CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Insects as an Alternative Source of Animal Protein in Southeast Asia

BACHELOR'S THESIS

Prague 2021

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Declaration

I hereby declare that I have done this thesis entitled Insects as an Alternative Source of Animal Protein in Southeast Asia independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague April 15, 2022

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Acknowledgements

I would like to thank my supervisor, Ing. Iva Kučerová, Ph.D. (Department of Sustainable Technologies of the FTA) for patience, help and mentoring.

Abstract

Although humans evolved eating insects and entomophagy is still a common practice in many countries around the world, western society views insect foods mostly with disgust. This thesis investigated available literature on topic of edible species of insects in Southeast Asia as a source of protein. Different species of insects including honeybees, crickets, palm weevils, mantises, wasps, or hornets were investigated in this work. Species of edible insects can be either farmed or harvested from wild. Insects are farmed not only for human consumption, but also as sustainable animal feed or to produce natural oil or fertilizer. Insects are very rich in nutrients. Edible insects have high content of protein with all essential amino acids present. Lipids can reach up to 36.5% of dry matter. Insects are also great source of minerals and vitamins. This work also describes preferred ontogenetic stages of each species and preferred ways of preparation. Furthermore, benefits of eating insects reach beyond nutrition, as they are easily raised and are great sustainable and more environment friendly alternative to conventional livestock, such as beef, pork, poultry, or fish. Outcome of this work is a comparative table of 9 farmed species and 21 species and groups of species that are foraged in the wild. Species coming from farms have undoubtedly the highest protein content when compared to wild caught species, even to individuals of the same species caught in wild. *Bombyx mori* larvae contain up to 71.4% of protein which is the highest of the investigated species. The most popular ways of processing are frying and roasting. Country with the highest rate of eaten insects is Thailand.

Key words: proteins, insect, human nutrition, protein sources, insect processing

1. Contents

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List of the abbreviations used in the thesis

Carb. -Carbohydrates

DM -Dry Matter

FAO – Food and Agriculture Organization of the United Nations

Lao PDR – Lao People’s Democratic Republic

n/a – Not Available

SE Asia – Southeast Asia

(J) - Javanese

(L) – Lao

(T) – Thai

(V) - Vietnamese

1. Introduction

With growing population of our planet, demand for food and animal products increases. Therefore, agricultural land is naturally expanding as well. Growing of agricultural areas poses threat to biodiversity and the accompanying increased production of greenhouse gasses, overuse of water, overuse of land, pollution, land erosion means great harm to the environment. With growing population, food insecurity increases in some parts of the world (Steinfeld et al., 2006).

Therefore, more sustainable, and effective approach is required. Alternative diet, implementing edible insects and insect products is a promising approach. Including insects as at least partial source of protein in human diet might at least partially undo the harm caused by agricultural activities (Tabassum et al. 2016).

Insects have been shown to be a great source of protein with all nine essential amino acids presents, unsaturated fats, A, D, E, K, C and B group vitamins, minerals with sufficient dietary fibre present (Xiaoming et al. 2010). Moreover, insects emit less greenhouse gasses, use less land, consume next to no water, and has higher feed to zoomass ratio than traditional livestock (Tabassum et al. 2016) (Pimentel et al., 1975) (Steinfeld et al., 2006).

Minilivestock is a logical step forward, not only for food insecure countries but for the whole world. Although, Western world is still sceptical towards this approach some insect products can be found in Europe and the United States (Tabassum et al. 2016).

Some species, such as crickets, black soldier fly larvae or mealworms are farmed in Southeast Asia using well working models for human food or as animal feed. Bigger number of species are collected in wild for direct human consumption or to be sold at local marketplaces. These species have little commercial value in bigger scale (Hanboonsong et al. 2013) (Hanboonsong & Durst 2014) (Watanabe & Satrawaha 1984).

2. Aims of the Thesis

This thesis aims to investigate available literature and electronic information databases to analyse alternative insect protein sources in Southeast Asia and to map the processing methods used.

3. Methodology

The work is based mainly on online research of insect protein sources. A systematic literature review is performed using an electronic search of ScienceDirect, Scopus, Web of Knowledge and Google Scholar. Primary search terms used are: "proteins", "insect", "human nutrition", "insects processing", and "Southeast Asia".

4. Literature Review

4.1 Human nutrition

4.1.1 Importance of protein in human nutrition

Proteins and are commonly known as basic building blocks of human and animal body. Ingested protein is digested and broken down into amino acids that are later utilized. Amino acids have function in the body unreplaceable by any other nutrient. Proteins are a valuable source of carbon and sulphur in human nutrition. Proteins and amino acids are crucial for overall health and development of the body including muscle growth, healthy immune system, bone maintenance, bone growth or healthy brain development as well. Proteins are also important basis for enzymes, hormones, haemoglobin and immunoglobins. Undernutrition may lead to anaemia, vascular problems, impaired immunity, or growth stunts (Wu 2015). Recommended daily intake of protein for minimally active adult is 0.83 grams per kg of bodyweight. On average, people in developed countries get 95 grams of protein daily, up to 60% being animal protein. People in developing countries get only around 45 grams a day and only 15% of animal protein. This deficit leads to undernutrition in population of developing countries (Tabassum, et al. 2016).

Table 1. Dietary protein requirements

Group	**Age**	**Protein g/kg of body weight/day**	**Reference**
Infants	0.3-0.5	1.52	(Tabassum et al. 2016)
	0.75-1.0	1.5	
Children	1-3	1.1	
	4-8	0.95	
Adolescents	9-13	0.95	
	14-18	0.85	
Adults	≥19	0.8	

Animal proteins have been shown to be superior to plant-based proteins in many ways, due to their amino acid profile. Plant proteins are often limited in certain amino acids such as tryptophan, methionine, lysine, and isoleucine. Animal proteins in adequate amounts are very important part of human nutrition as they are easily digestible, have complete amino acid profile or may improve quality of plant proteins when combined. Branch chained amino acids found in animal proteins act beneficially on blood pressure and healthy glucose metabolism. Some of the sources may be also rich in other important nutrients that are beneficial to human body including minerals, creatine, omega-3 fatty acids, vitamin D3, B vitamins, choline, and others. However, diet high in animal-based products may lead to series of health problems such as gout, high blood pressure, high cholesterol levels, or type II diabetes (Elmadfa and Meyer 2016).

4.2 Food security

Food security is most described as definition by FAO, defined at the World Food Summit in 1996: "Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet dietary needs and food preferences for an active and healthy life." (2009).

Food security can be measured by Global Food Security Index (GFSI), considering affordability, availability, quality and safety and natural resources and resilience. This model further investigates 58 individual indicators (The Economist, 2022). Another way to scale measure food security is the Core Food Security Measure (CFSM), using Rasch methods (Derrickson et al. 2000).

4.2.1 Pillars of food security

Basic pillars of food security are availability, accessibility, and affordability.

Availability is rooted in production and accessibility is connected to the distribution of the produce and or products (Aborisade B., Bach C., 2014). Therefore, there needs to be some at least basic level of infrastructure to provide so.

According to FAO, there are four dimensions of food security: physical availability, economic and physical access, utilisation, and stability of the other three dimensions over time (FAO 2008).

