along with minimum and maximum prices, necessary for the utility evaluation.

	Average (St. dev.) (€/Kg)	Min (€/Kg)	Max (€/kg)
Cricket flour	€ 206,62 (± € 237,22)	49,50 €	800,00 €
Cricket pasta	€ 31,20 (± € 15,60)	6,88 €	47,44 €

Cricket crackers	€ 61,18 (± € 15,81)	48,00 €	102,88 €
Whole crickets	€ 388,39 (± € 372,12)	99,50 €	1.300,00 €
Sweet crickets	€ 259,30 (± € 213,59)	106,80 €	632,67 €
Protein bars	€ 43,92 (± € 8,29)	35,00 €	55,00 €

Table 6: Average prices and standard deviation for cricket-base products categories

Analysing the results, it has been noticed a high dispersion of online prices for some categories (high standard deviation values). In order to appraise a final price for a standard cricket-based production, it has been decided to calculate new average worth excluding the observations outside the range $\bar{x} \pm \sigma$ (fig.12).

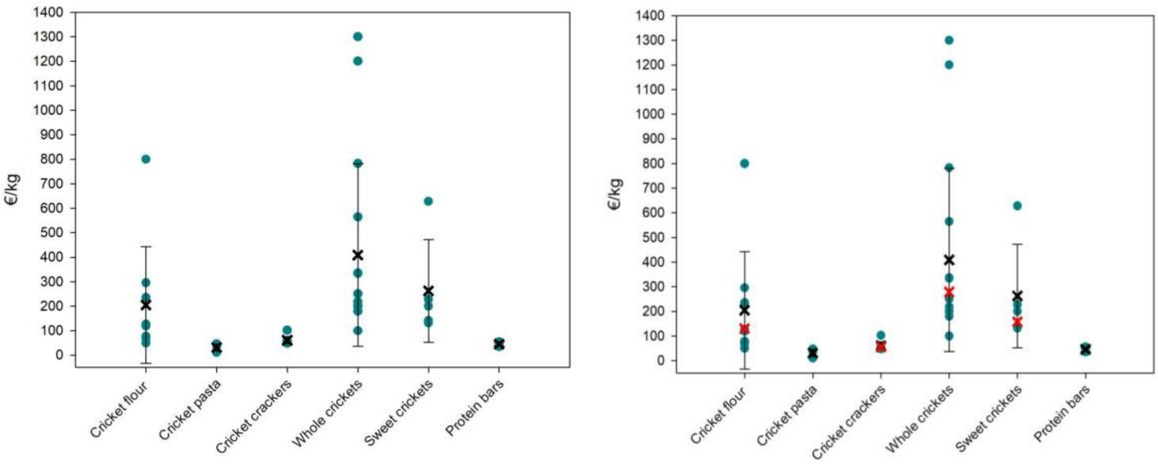

Figure 14: Vertical dispersion graph of insect-based products online prices: black 'x' average price // red 'x' new average prices for "standard" insect products

The new values are reported in Table 7, and they are the ones used to estimate final supermarket prices.

	Average (St. dev.) (€/Kg)	New Average (St. dev.) (€/kg)
Cricket flour	€ 206,62 (± € 237,22)	€ 132,45 (± € 87,89)
Cricket pasta	€ 31,20 (± € 15,60)	€ 31,20 (± € 15,60)
Cricket crackers	€ 61,18 (± € 15,81)	€ 56,01 (± € 3,29)
Whole crickets	€ 388,39 (± € 372,12)	€ 247,56 (± € 124,62)
Sweet crickets	€ 259,30 (± € 213,59)	€ 153,28 (± € 42,74)
Protein bars	€ 43,92 (± € 8,29)	€ 43,92 (± € 8,29)

Table 7: Average and new average prices with standard deviation

Using the common products prices as reference for cricket foods price determination, in Table 8 the arithmetic average of price per kilo and its standard deviation by each food category have been reported, either for products sold at supermarkets that the ones sold at web retailer platforms. It has been noticed a price difference between the same food categories at the two-selling channel. Indeed, common products sold online present higher prices than the ones of supermarkets, even if the online prices do not include a price increment due to home delivery expenditure (it is added as extra cost at the end of the shop). Percentage difference by each category are reported in the last column of Table 8, while its last value at the bottom is an average of the total results. It is considered also the total average difference because of lack of literature about the mechanisms behind the increment of online prices. In fact, it was not possible to say if the rising of price depended on food category or if it is a common percentage rate and the different categories percentage values obtained derived from the small size of the dataset used.

Product category	Supermarket samples (N°)	Supermarket price (Dev. Stan.)	Online samples (N°)	Online price (Dev. Stan.)	Percentage difference
Flour	13	€ 0,68 (±0,28)	7	€ 0,88 (±0,31)	-22,69%
Pasta	26	€ 1,98 (±0,46)	22	€ 2,33 (±0,54)	-15,02%
Crackers	19	€ 2,60 (±0,36)	12	€ 3,11 (±0,34)	16,39%
Salted peanuts	10	€ 8,00 (±2,28)	10	€ 9,09 (±1,67)	-11,99%
Pralines	17	€ 25,11 (±4,31)	10	€ 29,33 (±5,63)	-14,39%
Protein bars	5	€ 37,87 (±10,28)	7	€ 45,00 (±14,05)	-15,84%
Total average					-16,06%

Table 8: Sum up of Datasets on common products sold online and at supermarkets (for completed data see Annex 2 and Annex 3)

Successively, it has been reported in the Table 9 the recalculated average prices per kilo of cricket items with the application of the percentage difference either by category that the total average. It is necessary to remember that price of flour is the least reliable, because if price from internet to physical supermarkets changes by category the average percentage applied to this category leads to a result which is not the most suitable.