Utilization in food security is described as the way human body utilizes the nutrients in food and energy as an outcome of food preparation, feeding practices, diversity of diet and distribution of the food in household (FAO 2008). It is important to approach this matter in its complexity and not purely as access to sufficient calories. Other substances as vitamins, minerals and others need to be taken in account as well. For example, about 60 percent of global population is deficient in iron or global vitamin D3 deficiency in all ethnicities and all age groups (Misselhorn et al. 2012).

Another great example is vitamin A deficiency in population of rural Thailand that was attempted to combat with genetically modified “Golden rice” (Beyer 20120). From these examples it is clear, that sufficient energy intake does not equal sufficient nutrition.

By sustainability or stability in food security, diets that do not affect the environment and biodiversity, use natural resources optimally and are culturally acceptable and are safe and of sufficient nutritional value, are understood (Cole et al. 2018). Stability also includes political stability, economic factors, and rising food prices (FAO 2008).

4.2.2 Effects of food insecurity

Often, people in food insecure households, due to lack of budget, need to decide between education, healthcare, paying for housing, electricity etc. and buying food. In developing countries, it is common, that children work to support their families instead of going to school.

The most obvious effect of food insecurity is malnutrition resulting in wide array of health issues physical and psychosocial. Different macronutrient, vitamin and mineral deficiency has specific adverse effects. Children are more prone to malnutrition connected health issues as they need more nutrients per kilogram of weight than adults, for proper and healthy growth. Among health problems stemming from food insecurity are higher risk of depression and suicidal thoughts in adolescents, chronic conditions such as asthma, decrease in productivity and impaired learning and memory in school age children or impaired development of foetus in pregnant women (Ke & Ford-Jones 2015).

4.2.3 Alternative diet as a promising approach

By 2050 it is expected that population will exceed nine million people and that means there will be more mouths to feed. Current resources are shrinking, and more sustainable food sources are needed. About 70% of agricultural land is dedicated to raising and feeding livestock. Current resources are shrinking and demand for animal products is growing. Human agricultural activity has big part of responsibility for climate change. More of sustainable food sources are needed. Edible insects may be an effective and sustainable way to saturate the demand for quality animal-based protein (Cole et al. 2018).

As insects have higher feed to biomass conversion rate, emit less greenhouse gasses, use less water and take up less space and are able to transform low value organic materials to high quality to protein, it is clear, that implementing insects in human diet is logical way to move forward (Jansson & Berggren 2015). Moreover, some species can be easily bred at home as it is with Farm 432 project by Katharina Unger, producing up to 500g of larvae per week. That makes two meals (Unger 2013).

In western societies entomophagy is still widely looked down on. More education and awareness need to be raised among common public, same as it was done in Netherlands since the late 1990s (Jansson & Berggren 2015).

4.3.1 Entomophagy

Insects have always acted as a significant part of human diet across the world. Humans, similarly, to other higher primates, have evolved as entomophagous species. Diet rich in insects may have played key role in the rapid evolution of human brain (Tabassum et al. 2016).

Entomophagy is still commonly practiced in Asia, Africa, and South America. Local species of insects are easily accessible and broadly used in traditional cuisine, eaten unprocessed or sold as commercial products. Insects, frequently being more accessible than beef, pork, chicken, or fish, are often considered delicacies. 291 species of edible insects are recorded in Asia, most commonly being consumed in Southeast Asia (Cerritos 2009).

4.3.1 Reasons for practice of entomophagy

In 2000 survey conducted by Hanboonsong in Thailand, 75% of local respondents stated, that they eat insects because they are tasty. 65% of respondents also said, that it is a good snack. Nearly 50% of asked answered, that they use it in cooking or traditional medicine. Other responds were that locals use insects as food seasoning or consume them for their availability. Only 9% of respondents stated cultural tradition, 2% mentioned its local origins and only 0.38% stated pest control (Hanboonsong 2010).

Therefore, rather than for cultural tradition, insects are sought after for their taste and accessibility. Naturally, tastes differ in each region, but usually insect foods are eaten accompanied by herbs and spices, such as chilli, garlic, lemon, or pepper. It also has been noted that preference in insect species may reflect local abundance of the species (Xiaoming et al. 2010).

4.3.2. Environmental impacts

Other than economic and health benefits, there are several environmental benefits to eating insects too. Though still viewed with disgust or as bizarre and novelty foods by the western culture, edible insects can have largely beneficial impact on the environment when replacing traditional livestock such as cattle, pigs, poultry, or fish.

More eco-friendly and sustainable counterpart to classic livestock is so-called minilivestock such as edible insects. Traditional livestock production has many negative environmental impacts including global warming, greenhouse gasses production, land erosion, water overuse, loss of natural habitats and biodiversity or pollution (Pimentel et al., 1975) (Steinfeld et al., 2006).

Insects have the most efficient food to zoomass conversion rate. They are also fast growing and easily bred. Insects can also be raised in so-called vertical farms, saving great amount of space which is very desirable, considering overgrowing human population and cities, raising demand for agricultural land to produce enough food. This may be beneficial to biodiversity conservations as well, as vertical farms take less space and some of the semi-cultivated species are harvested at land that is already used for other agricultural activity without affecting the yield. Marine based food sources are no longer at sustainable levels either, therefore more sustainable food source is highly desirable at the moment (Abassi et al. 2016).

Contrastingly, foraging wild edible insects can result in a threat to the ecosystem, as locals often tend to overharvest. Significant quantity of caught insects may lead to natural food chain imbalance and pose a threat to biodiversity and the environment itself.

Furthermore, farmed insects from large-scale farming are fed traceable and high quality, often human grade, feed, and vegetable. It is near to impossible to track what has a wild caught insect eating before. This may pose a health risk for consumers in form of bioaccumulation of toxins or transmission of zoonotic diseases (Jansson & Berggren 2015).

Moreover, insect food may mean extra protein when incorporated into vegetarian or vegan diet. Although, majority of vegans have negative attitude, minority would consider insects as additional source of protein in their diets. Therefore, the morals of entomophagy as alternative to conventional animal-based diets is up for a debate (Faccio & Guiotto Nai Fovino 2019).

4.3.3. Digestibility of insect protein

Generally, protein range for insects at any life stage is 20-70%, often with all essential amino acids present.

As human and animal studies determining protein digestibility are difficult to conduct and are expensive, alternative multienzyme in vitro studies are usually performed (Churchward-Venne et al. 2017). Digestibility of insect protein usually ranges between 77% and 98% depending on the species and way of preparation (Ramos-Elorduy 1997).

For example, T*enebrio molitor* hemolypmh proteins have better digestibility in comparison to muscle proteins by 30% (Yi et al. 2016). Digestibility of termite proteins when compared to casein was 33% lower *in vivo* in rat models (Phelps et al. 1975).

4.3.4. Digestibility of chitin

Insects, crustaceans, and fungi contain chitin, insoluble polysaccharide that has plenitude of health benefits to humans but may affect digestibility of the species. Individual content of chitin in each stage of metamorphosis differs. Therefore, it is needed to differentiate the stage of ontogenesis of the individual. Additionally, different ontogenetic stages of insect species differ in protein content. Numerous studies of past decades have shown chitin to have positive effects on cardiovascular health, immune system, wound healing. Chitin also carries antibacterial and antifungal qualities. Chitosan, the deacetylated form of chitin is sold as weight management supplement (Dong et al. 2019). Although chitin is not commonly considered a potential allergen, it may trigger allergic reaction in individuals allergic to dust mites, crustaceans, mold or related cross-allergy (Gour & Lajoie 2016). After frequent exposure, individual may become more sensitive to this substance (Burton & Zaccone).

Content of chitin in edible insects negatively affects quality of the protein, measured by digestibility, amino acid availability, net protein utilization and protein efficiency ratio in rat models (Churchward-Venne et al. 2017).

4.3.5. Entomophagy in Souteast Asia

Mainland Southeast Asian countries, as part of Mekong River basin, share forest and water resource. People from these countries have similar taste and preference for insects as food, due to similar ecological, environmental, and socioeconomic background.

Many people in southeast Asia live below the poverty level. Such people do not have access to sufficient nutrition. Edible insects can combat malnutrition, especially protein-energy malnutrition in some countries.

In rural areas of Southeast Asia some people are not able to obtain more traditional animal protein sources due to sociocultural and socioeconomic limitations (Yhoung-Aree et al. 1996). Up to 44% of edible invertebrates in Thailand are insects. These species act as important source of protein in rural communities (Watanabe & Satrawaha 1984). Insect proteins are high quality, accessible in high quantities. Some species are also commonly consumed in urban areas, not only the rural ones (Yhoung-Aree et al. 1996).

Various species of edible insects are either farmed, semi-cultivated or collected in the wild.

Some species have fond tradition in local healing such as weaver ants from *Oecophylla* genus in Thailand and Myanmar or *Gryllus bimaculatus* as cure for hypertension or fever. Numerous ancient Thai medical books mention use of *apis* genus as ingredients in traditional medicines. Practice of medical use of some insect species keeps up to present day. Honeybees are also often used for apitherapy (Wongsiri et al. 2015).

In Thailand alone, it has been documented that more than 150 insect species are consumed (Hanboonsong 2010). It is estimated that in Lao PDR there are around 50 insect species consumed (Hanboonsong & Durst 2014). Around 200 insect species is eaten in the entire Southeast Asia (Xiaoming et al. 2010). Part of wild caught insects consumed in Thailand are imported from neighbouring countries such as Myanmar or Cambodia. (Hanboonsong et. Al 2013).

These are some of the most consumed insect species in countries of Southeast Asia. Species mentioned below can play a major role in local diets and may be the part of solution of world hunger. The species are further divided into two groups: Farmed and semi-cultivated edible insects and wild caught edible insects.

4.3.6. Insect farming

The technology has advanced and developed so there are means to farm some of edible insect species. Larvae of *Tenebrio molitor* – the mealworm and two-spotted crickets – *Gryllus bimaculatus*, are usually farmed as animal food, meanwhile house crickets (*Acheta domesticus)* and palm weevils *(Rhyncophorus ferrugineus* and *Rhynocophorus vulneratus)* are usually farmed for human diet (Hanboonsong et al. 2013).

It is important to farm species that are locally distributed, so it does not pose threat to local biodiversity and environment in case the insets in unintentionally released into the wild (Jansson & Berggen 2015).

Thailand acts as a superpower in edible insect production. The insect farming technology was developed in 1998 and there are around 20,000 cricket farms throughout

Thailand. Cricket farming has recently become a significant part of part of animal production and acts as main income for some farmers. Unfortunately, most of the farmers would not be able to do business globally, as they do not meet international food standards (Hanboonsong et al. 2013).

The farming situation in Lao PDR is different though. Although entomophagy is a common practice there, until recently, people relied more on harvesting insects in the wild. Before 2010, there were only two cricket farmers near the Vientiane capital. In 2010 the Edible Insect Demonstration Unit was founded by Faculty of Agriculture, National University of Lao PDR with support of FAO, focusing on raising A*cheta domesticus, Tenebrio molitor, Rhynchophorus ferrugineus* and *Oecophylla smaragdina* (Hanboonsong & Durst 2014).

Crickets are usually bred in cylinder pens, plywood boxes or in plastic drawers. The females lay eggs in seven to fourteen days durations. Eggs are then, daily moved into incubators and hatch in seven to ten days. Adults are then harvested when 45 days old. Cricket population is well sustainable as their reproduction cycle can be repeated one to three times (Hanboonsong et al. 2013).

Rhyncophorus ferrugineus and *Rhynocophorus vulneratus* are considered pests because they heavily damage palm tree plantations. Palm weevils can be either farmed or semi-cultivated as sort of biproduct in plantations. Palm weevil farming is typical for Southeast Thailand and is concerning R*hynocophorus ferrugineus*, in other regions such as Vietnam or Laos R*hynocphorus vulneratus* are dominantly wild caught (Rugman-Jones et al. 2013).

The weevils can be bred traditionally on the palm trunks and stems. In 50 cm pieces of palm trunks with five drilled holes are released five pairs of adults. It takes 40 to 45 days until harvest of circa five kilograms of weevil larvae per trunk. Or they can be bred in plastic containers filled with palm stalk and pig feed. The yield is comparable, but it takes less time to harvest. About 25 to 30 days.

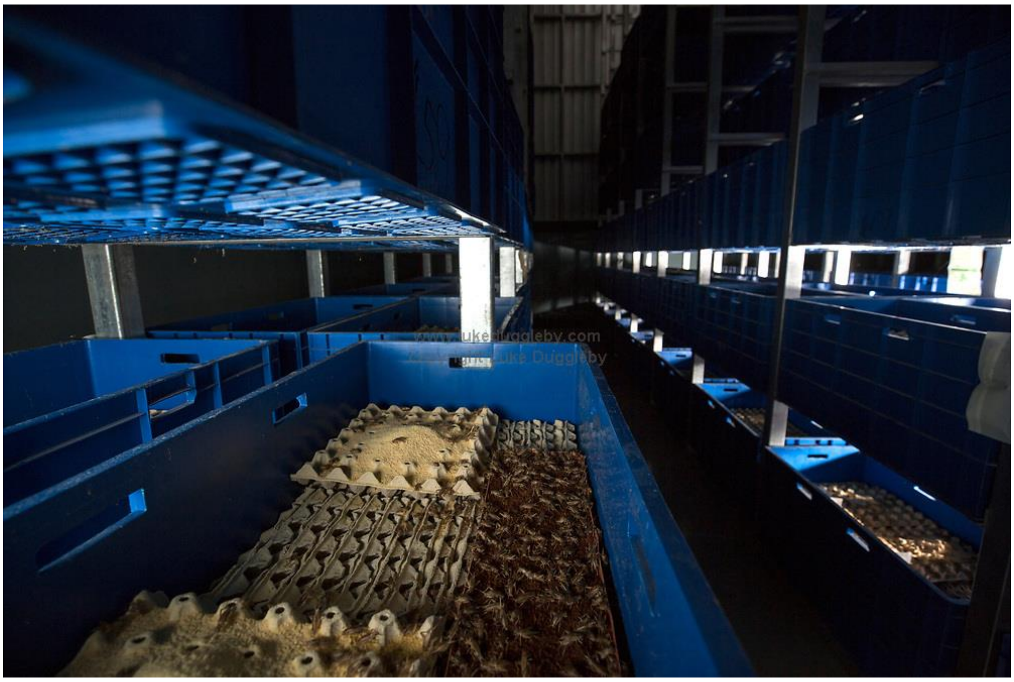
Usually, palm tree weevil is a secondary income for farmers with primary income being agricultural crops such as rubber, rice, or coconuts (Hanboonsong et al. 2013).