		Possible price at shelves (min;max) €/kg	
Product Category	Average price (min;max) €/kg	Category % applied	Average % applied
Cricket flour	€132,45 (€49,50; €800,00)	**€102,40** (€38,27; €618,48)	**€111,18** (€41,55; €671,52)
Cricket pasta	€31,20 (€6,88; €47,44)	**€26,51** (€5,85; €40,31)	**€26,19** (€5,87; €39,82)
Cricket crackers	€ 56,01 (€48,00; €102,88)	**€46,83** (€40,13; €86,02)	**€47,01** (€40,29; €86,36)
Whole crickets	€247,56 (€99,50; €1300,00)	**€217,88** (€87,57; €1144,13)	**€207,80** (€83,52; €1091,22)
Sweet crickets	€153,28 (€106,80; €632,67)	**€131,22** (€91,43; €541,63)	**€128,66** (€89,65; €531,06)
Protein bars	€ 43,92 (€35,00; €55,00)	**€36,96** (€29,46; €46,29)	**€36,87** (€29,38; €46,17)

Table 9: Cricket-based products average price per kilo and their possible prices at supermarkets shelves

3.3.4 UTILITY DETERMINATION

As the utility refers to the total satisfaction received from consuming a good or service, the neoclassical economic theory, based on rational choice, assumes that consumers will strive to maximize their utility.

Regarding the analysis for this cricket-based line it has been decided to apply the Lancaster model theory, in a qualitative way. It states that consumers derive utility not from the actual contents of the basket but from the characteristics of the goods in it. It implies that the final price is determined by this formula:

$$P_{final} = \bar{P}\ (standard\ product\ price) + utility\ given\ by\ each\ feature\ of\ the\ good$$

Tables in the Annex 4 shows the information provided by the online shops and by labels, for each considered product. Looking at the most advertised features and data from the literature, considering cricket-based foods as a whole, characteristics which seemed to affect price have been listed, dividing them in two groups: those that could have a positive influence (+) on the utility and those that have a positive or negative influence (+/-) on it and could also be uninfluential.

+	+/-
% insects	organic
% proteins (quality)	natural
brand	sustainability
safety/traceability	whole VS processed products
nutritional claims	

Table 10: Characteristics which affect price

For instance, the percentage of insects seems to play an essential role in price determination, given that both cricket flour and whole insects (sweet and salted) have market prices significantly higher than the other products considered. This could be related to the fact that trade in insects as food to Western countries is driven mainly by demand from migrated communities, or by the development of niche markets for exotic foods (Van Huis, et al., 2013). So, we can suppose that, nowadays, consumers of insects in western areas are people really interested in eating them, and not merely looking for simple market substitutes of traditional foodstuffs. However, knowing that prices are representations not only of the maximization of consumer utility, but also of the firm profit, we can suppose that higher prices could reflect higher costs of production, too. In fact, despite there are no standards governing rearing and processing of insects, suppliers have to pay attention to lot of conditions in the rearing facility such as temperature, light, humidity, ventilation, rearing containers, population density, etc. (Rumpold & Schluter, 2013). As it emerges from the literature, confirmed by *Insetti Commestibili*, an Italian producer operating in Veneto, manual labour is still required to complete lot of these tasks, leading to a significant increase in costs. Taking into account, instead, claims about nutritional properties, protein content and quality it has been supposed they might affect consumer utility because of the frequency at which they appear on labels (considering that generally they are not advertised in the corresponding traditional foods). This is consistent with the commonly accepted practice of classifying insects as protein-rich products (Lombardi et al., 2019). Finally, guarantees about safety/traceability, even if not directly reported on the package, seem to be of a high importance for food purchase process, especially for edible-insects case (Lombardi et al., 2019). Brand turned out to be always influential for price change.

Among features on the right part of the table (+/-), few words should be spent on whole insects compared to processed products. From the collected data prices of whole products are higher respect to powder ones (*vide infra* Annex 4), in contrast with the results of some researches showing a lower acceptability in developed countries, for the visible insect (Peri, 2013) (Vantomme et al., 2014). This could be explained, probably, by higher costs of production, more than real higher consumers utility. Indeed, in case of whole crickets, selection and packaging are done manually, too. Moreover, the packaging should be resistant enough to avoid damages to the dried insect as well as to guarantee the freshness of the product. According to the information provided by *Insetti Commestibili*, each pack costs around 60-70 cents, an expensive input considering that the average weight of the product in a box is 15g. Other considerations can be made on information such as "sustainable" or "natural", which are not always associated with the most expensive cricket foods; probably because they depend on consumers awareness about their definition and importance, thus the associated utility can change within countries and consumers profiles considered (Cecchini et. al, 2017).

Lastly, it has been tried to identify the key determinants in the difference between minimum and maximum prices for each product categories, as showed in Table 11.