4.3.7. Farms

Cricket Lab is large-scale cricket *(Acheta domesticus)* flour producer Cricket Lab located in Chiang-Mai, Thailand. It is the world's biggest insect farm of its kind and globally is one of the most important players in insect products for human nutrition. Cricket Lab is closely connected to Czech manufacturer of cricket protein products SENS. At Cricket Lab vertical farming is implemented which allows them large yield on relatively small space. Vertical faming system can be seen in figure 1. The crickets are usually fed chicken feed which is to be replaced with vegetables shortly before harvest. Large-scale producers, such as Cricket Lab, use traceable human food-grade feed, to feed their crickets maintaining high standard of quality.

Cricket Lab also swore to educate local farmers in near future (Cricket Lab 2018).

Figure 1. Vertical cricket farm (Photo by Luke Duggelby)



Entobel is Singapore-based company with farming facility in southern Vietnam. Currently they focus on products made from *Hermetia illucens* with emphasis on quality and traceability. Their portfolio currently consists of three products. H-Meal – defatted, dried larvae for animal feed, H-Oil – extracted oil from larvae with potential applications in various industries and H-Ferti – organic fertilizer made from larvae frass and nondigested substrate. Entobel currently does not make any products intended for human consumption (Entobel 2020).

Entofood company is based in Malaysia. They also manufacture sustainable products from *Hermetia illucens larvae.* Their product portfolio is the same as the one of Entobel: protein feed, extracted oil and fertiliser made from black soldier fly larvae (Entofood 2016).

Global Bugs, company based in Bangkok, Thailand is producer of crickets and cricket products. Their portfolio contains variety of cricket products, including protein powder, protein bars, roasted crickets in different flavours and cricket-based fertilizer.

The Cricket Hop is a UK based company with award-winning cricket farm in Vietnam. Their only product is Cricket flour. Crickets are fed by casava root leaves grown by the company (The Cricket Hop Co. 2018-2021).

4.4. Farmed edible insects

4.4.1 *Acheta domesticus*

Representative of the Gryllidae family is house cricket and is commonly consumed in southeast Asia, usually roasted. This species has been recently one of the most discussed insect species suitable for human diet due to already existing effective farming techniques, it's very high protein content and suitable amino acid profile. Furthermore, 66.6% of dry weight of house cricket is protein, making it the best source of protein among edible insects. All the essential amino acids are present, and their content is higher than in conventional animal-based proteins (Von Hackewitz 2018).

Blanched crickets have total energy of 134 kcal per 100g with 12.9% of protein, 8,1% carbohydrate, 5,5% of fat, 76mg of calcium and 9,5mg of iron (Hanboonsong & Durst 2014).

Acheta domesticus is an introduced species from temperate regions of Europe and the United States. Although, there are native cricket species, some of which are farmed, such as *Gryllus bimaculatus* in Thailand, *Achtea domesticus* is preferred due to its better taste (Hanboonsong et al. 2013).

In Lao PDR, house crickets are called Chi lor. House crickets can be collected from wild but more commonly are farmed (Hanboonsong & Durst 2014).

According to SENS, their cricket flour contains 436 kcal. Macronutrient content of *Acheta domesticus* can be seen in table below. Crickets contain 0.8 g sodium and 5.67 mg of iron. They are also rich in vitamin B12 (SENS Food 2020).

Table 2. Nutrients in *Acheta domesticus* **% of DM**

	Protein	Fats	Carbohydrates	fiber	Reference
Adult	70	20	0.5	9.5	(SENS Food 2020)

4.4.2 *Apis spp.*

Honeybees belong to the Apidae family. They have been domesticated more than 7.000 years ago, mostly for production of prized honey (Oldroyd 2012). But some communities in rural Southeast Asia eat their larvae and even adults as source of protein (Watanabe & Satrawaha 1984).

Not only domesticated honeybees but wild harvested species are consumed. In Thailand, whole beehives are sold with all their contents and bees alive. Honey, honeycombs, larvae, and adults are consumed. Beeswax, then, can be repurposed. Thai people call bees either Pung or Rueng Pung (Watanabe & Satrawaha 1984).

Some of popular ways of preparations are whole honeycombs grilled in banana leaves, the brood cooked in soup or eaten with rice, stir-fried, steamed, scrambled or in an omelette (Ghosh et al. 2020). Among the commonly consumed bee species is wild *Apis florea* – dwarf honeybee. Brood of this species contains 37.53 g per 100 g of dry matter. *Apis florea* are excellent source of minerals, as can be seen in table below. Mineral content of honeybees, in most cases surpasses conventional protein sources. (Ghosh et al. 2020).

Table 3. Mineral content *Apis Florea* mg in 100g of DM

	Ca	Na	Mg	K	P	Fe	Zn	Mn	Cu	Reference
Adult	80	84.9	144.2	1519.3	1368.9	9.4	8.7	0.1	2.2	(Ghosh et al. 2020)
Pupal	67.1	72.9	117.2	1235	1105	7.9	7.7	0.4	2.9	(Ghosh et al. 2020)

4.4.3 *Bombyx mori*

Silk moths in Thai marketplaces are usually sold steamed. They can be purchased most of the year (Watanabe & Satrawaha 1984).

Silk moths, belonging to Bombycidae family, called Duck Dae Tua Mai in Thai, have been farmed for at least 7.000 years for production of silk. Larvae and pupae of silkworm are very popular food in Vietnam or Thailand and are usually sold steamed. The larvae, of all stages, are the highest in protein, they have around 71.4% of protein in dry matter, (Yu et al. 2008) whether pupas have around 55.6% of protein and about 32.2% of lipids in dry matter (Tomotake et al. 2010).

4.4.4 *Gryllus bimaculatus*

Gryllus bimaculatus, sometimes called A*cheta bimaculata* is commonly known as two-spotted cricket or field cricket. In Thai known as Ching Reed, Ching Klong, Chi Pom. Same as other cricket species, adults are consumed. Usually sold steamed, but preffered preparation for consumption is roasting or frying. Two-spotted crickets can be purchased during the end of rainy season, from September to October (Watanabe & Satrawaha 1984).

Two-spotted cricket belongs to the Gryllidae family. This species is widely used as feed for animals throughout the world. In Asia, field crickets have been used as medicine for fever or hypertension. According to Korea Food Research Institute, best processing for these crickets is lyophilization process leading to least degradation of crude protein, crude fat and crude fibre compared to hot air-drying process (90°C for 7 hours), roasting (160°C for 40 minutes) or frying (180°C for 30 secomds). However, contents of separate amino acids may not reflect that completely. Lyophilized crickets contain about 64,44% of crude protein, making them great source of

Table 4. Nutrient content of *Gryllus bimaculatus* in different processing methods

	LP	Hot air	Roasting	Frying	Mean	Reference
Moisture (%)	1.44±0.02	7.25±0.03	12.63±0.13	14.28±0.63	8.90±5.26	
Crude protein (%)	64.44±0.11	62.19±0.65	55.08±0.07	26.48±0.21	52.05±15.84	
Crude fat (%)	15.53±0.19	15.47±0.43	17.27±0.18	45.87±0.04	23.54±13.49	(Kim et al. 2015)
Crude ash (%)	5.42±0.22	4.37±0.05	3.86±0.03	1.74±0.01	3.85±1.41	
Crude fiber (%)	10.38±0.17	9.32±0.01	10.07±0.04	10.02±0.14	9.95±0.42	
Chitin %	9.77±0.06	12.25±0.05	11.27±0.05	6.36±0.33	9.91±2.39	

protein in food insecure countries. Low moisture content suggests good storability (Kim et al. 2015).

4.4.5 *Hermetia illucens*

Also called black soldier fly, *Hermetia illucens* is a representative of family Stratiomyidae. Information and on human consumption of black soldier fly are hard to find. Although it may not be a traditional Southeast Asian food source, this widespread species of fly is recently one of the most discussed species of edible insects.

Larvae can be produced, not only for human food, but also for animal feed, fertilizers and oil production. One of their most prized qualities is their highly efficient ability to convert organic material into insect biomass. This includes food waste and manure. Therefore, H*ermetia illucens* farming is highly sustainable. Another pro would be how easy production of black soldier larvae is, as the don't need any special facilities. These flies also do not concentrate mycotoxins or pesticides and do not spread diseases, which is highly desirable (Wang & Shelomi 2017). *Hermetia illucens* can be also easily produced in smaller scale in home environment (Unger 2013).

Hermetia illucens larvae contain about 42% of crude protein and 29% of fat, that is significantly higher in saturated fats, than other insect species (Wang & Shelomi 2017).

4.4.6 *Oecophylla smaragdina*

Also known as weaver ants or Asian green ants serve multiple purposes. Firstly, these ants are used in agroforestry and plantations as an effective pest control as they prey on plenitude insects that are harmful to the crops. Therefore, *Oecophylla smaragdina* may be semicultivated species (Offenberg & Wiwatwitaya 2010). Weaver ants have tradition in forementioned indigenous healing and are also used as bird and chicken feed (Offenberg & Wiwatwitaya 2010). Furthermore, *Oecophylla smaragdina* are safe for human consumption and have high content of protein and fatty acids. Larvae and pupae are preferred to imagos and the queen caste is preferred to males and workers. The brood of this ant is often targeted during the harvest because it is not vital for survival of the colony. Ants are collected with bamboo basket tied to a bamboo pole from tree crowns (Hanboonsong & Durst 2014).

Oecophylla smaragdina belong to the Formicidae family. Called Khai Mot Daeng or Mae Peng by Thai people and Mot deng in Lao. Eggs, Larvae, pupae, adults, including queen caste are consumed. They are usually sold steamed and can be easily purchased during the dry season (Watanabe & Satrawaha 1984).

Green weaver ant is considered delicacy. Brood, same as imagos, are a part of many Thai or Lao dishes. Queen caste is consumed steamed with curry paste, in spicy salad or in curry. Brood is consumed in yum khai mod daeng salad or as topping (Raksakantong et al. 2010).

Table 5. Nutrient content in *Oecophylla smaragdina* % of DM

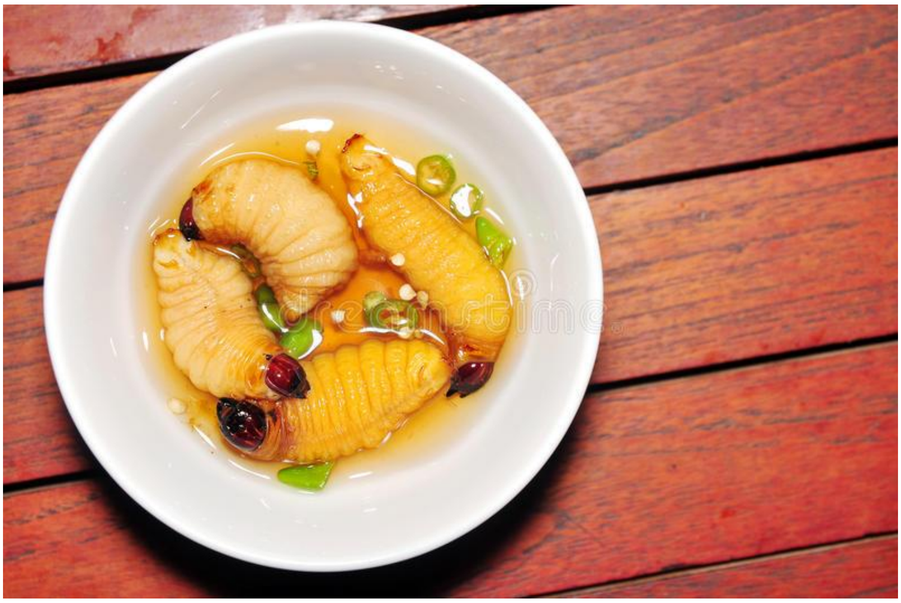
	Protein	Fat	Carb.	Fiber	Ash	Reference
Adult	55.28	14.99	11.75	19.84	6.68	(Raksakantong et al. 2010)
Queen caste	37.46 ± 0.20	36.87 ± 0.31	14.43 ± 0.46	8.26 ± 0.32	2.98 ± 0.10	

4.4.7 *Rhynocophorus* spp.

Palm weevil also known as Asian palm weevil, red palm weevil or sago palm weevil is species of snout beetle from *Curculionidae* family. Larval grub, đuông dừa in Vietnamese, Dong Mak Prao in Lao. Palm weevils are usually consumed raw and still alive without condiments or with fish sauce as main dish as can be seen in figure 2.

They are also very popular in Malaysia. Malaysians prefer their sago worms fried and refer to them as “sago delight” (Hanboonsong & Durst 2014).

Figure 2. Live palm weevils served in fish sauce (Photo by Jamesbox)



Rhynocophorus vulneratus is closely related species consumed in Thailand and Malaysia. Until recently, these two species were considered just different colour variant of the same species. Therefore, locals do not differentiate *Rhyncophorus ferrugineus* and *Rhynocophorus vulneratus* and populations of these two species may overlap in some areas (Rugman-Jones et al. 2013). Sago worms in Thailand are consumed raw, stir fried or as processed packaged snacks.

Considered pests because they feed of palm tree trunk or other. They pose a serious threat to sago, coconut, oil, and date palms. (Rajamanickam et al. 1996) These species are now semicultivated or farmed. Other than for human food, red palm weevils can be used as feed for animals (Hanboonsong & Durst 2014).

Farmed palm weevils have undoubtedly higher nutritional value than the wild caught ones. Palm weevil larvae raised on farms are high in fat, ranging between 52.4 and 60.1% of dry matter. They have good balance of saturated fatty acids (43.41%) and unsaturated fatty acids (53.68%), and they are low in cholesterol (Cito et al. 2017). Protein content ranges between 18%-28.5% of dry mass is protein with all nine essential amino acids present. Also rich in macroelements as potassium, phosphorus, magnesium, sodium, and calcium and microelements such as zinc, manganese, iron, and copper. Then, carbohydrate content is very low (Chinarak et al. 2020) (Cito et al. 2017).

4.4.8 *Tenebrio molitor*

*Tenebrio molitor is c*ommonly consumed as larvae of mealworm beetle. All stages, including adults, are edible though and are commonly consumed. English name mealworm refers to the larval state of this beetle that can be eaten either by humans or used as animal feed. Lao locals call the larvae Dong Nannok (Hanboonsong & Durst 2014).

The larval state of the beetle is usually used due to its high protein content. Supplementation of *Tenebrio molitor* in daily ration of feed for broiler chickens and weaning pigs have been shown to positively influence the growth and nutrient utilization without any observed adverse effects. It also has been shown to be an effective replacement to fishmeal in weening pigs feed rations (Hong et al. 2020).