Product	Min. Price (€/kg)	Max. Price (€/kg)	Key determinant
Flour	49,50 €	800 €	Natural claim
Pasta	6,88 €	47,44 €	Brand / % insects
Crackers	48,00 €	102,88 €	Brand
Whole crickets	99,50 €	1300,00 €	Nutritional aspects / organic
Sweet crickets	106,80 €	632,67 €	% insects / sustainability
Protein bars	35,00 €	55,00 €	% proteins (quality) / organic

Table 11: Key determinants in the difference between minimum and maximum prices

The most interesting cases are:

- cricket pasta, where percentage of insects seem to be important, becoming higher for higher prices. However, goods with the minimum and maximum price share in common the amount of cricket in them, making us to suppose that for this category brand plays an essential role on utility;
- cricket crackers, where the product presenting the higher price does not possess particular distinctive properties respect to others. Moreover, despite the percentage of insects in it is the lower among the considered goods, looking at all the crackers it is not possible to suppose a negative correlation between insect content and prices for this category. So, brand seems most important than other traits;
- whole crickets, where is registered the higher difference between minimum and maximum price. Looking at the data emerges that the most expensive product is characterised by high nutritional value, as well as organic certification. Nevertheless,

these claims can be found on other items, too, leading to hypothesize that a so high price could depend, once again, mainly on the brand.

To conclude, it is important to underline that all the assumptions that has been made were based on very few data and that, according to willingness to pay literature analysis, different claims have different impact on WTP[39], based on individual variables such as consumer profile and preferences, as well as place, country and type of product.

3.3.5 RESULTS AND CRITICISMS

The results of this investigation allowed to suppose that a cricket-based line could be put on Italian supermarket shelves at lower prices respect to the same products today supplied by online platforms. This, along with a higher availability of this kind of foods, might lead to a possible increase in demanded quantity. Considering, instead, factors affecting consumers utility, health-related attributes seem to be the most influent features, along with percentage of insect used, while environmental aspects, up to now, do not impact so much on the final price. However, from the data obtained, variations are present among different categories, and, as emerges from the literature, for this kind of products information on the benefits of insect consumption plays a major role in consumers acceptability and WTP (Lombardi et al., 2019).

Despite the obtained results are consistent with supermarket prices applied for insect-based products in other European countries[40] and that the identified features which could affect consumers utility are supported by data from the literature, this empirical analysis presents lot of criticisms. First of all, complete and available databases nor on edible insects prices nor on online and retail food prices have been found. The datasets created are based on very few observations and they include prices registered only at the beginning of 2020. So, to obtain more consistent results, it would be necessary to collect more data covering a wider timespan (one or several years). This might allow, also, to capture possible changes in consumers preference and utility for the considered novel foods.

Secondly, the online platforms included in the analysis operates at the international level and, therefore, prices probably derive from the equilibrium between an international demand and an international supply. It is possible to suppose, then, that the real demand in Italy could

[39] Willingness to Pay.
[40] A box containing 14 g of whole crickets, produced by Jimini, are sold at 7€ by Carrefour in Spain.

be different from the global one, because of different consumers attitudes, habits and values, resulting in different market prices.

The last problem is that considerations on consumers utility are made only looking at prices and not at real transactions data, in fact, we do not know what, among the analysed goods, are the most consumed ones. Hence, it is quite difficult to understand if higher prices are a reflection mainly of higher costs of production or of an effective higher preference of consumers toward certain attributes.

In the end, to understand the truthfulness of these hypothesis it would be necessary to access to Italian transaction data, as well as to have more studies carried out on Italian consumers (both on new potential buyers, adopting contingent valuation methods, and on people who already consume edible insects, through hedonic pricing approach).

CONCLUSIONS

Over the last few years, researchers have produced a significant amount of literature on edible insects. These works primarily focus on nutritional aspects and environmental issues, with the prospect of finding new and sustainable food resources for a world whose population is ever growing. The assessment of such strands is certainly helpful to shed more light on food consumption and the impact it has on our lives as well as on our planet. In fact, it has become apparent that it is necessary to rethink our approach to food, in a more sustainable and future-oriented way.

The reasons why we should consider introducing edible insects and insect-based products in our future dietary patterns have been largely discussed. There is however a clear lack of literature about the historical and psychological processes that have brought some people to consider them disgusting and some other to eat them regularly. Except for F.S. Bodenheimer's *Insects as human food* (1951) and Marvin Harris' *Good to eat* (1985), dealing with the topic respectively from a historical and an anthropological point of view, only recently researchers started to publish on the psychological aspects of eating novel foods and on consumer behaviour. Nevertheless, this research avenue still lacks the number of trials necessary to be considered significant. Even less material was produced in the historical area after *Insects as human food* (Bodenheimer, 1951), where results on Asian and Oceanian populations are often inaccurate.

One of the aims of this dissertation, especially in relation to the definition of a timeline of entomophagy, is to try and piece together all the historical sources available in an effort to catalogue them temporally and geographically. Throughout the analysis of historical, religious and legislative texts it was easier to ascertain Marvin Harris' cultural materialism theory: foods that are better to eat are those that tip the scale towards pragmatic benefits. Edible insects still do not do this, at least in the Western countries, where people avoid eating them. Further to that, we should consider Western people's (tendency to) neophobia towards exotic products and the mental pairing "insect-dirt" they usually make. The disgust factor determines the primary cause for the refusal of eating insects: reducing it implies making insect-based products more appealing and palatable. If that does not happen, market development for these new products cannot be possible.