Mealworm larvae are high in protein. The content of protein ranges between 46.44 and 60.21% of dry matter with good amino acid profile rich in branch-chained amino acids. Mealworms are also an excellent source of polyunsaturated fats, zinc, magnesium, and B vitamins (Grau et al. 2017). In comparison to beef and chicken meat, mealworms have significantly higher nutritional value (Payne et al. 2015).

Adults of T*enebrio molitor* have outer cuticles that are rich in chitin, a polysaccharide carrying numerous health benefits for humans. This may open market opportunities for mealworms and mealworm products for humans in future.

Table 6. Nutrient content in *Tenebrio molitor* % of DM

	Protein	Fat	Carb.	Fiber	Ash	Reference
Larvae	52.4	30.8	n/a	7.43	4.2	(Grau et al. 2017)

4.5. Wild caught species

4.5.1 Acrididae

Various species of locusts and grasshoppers are part of Southeast Asian diet. Including species like *Oxya japonica, Cyrtacantacris tatarica or Locusta migratoria. Locusta migratoria* is a migrative species, therefore accessibility of this species highly seasonal and varies in each country (Adalla & Cleofac 2010).

Roasted and fried grasshoppers, often spiced, are a very popular snack, eaten similarly to nuts or chips in the West. Especially with consumption of beer or other alcoholic beverages. It is common to find mixture of grasshoppers, locusts, and mantises on markets. Grasshoppers are often imported from Cambodia (Hanboonsong et al. 2013).

Locusts, called Tukkatan in Thai, are usually sold mixed with grasshoppers and mantises, and are sold steamed or live. They can be purchased during rainy season. Adult stages of these species are a very popular food in Southeast Asia. Preferred ways of preparation are roasting or frying. In Lao, grasshoppers are called Tak Tane and are collected during November and December (Watanabe & Satrawaha 1984).

Some of documented eaten species in Sumatra are *Mecopoda elongata*, *Oxya chinensis*, *Phloea antennata*, *Gastrimargus marmosatus*, *Cantopis infuscatus*, *Valanga nigricornis sumaterensis* and *Patanga succinta* (Van der Meer Mohr 1965).

Blanched grasshopper contains 96 kcal/100g with 14.3% protein, 2.2% carbohydrates, 3.3% lipids. 27.5 mg calc and 3mg iron (Watanabe & Satrawaha 1984).

4.5.2. Brachytrupes portentosus

Short-tailed cricket, another species from Gryllidae family. Although this species is similar to *Acheta domesticus* or *Gryllus bimaculatus*, there are no records of this species being farmed. Short-tailed cricket is consumed roasted, fried, or toasted and is accessible during September and December. They call them Chi nai in Lao (Raksakantong et al. 2010) (Hanboonsong & Durst 2014).

Table 7. Nutrient content in *Brachytrupes portentous* % of DM

	Protein	Fat	Carb.	Fibre	Ash	Reference
Adult	48.69 ± 0.25	20.6 ± 0.60	9.74 ± 0.50	11.61 ± 0.20	9.36 ± 0.34	(Raksakantong et al. 2010)

4.5.3. Buprestidae

Buprestidae is one of the biggest families of beetles. They are generally referred to as metallic wood borers and are also known as jewel beetles. This includes *Chrysochroa* and *Sternocera* genuses. (Watanabe & Satrawaha 1984).

Jewel beetles are called Malaeng Tub in Thai. They are consumed in their adults stages and are usually sold live. They can be purchased during the end of rainy season. Beetles of these genuses are commonly consumed fried, roasted or as a part of other meals (Watanabe & Satrawaha 1984).

More research on nutritional value of species from Buprestidae family needs to be done.

4.5.4. Cicadoidea

Species of cicadas are commonly collected in Southeast Asia. That includes, for example: *Orientopsaltria sp.* or *Dundubia intermarata.* Lao name for cicada is Chak Chan (Hanboonsong & Durst 2014). One of species of cicada typical for Thai market is *Meimuna opalifera* (Raksakantong et al. 2010). Genuses typical for Sumatra are *Platylomia* spp.*, Dundubia* spp. and *Pomponia* spp (Van der Meer Mohr 1965). Cicadas are also one of few recorded species eaten in Timor-Leste (Castro AF 2013).

These species are consumed in nymphal stage or as adults. Harvested from April to May, adults are usually collected with stick traps made of bamboo pole and tree resin. During the peak of the season 80 adults can be collected in an hour. Nymphs are found underground, around the trees where adults live. To find nymphs the soil around the tree needs to be dug. Approximately 500 nymphs can be collected from dusk till dawn (Hanboonsong & Durst 2014).

Cicadas are of high financial value. Adult cicadas are collected during March and April. Nymphs are accessible throughout the year as they spend most of their life in nymphal stage, some species even years. Although accessible during most of the year, nymphs are more expensive than adults (Hanboonsong & Durst 2014).

Cicadas are usually consumed roasted, fried, toasted, or mixed with chilli into paste (Raksakantong et al. 2010).

Table 8. Nutrient content in *Meimuna opalifera* % of DM

	Protein	Fat	Carb.	Fiber	Ash	Reference
Adult	47.23 ± 0.50	8.53 ± 0.30	15.98 ± 0.10	19.22 ± 0.30	9.04 ± 0.62	(Raksakantong et al. 2010)

4.5.5. Dytiscidae

Dytiscidae is a broad family of predacious diving beetles, also called water beetles including *erectes, cybister, hydaticus, laccophilus, copelatus and rhataticus* genuses (Hanboonsong 2010).

Water beetles are called Malaeng Tub Tow in Thai. These species are consumed in adult stages. Usually sold steamed, they are accessible during rainy season (Watanabe & Satrawaha 1984).

Information on nutritional value of diving beetles is not available. More research is needed.

4.5.6. Dung beetles

All species of dung beetles belong to superfamily Scarabaeoidea. Various species of dung beetles including *Copris* spp., *Onthophagus* spp., *Onitis* spp., *Heliocopris* spp., or *Liatongus* spp. are popular food in Southeast Asia.

Known as Kood Chi or Good Gi in Thai and Chud Chii in Lao. Adult dung beetles are sold during rainy season, usually steamed. Common ways to prepare dung beetles is to fry them, cook them in curry or mix into chilli paste (Watanabe & Satrawaha 1984) (Hanboonsong & Durst 2014).

Table 9. Nutrient content in *Copris nevinsoni* % of DM

	Protein	Fat	Carb.	Fiber	Ash	Reference
Adult	54.43 ± 0.26	13.61 ± 0.15	7.63 ± 0.26	15.15 ± 0.70	9.18 ± 0.50	(Raksakantong et al. 2010)

4.5.7. Exopotus **spp.,** *Holotrichia* **spp.,** *Phylophaga* **spp.**

Beetles from Scarabaeidae family, commonly refered to as June beetle or May beetles. In Thai, beetles with metallic elytra are called Malaeng Kinoon Daeng and beetles with dark elytra are called Malaeng Kinoon Mone in Thai. Lao people call them Chi noun. These beetles are eaten in their imago stages. It is common to find them sold steamed at Thai marketplaces. During June and May beetles are available for purchase (Watanabe & Satrawaha 1984).

Before cooking, forewings are removed, and bugs are soaked in water overnight. Bugs are then prepared by roasting, frying, steaming, cooked in curry with vegetables or used for dipping (Hanboonsong & Durst 2014) (Raksakantong et al. 2010).

Depending on species, beetles are either collected from soil on agricultural lands and weedy areas or collected from trees (Hanboonsong & Durst 2014).

Table 10. Nutrient content in *Holotrichia* spp. % of DM

	Protein	Fat	Carb.	Fiber	Ash	Reference
Adult	51.74 ± 0.21	5.41 ± 0.50	11.20 ± 0.60	19.31 ± 0.30	12.34 ± 0.10	(Watanabe & Satrawaha 1984)

4.5.8. Gryllotalpa africana

Also known as mole cricket is a representative of Gryllidae family. Malaeng Krachorn in Thai. Same as other cricket species, adults are consumed, and preferred way of preparation are roasting and frying. Crickets are sold live, mainly during rainy season (Watanabe & Satrawaha 1984).

There are records of *Gryllotalpa Africana* consumption in Sumatra along other cricket species. (Van der Meer Mohr 1965) In Philippines, mole crickets are particularly popular. One of the most popular restaurant dishes are mole crickets sautéed in garlic and onions, with soy sauce, vinegar and hot peppers (Adalla & Cleofac 2010).

Similarily to *Brachytrupes portentosus* there are no records of this cricket species being farmed.

4.5.9. Hyblaea puera

Also known as teak caterpillar or teak defoliator is an immature stage of a moth endemic to South and Southeast Asia. Usually cocoons are eaten, but this seasonal delicacy can trigger allergic reaction in some people. Cocoons are fried in coconut or palm oil with salt. As cocoons cannot fight back, they are easily harvested from the trees. Seasonally, every member of the community, including elders and children forage the cocoons together. Javanese locals call them Enthung Jati (Dwi 2010).

4.5.10. Hydrophilous **spp.**

Multiple species of scavenger beetles from *Hydrophilous* genus, belonging to Hydrophidae family, can be found in Southeast Asian marketplaces. Often to be found mixed with *Cybis* spp. In Thailand, scavenger beetles are called Malaeng Nian. The beetles are sold steamed (Watanabe & Satrawaha 1984). Adults and nymphs can be consumed (Hanboonsong 2010).

4.5.11. Hypomeces squamosus

Green weevil or gold dust weevil, Meng Xang in Lao, is a beetle from Curculionidae family. It is a widespread species throughout Southeast Asia. Green weevils are usually eaten fried in addition to other food.

Green weevils are handpicked during March and April. They are collected after attracting them to light. Additionally, collectors can shake the tree to make the beetles fall down (Hanboonsong & Durst 2014).

Data on nutritional value of this species are not available. More research is needed.

4.5.12. Lethocerus indicus

Giant water bug from Belostomatidae family is another staple of Southeast Asian street food. Grilled or fried with herbs and spices, water bugs are sold especially by street vendors in Thailand. Important to note, wings and outer exoskeleton need to be removed before eating.

Malaeng Da Na is Thai name for this beetle. Adults of this insects are usually sold steamed or live in marketplace. During late rainy season, mature eggs form the ovary are consumed as well. Although males are preferred to females. Giant water bugs can be purchased during the entirety of the year (Watanabe & Satrawaha 1984). Nutrient levels vary depending on current season (Radhakrishore et al. 2015).

Table 11. Nutrient range in *Lethocerus indicus* % of DM

	Protein	Fat	Carb.	Reference
Adult	16.16±0.208 - 19.33±0.251	15.25±0.040 - 17.933±0.041	1.887±0.006 - 3.443±0.030	(Radhakrishore et al. 2015)

4.5.13.Mantidae

Mantidae is family of insects known under common name mantis. This ingcludes various species such as *Tenodera ariddifolia, Tenodera sinensis* or *Mantis religiosa.* Lao people call mantises Meang hamphee or Meang mai (Hanboonsong & Durst 2014). In Sumatra, *Hierodula vitrea* and *Tenodera aridifolia* are consumed (Van der Meer Mohr 1965).

Very little information on nutritional value, consumption and way of preparation is available. It is suggested that mantises are consumed the same as grasshoppers, often in combination with (Xiaoming et al. 2010) (Watanabe & Satrawaha 1984).

4.5.14. Notonectidae

Aquatic insects known as swimmers or backswimmers. This includes *Anisops barbutus* and *Anisops bouvieri* (Xiaoming et al. 2010). Swimmers are known as Malaeng Muan Won or Manghua Qai in Thailand. Adult stages are consumed, usually mixed with other aquatic insects (Watanabe & Satrawaha 1984).

More research on nutritional value of Notonetidae is required.

4.5.15. Odonata

Odonata is an order of flying insects, known under common name dragonfly. Dragonflies, including Aeschnidae, Libelluidae and Gomphidae families, are popular food in Southeast Asia. Dragonflies are consumed in their immature stages that all are aquatic. Usually not targeted primarily, dragonfly larvae or nymphs are collected while foraging for other freshwater species such as fish, crabs, or frogs (Hanboonsong & Durst 2014).

Larvae are more popular in Thailand. Dragonfly larvae are called Pong Peng or Malaeng Ngum in Thai. Larvae are usually sold live and can be purchased at the end of rainy season (Watanabe & Satrawaha 1984). People of Lao PDR prefer nymphs and call them Mieng Naa Gam (Hanboonsong & Durst 2014).

Range of protein in Odonata larvae is 40-65%, depending on species (Xiaoming et al. 2010).

4.5.16. Omphisa spp.

There are records of 11 *Omphisa* species distributed in Southeast Asia. It is bamboo caterpillar or bamboo worm is larva of a moth from *Crambidae* family, that inhabits bamboo. The larvae live inside of bamboo and feeds on the pulp. To mir or Daung Nor Mai in Lao. Larvae are collected from bamboo culm just with a knife and patience (Hanboonsong & Durst 2014).

Widely popular in Lao PDR, Myanmar, and Thailand. Bamboo borers from *Omphisa* spp. are known to feed on at least five species of bamboo. Bamboo catterpillars can be purchased throuhout the year with exception of the months from July to September (Singtripop et al. 1999).

4.5.17. Phasmatodeae

A few mentions of consumption of tree and stick insects can be found in literature. Mostly adults are consumed, but in some species, such as *Haaniella grayi grayi,* eggs are considered delicacy (Xiaoming et al. 2010).

More research on ways of preparation and nutritional values of these species is needed.

4.5.18. Rhynocophorus bilineatus

In Indonesia, *Rhynocophorus bilineatus,* ulat sagu in Javanese, is distributed. Also called sago larva or black palm weevil, this species is one of the few species Indonesians collect not only for their own needs but as well sell at markets. In past decades, Indonesian sago forests have been cut down due to oil palm plantations establishment. This has affected the trade and therefore consumption of this species. Despite the popularity of black palm weevil larvae, there is no husbandry of this species (Ramandey & Van Mastrig 2010). This presents a potential scenario for other species harvested from wild. Thus, more focus needs to be shifted towards farmed insects.

4.5.19.Termitidae

Termitidae is a wide family of insects. Termites are one of the most important species consumed. Termites are favoured among great apes and probably was by early humans too (Deblauwe 2009). Termites are one of the few species that can be found on every continent, except for antarctica. This makes them very accessible source of protein (Bignell et al. 2010). In Southeas Asia, termites are preferably consumed roasted with salt or fried (Raksakantong et al. 2010).