Focusing on the Mediterranean diet framework, the assumption is to gradually introduce insect-based products in order to provide an alternative source of proteins, relieving in part the impact meat and fish production has on the environment. At the moment, this process is not cost-effectively sustainable, but there is the hope for a decrease in costs with an increasing demand and a better awareness about insects and their by-products in the next few years.

ANNEX

A1: Dataset on cricket-based products online prices

			1/10/2020		2/2/2020		
Website	Brand	Serving (g)	Price per serving (€)	Price (€/kg)	Price per serving (€)	Price (€/kg)	Price (€/kg)
Cricket flour							
https://www.multivores.com/it/	Tmeatfood (fr)	100	12,60 €	126,00 €	" "	" "	**126,00 €**
https://21bites.it/	Entopure(holland)	100	25,95 €	295,50 €	" "	" "	**295,50 €**
http://www.insetticommestibili.it/	Small Chomp (IT)	20	16,00 €	800,00 €	" "	" "	**800,00 €**
https://www.futurefoodshop.com/#	Cruncy critters	100	7,16 €	71,60 €	7,66 €	76,60 €	**74,10 €**
https://www.futurefoodshop.com/#	Eat Crawlers	50	11,78 €	235,60 €	11,86 €	237,20 €	**236,40 €**
https://crickefood.com/	Crické	100	11,95 €	119,50 €	" "	" "	**119,50 €**
https://tibiona.it/	TiBioNa (IT)	100	4,95 €	49,50 €	" "	" "	**49,50 €**
https://exoprotein.com/	Exo	113	10,80 €	95,58 €	" "	" "	**95,58 €**
https://www.thailandunique.com/	Thailand Unique	100	6,75 €	67,50 €	5,85 €	58,50 €	**63,00 €**
Average: € 206,62 (± € 237,22)							
Cricket pasta							
https://www.multivores.com/it/	Tmeatfood (fr)	125	4,65 €	37,20 €			**37,20 €**
https://www.multivores.com/it/	Tmeatfood (fr)	125	4,50 €	36,00 €			**36,00 €**
https://www.multivores.com/it/	Tmeatfood (fr)	125	5,40 €	43,20 €			**43,20 €**
https://www.thailandunique.com/	Nutribug	250	3,50 €	14,00 €	1,72 €	6,88 €	**10,44 €**
https://www.futurefoodshop.com/#	Eat Crawlers	250	11,74 €	46,96 €	11,86 €	47,44 €	**47,20 €**
https://www.bugsolutely.com/	Bugsolutely	350	3,90 €	11,14 €	5,30 €	15,14 €	**13,14 €**
Average: € 31,20 (± € 15,60)							

Cricket crackers							
https://21bites.it/	Crickè (UK)	85	4,90 €	57,65 €	" "	" "	**57,65 €**
https://21bites.it/	Crickè (UK)	85	4,90 €	57,65 €	" "	" "	**57,65 €**
https://21bites.it/	Crickè (UK)	85	4,90 €	57,65 €	" "	" "	**57,65 €**
https://21bites.it/	Crickè (UK)	85	4,90 €	57,65 €	" "	" "	**57,65 €**
https://21bites.it/	Little Food	125	6,00 €	48,00 €	" "	" "	**48,00 €**
http://www.insetticommestibili.it/	Small Chomp (IT)	160	9,00 €	56,25 €	" "	" "	**56,25 €**
https://www.futurefoodshop.com/#	Little food	125	7,06 €	56,32 €	7,11 €	56,88 €	**56,60 €**
https://www.futurefoodshop.com/#	Little food	125	7,04 €	56,48 €	7,11 €	56,88 €	**56,68 €**
https://www.futurefoodshop.com/#	Minusfarm(Fr)	45	4,60 €	102,22 €	4,63 €	102,89 €	**102,56 €**
Average: € 61,18 (± € 15,81)							

Whole crickets for aperitif							
https://www.multivores.com/it/	Tmeatfood (fr)	35	6,99 €	199,71 €	" "	" "	**199,71 €**
https://www.multivores.com/it/	Tmeatfood (fr)	35	6,99 €	199,71 €	" "	" "	**199,71 €**
https://www.multivores.com/it/	Tmeatfood (fr)	35	6,99 €	199,71 €	" "	" "	**199,71 €**
https://www.multivores.com/it/	Tmeatfood (fr)	35	7,10 €	202,86 €	" "	" "	**202,86 €**
https://www.multivores.com/it/	Tmeatfood (fr)	35	6,99 €	199,71 €	" "	" "	**199,71 €**
https://www.multivores.com/it/	Tmeatfood (fr)	35	7,10 €	202,86 €	" "	" "	**202,86 €**
https://www.multivores.com/it/	Tmeatfood (fr)	50	12,50 €	250,00 €	" "	" "	**250,00 €**
https://21bites.it/	Micronutris (Fr)	5	6,00 €	1.200,00 €	" "	" "	**1.200,00 €**
https://21bites.it/	Micronutris (Fr)	5	6,00 €	1.200,00 €	" "	" "	**1.200,00 €**
https://21bites.it/	Micronutris (Fr)	5	6,50 €	1.300,00 €	" "	" "	**1.300,00 €**
https://21bites.it/	Jimini's	14	7,90 €	564,29 €	" "	" "	**564,29 €**
https://21bites.it/	Jimini's	14	7,90 €	564,29 €	" "	" "	**564,29 €**

https://www.futurefoodshop.com/#	Little Food	35	7,64 €	218,29 €	7,72 €	220,57 €	**219,43 €**
https://www.futurefoodshop.com/#	Little Food	35	7,64 €	218,29 €	7,72 €	220,57 €	**219,43 €**
https://exoprotein.com/	EXO	15	2,70 €	180,00 €	" "	" "	**180,00 €**
https://exoprotein.com/	EXO	15	2,70 €	180,00 €	" "	" "	**180,00 €**
https://exoprotein.com/	EXO	15	2,70 €	180,00 €	" "	" "	**180,00 €**
https://exoprotein.com/	EXO	15	2,70 €	180,00 €	" "	" "	**180,00 €**
http://www.insetticommestibili.it/	Small Chomp (IT)	15	5,00 €	333,33 €	" "	" "	**333,33 €**
https://crickefood.com/	Crické	100	9,95 €	99,50 €	" "	" "	**99,50 €**
https://www.thailandunique.com/	Thailand Unique	15	5,04 €	336,00 €	3,40 €	226,67 €	**281,33 €**
Average: € 388,39 (± € 372,12)							
Sweet crickets							
https://www.multivores.com/it/	Tmeatfood (fr)	35	6,99 €	199,71 €	" "	" "	**199,71 €**
https://21bites.it/	Entis (Finland)	50	6,60 €	132,00 €	" "	" "	**132,00 €**
https://21bites.it/	Entis (Finland)	50	6,60 €	132,00 €	" "	" "	**132,00 €**
https://21bites.it/	Entis (Finland)	50	6,60 €	132,00 €	" "	" "	**132,00 €**
https://www.futurefoodshop.com/#	Eat Crawlers	15	9,42 €	628,00 €	9,49 €	632,67 €	**630,33 €**
https://www.futurefoodshop.com/#	Eat Crawlers	15	9,42 €	628,00 €	9,49 €	632,67 €	**630,33 €**
https://www.futurefoodshop.com/#	Wholi	50	7,07 €	141,40 €	5,34 €	106,80 €	**124,10 €**
https://www.futurefoodshop.com/#	Wholi	50	7,07 €	141,40 €	5,34 €	106,80 €	**124,10 €**
https://www.thailandunique.com/	Thailand Unique	11	2,50 €	227,27 €	2,54 €	230,91 €	**229,09 €**
Average: € 259,30 (± € 213,59)							
Protein bars							
https://21bites.it/	Jimini's	40	2,20 €	55,00 €	" "	" "	**55,00 €**
https://21bites.it/	Jimini's	40	2,20 €	55,00 €	" "	" "	**55,00 €**

https://21bites.it/	Jimini's	40	2,20 €	55,00 €	" "	" "	**55,00 €**
https://21bites.it/	Jimini's	40	2,20 €	55,00 €	" "	" "	**55,00 €**
https://21bites.it/	SENS	60	2,80 €	46,67 €	2,33 €	38,83 €	**42,75 €**
https://21bites.it/	SENS	60	2,80 €	46,67 €	2,33 €	38,83 €	**42,75 €**
https://21bites.it/	SENS	50	2,33 €	46,60 €	1,85 €	37,00 €	**41,80 €**
https://21bites.it/	SENS	50	2,33 €	46,60 €	1,85 €	37,00 €	**41,80 €**
https://21bites.it/	SENS	50	2,33 €	46,60 €	1,85 €	37,00 €	**41,80 €**
https://exoprotein.com/	EXO	60	2,10 €	35,00 €	" "	" "	**35,00 €**
https://exoprotein.com/	EXO	60	2,10 €	35,00 €	" "	" "	**35,00 €**
https://exoprotein.com/	EXO	60	2,10 €	35,00 €	" "	" "	**35,00 €**
https://exoprotein.com/	EXO	60	2,10 €	35,00 €	" "	" "	**35,00 €**
Average: € 43,92 (± € 8,29)							

A2: Dataset on common products at physical supermarkets

Supermarket	Brand	Serving (g)	Price per serving	Price (€/kg)
		Salted Crackers		
Alì	Vale	500	€ 1,20	€ 2,40
Alì	Doriano	500	€ 1,49	€ 2,98
Alì	Mulino Bianco	500	€ 1,28	€ 2,56
Carrefour	Carrefour	500	€ 1,09	€ 2,18
Carrefour	Doriano	700	€ 2,05	€ 2,93
Carrefour	Gran Pavesi	560	€ 1,55	€ 2,77
Carrefour	Mulino Bianco	500	€ 1,65	€ 3,30
	Mulino Bianco	560	€ 1,49	€ 2,66
Auchan	Gran Pavesi	500	€ 1,55	€ 2,77
Auchan	Auchan	560	€ 1,15	€ 2,05
Auchan	Mulino Bianco	500	€ 1,25	€ 2,50
Auchan	Doriano	700	€ 1,65	€ 2,36
Auchan	Auchan	500	€ 1,09	€ 2,18
Crai	Gran Pavesi	560	€ 1,65	€ 2,95
Crai	Mulino Bianco	500	€ 1,55	€ 3,10
Crai	Crai	560	€ 1,49	€ 2,66
Esselunga	Esselunga	560	€ 1,19	€ 2,13
Esselunga	Gran Pavesi	560	€ 1,49	€ 2,67
Esselunga	Mulino Bianco	500	€ 1,12	€ 2,24
		Wheat flour 00		
Alì	Barilla	1000	€ 0,41	€ 0,41
Alì	Molino Rossetto	1000	€ 0,46	€ 0,46
Carrefour	Simec	1000	€ 0,35	€ 0,35
Carrefour	Barilla	1000	€ 0,59	€ 0,59
Crai	Barilla	1000	€ 0,59	€ 0,59
Crai	Crai	1000	€ 0,53	€ 0,53
Crai	Dal Borgo	1000	€ 0,59	€ 0,59
Crai	Molino Spadoni	1000	€ 1,19	€ 1,19
Esselunga	Esselunga	1000	€ 0,48	€ 0,48
Esselunga	Barilla	1000	€ 0,79	€ 0,79
Esselunga	Moluno Chiavazza	1000	€ 0,99	€ 0,99
Auchan	Molino Chiavazza	1000	€ 1,20	€ 1,20
Auchan	Barilla	1000	€ 0,66	€ 0,66
		Durum wheat pasta		
Alì	Voiello	500	€ 1,08	€ 2,16
Alì	De Cecco	500	€ 1,09	€ 2,18
Alì	Sgambaro	500	€ 0,95	€ 1,90
Alì	Barilla	500	€ 0,65	€ 1,30

Carrefour	De Cecco	500	€ 0,97	€ 1,94
Carrefour	Voiello	500	€ 1,25	€ 2,50
Carrefour	Rummo	500	€ 1,19	€ 2,38
Carrefour	Molisana	500	€ 1,03	€ 2,06
Carrefour	Pasta Zara	500	€ 0,79	€ 1,58
Crai	Sgambaro	500	€ 1,05	€ 2,10
Crai	Crai	500	€ 1,49	€ 2,98
Crai	Garofalo	500	€ 0,99	€ 1,98
Crai	Barilla	500	€ 0,69	€ 1,38
Esselunga	Esselunga	500	€ 0,59	€ 1,18
Esselunga	Rummo	500	€ 1,25	€ 2,50
Esselunga	De Cecco	500	€ 0,81	€ 1,62
Esselunga	Voiello	500	€ 1,25	€ 2,50
Auchan	Voiello	500	€ 0,75	€ 1,50
Auchan	De Cecco	500	€ 0,95	€ 1,90
Auchan	Liguori	500	€ 1,29	€ 2,58
Auchan	Garofalo	500	€ 0,99	€ 1,98
Auchan	Rummo	500	€ 1,19	€ 2,38
Auchan	Pasta Jolly	500	€ 1,09	€ 2,18
Auchan	Pasta Jolly	500	€ 0,79	€ 1,58
Auchan	Sgambaro	500	€ 0,95	€ 1,90
Auchan	Barilla	500	€ 0,65	€ 1,30
Salted Peanuts				
Alì	Vale	250	€ 1,65	€ 6,60
Alì	Cameo	300	€ 2,79	€ 9,39
Carrefour	Cameo	500	€ 4,09	€ 8,18
Carrefour	Carrefour	250	€ 1,45	€ 5,80
Crai	Crai	250	€ 1,19	€ 4,76
Crai	Cameo	300	€ 2,39	€ 7,97
Esselunga	Esselunga	300	€ 1,75	€ 5,84
Esselunga	EuroCompany	200	€ 2,29	€ 11,45
Auchan	Nut Club	250	€ 2,80	€ 11,20
Auchan	San Carlo	300	€ 2,65	€ 8,83
Pralines				
Alì	Baci	200	€ 5,50	€ 27,50
Alì	Perugina	200	€ 5,50	€ 27,50
Carrefour	Mon cheri	168	€ 4,25	€ 25,30
Carrefour	Lindor	200	€ 5,99	€ 29,95
Carrefour	Ferrero	200	€ 5,69	€ 28,45
Crai	Baci	200	€ 6,49	€ 32,45
Crai	Mon cheri	168	€ 4,15	€ 24,70
Crai	Ferrero	200	€ 5,19	€ 25,95

Crai	Lindor	200	€ 5,99	€ 29,95
Esselunga	Pocket Coffee	225	€ 4,79	€ 21,29
Esselunga	Lindor	200	€ 4,99	€ 24,95
Esselunga	Mon cheri	168	€ 4,19	€ 24,95
Auchan	Delacre	125	€ 1,99	€ 15,92
Auchan	Mon cheri	168	€ 4,20	€ 25,00
Auchan	Pocket Coffee	225	€ 7,50	€ 18,75
Auchan	Passioni	155	€ 2,99	€ 19,29
Auchan	Baci	200	€ 4,99	€ 24,95
Protein bars				
Alì	Enervit	40	€ 1,00	€ 25,00
Alì	Enervit	40	€ 1,50	€ 37,50
Carrefour	Enervit	40	€ 1,77	€ 44,22
Carrefour	Enervit	40	€ 1,26	€ 31,50
Esselunga	Maama	40	€ 2,05	€ 51,15

A3: Dataset on common products on online shop platforms

Website	Supermarket	Brand	Serving (g)	Price per serving	Price per kilo
Wheat flour 00					
www.supermercato24.it	Alì	Molino Rossetto	1000	€ 1,19	€ 1,19
www.supermercato24.it	Alì	Barilla	1000	€ 0,66	€ 0,66
www.supermercato24.it	Auchan	Spadoni	1000	€ 1,43	€ 1,43
www.supermercato24.it	Auchan	Barilla	1000	€ 0,70	€ 0,70
www.supermercato24.it	Carrefour	Barilla	1000	€ 0,79	€ 0,79
https://www.prontospesa.it/	-	Barilla	1000	€ 0,79	€ 0,79
https://www.prontospesa.it/	-	Crai	1000	€ 0,59	€ 0,59
Salted crackers					
www.supermercato24.it	Alì	Doriano	700	€ 1,86	€ 2,66
www.supermercato24.it	Alì	Colussi	500	€ 1,68	€ 3,36
www.supermercato24.it	Alì	Mulino Bianco	500	€ 1,73	€ 3,46
www.supermercato24.it	Auchan	Gran Pavesi	560	€ 1,66	€ 2,96
www.supermercato24.it	Auchan	Mulino Bianco	500	€ 1,56	€ 3,12
www.supermercato24.it	Auchan	Doriano	700	€ 1,98	€ 2,83
www.supermercato24.it	Carrefour	Carrefour	500	€ 1,35	€ 2,70
www.supermercato24.it	Carrefour	Gran Pavesi	500	€ 1,89	€ 3,38
www.supermercato24.it	Carrefour	Mulino Bianco	500	€ 1,59	€ 3,18
https://www.prontospesa.it/	-	Crai	500	€ 1,33	€ 2,66
https://www.prontospesa.it/	-	Mulino bianco	500	€ 1,79	€ 3,58
https://www.prontospesa.it/	-	Gran Pavesi	560	€ 1,95	€ 3,48
Durum wheat pasta					

www.supermercato24.it	Alì	De Cecco	500	€ 1,26	€ 2,52
www.supermercato24.it	Alì	De Cecco	500	€ 1,19	€ 2,38
www.supermercato24.it	Alì	Voiello	500	€ 1,50	€ 3,00
www.supermercato24.it	Alì	Garofalo	500	€ 1,19	€ 2,38
www.supermercato24.it	Alì	Pata Jolly	500	€ 0,95	€ 1,90
www.supermercato24.it	Alì	Barilla	500	€ 0,95	€ 1,90
www.supermercato24.it	Auchan	Voiello	500	€ 1,42	€ 2,84
www.supermercato24.it	Auchan	De Cecco	500	€ 1,26	€ 2,52
www.supermercato24.it	Auchan	Barilla	500	€ 0,85	€ 1,70
www.supermercato24.it	Auchan	Garofalo	500	€ 1,14	€ 2,28
www.supermercato24.it	Auchan	Pasta Jolly	500	€ 1,28	€ 2,56
www.supermercato24.it	Carrefour	De Cecco	500	€ 1,39	€ 2,78
www.supermercato24.it	Carrefour	Voiello	500	€ 1,35	€ 2,70
www.supermercato24.it	Carrefour	Rummo	500	€ 1,25	€ 2,50
www.supermercato24.it	Carrefour	Molisana	500	€ 1,15	€ 2,30
www.supermercato24.it	Carrefour	Carrefour	500	€ 0,55	€ 1,10
https://www.prontospesa.it/	-	Barilla	500	€ 0,85	€ 1,70
https://www.prontospesa.it/	-	Crai	500	€ 0,59	€ 1,18
https://www.prontospesa.it/	-	Garofalo	500	€ 1,35	€ 2,70
https://www.prontospesa.it/	-	De Cecco	500	€ 1,45	€ 2,90
https://www.prontospesa.it/	-	Voiello	500	€ 1,39	€ 2,78
https://www.prontospesa.it/	-	Rummo	500	€ 1,35	€ 2,70
Salted peanuts					
www.supermercato24.it	Alì	Jumbo	500	€ 3,59	€ 7,16
www.supermercato24.it	Alì	Cameo	300	€ 2,88	€ 9,60
www.supermercato24.it	Esselunga	Lorentz	500	€ 4,50	€ 9,00
www.supermercato24.it	Esselunga	Cameo	500	€ 5,82	€ 11,64
www.supermercato24.it	Auchan	Cameo	300	€ 2,52	€ 8,40
www.supermercato24.it	Auchan	Nut Club	250	€ 2,87	€ 11,50
www.supermercato24.it	Carrefour	Cameo	500	€ 4,19	€ 8,38
www.supermercato24.it	Carrefour	Carrefour	250	€ 1,59	€ 6,36
https://www.prontospesa.it/	-	San carlo	300	€ 2,78	€ 9,25
https://www.prontospesa.it/	-	Cameo	300	€ 2,90	€ 9,63
Pralines					
www.supermercato24.it	Alì	Baci	200	€ 7,74	€ 38,70
www.supermercato24.it	Alì	Lindt	200	€ 7,19	€ 35,95
www.supermercato24.it	Auchan	Pocket Coffee	225	€ 5,86	€ 26,04
www.supermercato24.it	Auchan	Baci	200	€ 6,28	€ 31,40
www.supermercato24.it	Carrefour	Mon cheri	315	€ 8,05	€ 25,56
www.supermercato24.it	Carrefour	Lindor	200	€ 6,79	€ 33,95
www.supermercato24.it	Carrefour	Ferrero	375	€ 10,15	€ 27,07
https://www.prontospesa.it/	-	Lindor	200	€ 5,99	€ 29,95

https://www.prontospesa.it/	-	Poket coffee	225	€ 4,99	€ 22,18
https://www.prontospesa.it/	-	Mon cheri	315	€ 7,09	€ 22,51
Protein bars					
https://www.prontospesa.it/	-	Kellogs	32	€ 0,80	€ 24,91
www.supermercato24.it	Alì	Enervit	40	€ 2,27	€ 56,75
www.supermercato24.it	Alì	Peso Forma	31	€ 0,84	€ 27,10
www.supermercato24.it	Esselunga	Maama	40	€ 2,45	€ 61,14
www.supermercato24.it	Conad	Enervit	40	€ 1,79	€ 44,75
www.supermercato24.it	Famila	Enervit	40	€ 1,93	€ 48,25
www.supermercato24.it	Famila	Enervit	40	€ 2,08	€ 52,11

A4: Dataset on cricket-based product registered features

Price (€/kg)	Brand	% of insect	% of proteins	High quality proteins	Nutritional claims	Free from	Organic	Sustainable	Natural
Cricket flour									
49,50 €	TiBioNa (IT)	100%		X	X				X
63,00 €	Thailand Unique	100%	80%	X				X	
74,10 €	Cruncy critters	100%		X			X	X	X
95,58 €	Exo	100%				GMO / Gluten / Soy / Dairy			
119,50 €	Crické	100%	76%	X	X				
126,00 €	Tmeatfood (fr)	100%							
236,40 €	Eat Crawlers	100%		X	X				X
295,50 €	Entopure(holland)	100%		X	X				
800,00 €	Small Chomp (IT)	100%							X
Cricket pasta									
6,88 €	Nutribug	10%				Gluten			X
13,14 €	Bugsolutely	5%		X	X			X	
36,00 €	Tmeatfood (fr)	7%		X			X		X
37,20 €	Tmeatfood (fr)	7%		X			X		
43,20 €	Tmeatfood (fr)	6,74%		X			X		
47,44 €	Eat Crawlers	10%		X					
Cricket crackers									
48,00 €	Little Food	12%		X	X		X		
56,25 €	Small Chomp (IT)								X
56,60 €	Little food	12%		X	X		X		
56,68 €	Little food	12%		X	X		X		
57,65 €	Crickè (UK)	15%	22,70%	X					X

57,65 €	Crickè (UK)	15%	22,70%	X					X
57,65 €	Crickè (UK)	15%	22,70%	X					X
57,65 €	Crickè (UK)	15%	22,70%	X					X
102,89 €	Minusfarm(Fr)	5%		X	X				
Whole crickets									
99,50 €	Crické	100%	68%	X	X				
180,00 €	EXO		40%	X					
180,00 €	EXO		40%	X					
180,00 €	EXO		40%	X					
180,00 €	EXO		40%	X					
199,71 €	Tmeatfood (fr)						X		
199,71 €	Tmeatfood (fr)						X		
199,71 €	Tmeatfood (fr)						X		
199,71 €	Tmeatfood (fr)						X		
202,86 €	Tmeatfood (fr)						X		
202,86 €	Tmeatfood (fr)						X		
219,43 €	Little Food	100%		X	X				
219,43 €	Little Food	100%		X	X		X		
250,00 €	Tmeatfood (fr)	100%		X			X		
281,33 €	Thailand Unique			X	X				X
333,33 €	Small Chomp (IT)			X					
564,29 €	Jimini's								
564,29 €	Jimini's								
1.200,00 €	Micronutris (Fr)	90%		X	X		X		
1.200,00 €	Micronutris (Fr)	96%		X	X				
1.300,00 €	Micronutris (Fr)	100%		X	X				

Sweet crickets									
106,80 €	Wholi	8%		X	X				
106,80 €	Wholi	8%		X	X				
132,00 €	Entis (Finland)	7,50%		X					
132,00 €	Entis (Finland)	7,50%		X					
132,00 €	Entis (Finland)	7,50%		X					
199,71 €	Tmeatfood (fr)						X		
229,09 €	Thailand Unique					Gluten			
632,67 €	Eat Crawlers	60%						X	
632,67 €	Eat Crawlers	60%						X	
Protein bars									
35,00 €	EXO		17%	X					
35,00 €	EXO		17%	X					
35,00 €	EXO		17%	X					
35,00 €	EXO		17%	X					
41,80 €	SENS	10%				Gluten			X
41,80 €	SENS	10%				Gluten			X
41,80 €	SENS	10,00%				Gluten			X
42,75 €	SENS	20%		X		Gluten			X
42,75 €	SENS	20%		X		Gluten			X
55,00 €	Jimini's	5,50%	20%	X			X		
55,00 €	Jimini's	5,50%	20%				X		
55,00 €	Jimini's	5,50%	20%				X		
55,00 €	Jimini's	5,20%	20%				X		

	Visible insect	Average price (€/kg)
Cricket pasta	No	€ 31,20
Protein bars	No	€ 43,92
Cricket crackers	No	€ 56,01
Cricket flour	No	€ 132,45
Sweet crickets	Yes / No	€ 153,28
Whole crickets	Yes	€ 247,56

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