Table 12. Nutrient content in *Trinervitermes germinates* % in DM

	Protein	Fat	Carb.	Fiber	Ash	Reference
Adult	42.63 ± 0.18	36.55 ± 0.50	12.34 ± 0.30	6.14 ± 0.12	2.34 ± 0.23	(Raksakantong et al. 2010)

4.5.20.Tessaratoma spp.

Stink bugs belong with the most common insect species used for food in Southeast Asia. Among which is *Tessaratoma papillosa* - Longan stink bug, a typical representative of this group in Thailand. Stink bugs are usually eaten roasted, in curry or chilli paste. It is one of few species that has been recorded eaten raw with sticky rice (Hanboonsong & Durst 2014) (Raksakantong et al. 2010).

In Lao PDR, several species of sting bugs are foraged. Locals call stink bugs Mieng Keng and they collect them from March to May, using bamboo pole and tree sap glue or shaking trees and picking up fallen bugs (Hanboonsong & Durst 2014).

Table 13. Nutrient content in *Tessaratoma papillosa* % in DM

	Protein	Fat	Carb.	Fiber	Ash	Reference
Adult	50.54 ± 0.25	23.55 ± 0.78	6.71 ± 0.20	13.85 ± 0.47	5.35 ± 0.10	(Raksakantong et al. 2010)

4.5.21. Vespa spp.

Wasp and hornet larvae are called Tor in Lao. Some of typical species for Southeast Asia are *Vespa affinis* and *Vespa tropica* (Hanboonsong & Durst 2014). Species eaten in Sumatra also include *Vespa luctuosa, Provespa anomala or provespa nocturna* (Van der Meer Mohr 1965).

Wasps and hornets are usually collected in June using meat as bait to attract adults, then the nest is located, and the hive is smoked out during the night, when the insects are less active. Adults and brood are consumed in similar matter to *Apis* spp. (Hanboonsong & Durst 2014).

Table 14. Nutrient content in *Vespa velutina, Vespa mandarina* % in DM

	Protein	Carb.	Fat	Reference
Vespa velutina	37.9 ± 1.65	n/a	11.5 ± 1.31	(Ghosh et al. 2021)
Vespa mandarina	36.8 ± 2.37	n/a	20.1 ± 3.75	

Table 15. Mineral content in *Vespa velutina, Vespa mandarina* mg per 100g of DM

	Ca	Na	Mg	K	P	Fe	Zn	Mn	Cu
Vespa velutina	38.8 ± 0.04	10.4 ± 0.02	63.9 ± 0.01	751.6 ± 0.87	561.2 ± 1.18	10.0 ± 0.12	7.2 ± 0.02	0.6 ± 0.02	2.2 ± 0.04
Vespa mandarina	27.4 ± 0.20	30.8 ± 0.40	33.0 ± 0.44	422.7 ± 6.58	322.5 ± 2.93	7.2 ± 0.41	4.7 ± 0.01	0.1 ± 0.01	0.9 ± 0.01

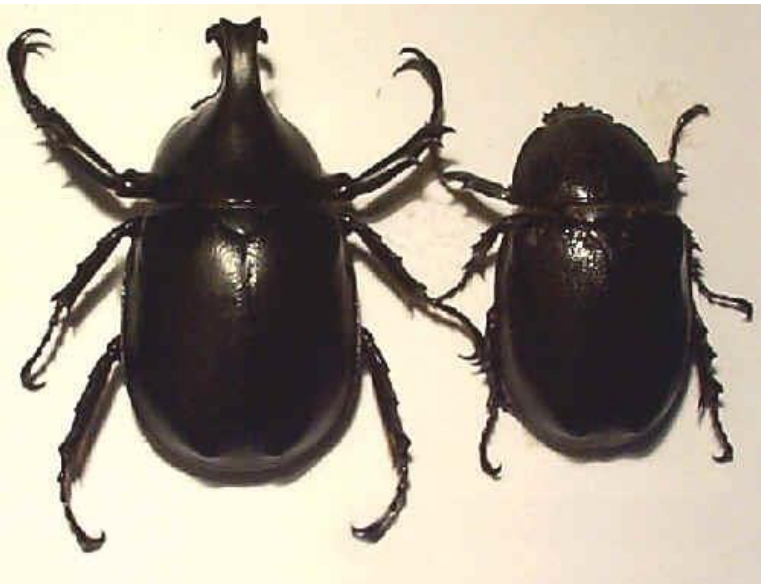
4.5.22. Xylotrupes gideon

Hercules beetles are form Dynastidae subfamily, also known as rhinoceros beetles. Hercules beetles have specific look with big horns. Horns are typical for males; females do not have any horns, as seen in Figure 3 below. Due to this sexual dimorphism, females are preferred for food. Males can be kept as pets.

Hercules beetles are called Malaeng Krarm or Duang Ma Prao in Thai. Adults are usually consumed. They can be purchased live during the end of rainy season (Watanabe & Satrawaha 1984).

Approximate nutritional value of *Xylotrupes gideon* is 375.54 kcal. Crude protein in scarab beetles ranges between 68.54 and 79.33%, crude fat range is 4.00 to 5.50% and carbohydrates vary from 5.28 to 11.84%. Then crude fibre ranges between 5.16 and 8.28% and total mineral content is 0.80 to 4.98% (Bhattacharyya et al. 2018).

Figure 3. Male and female of *Xylotrupes Gideon (*Photo by Brisbane Insects)



4.6. Evaluation of data

As can be seen in Table 16. Species of edible insects in Southeast Asia, Thailand is rich in diversity of eaten insect species. 83.3% of the investigated species are eaten in Thailand.

63.3% of species in Table 16. are eaten in their adult stages. 43.3% of species are consumed in their larval stage, which is the most common immature stage to eat.

The highest protein content is found in *Bombyx mori* larvae, but there is a 15.8% difference in protein content of *Bombyx mori* pupae (Yu et al. 2008) (Tomotake et al. 2010). Therefore, not only the species eaten but the current ontogenetic stage of the insect needs to be considered. The second highest protein content is 66% in adults of *Acheta domesticus* and the third is 64% in *Gryllus bimaculatus. Nota bene* all the highest-ranking species are farmed species. Furthermore, there can be difference of protein content as high as 10.5% percent between farmed and wild collected individuals of the same species, as can be seen in case of *Rhynocophorus* sp. (Cito et al. 2017) (Chinarak et al. 2020). This is due to ideal conditions the insetcs are farmed in and quallity feed they are fed.

Frying and roasting are the most popular ways of processing edible insects. 63.3% of investigated species are documented to be eaten fried. Popularity of this processing method is probably due to increased fat content and enhanced taste (Stier 2000). Roasting ins second most popular method to cook edible insects as 56,7% of species above are documented to be eaten roasted. Despite the lesser popularity, roasting is more suitable preparation method as it is not connected with adverse health effects as frying (Stier 2013). Furthermore, frying leads to more degradation of protein than roasting. As can be seen in *Tenebrio molitor* case, the difference in roasted and fried mealworms was approximately 28.6% (Kim et al. 2015).

Table 16. Species of edible insects in Southeast Asia

Latin name	English name	Distribution	Local name	Cultivated	Stage of consumption	Protein % dry matter	Preferred preparation	References
Acheta domesticus	House cricket	Lao PDR	Chi Lor (L)	Y	Imgaos	66	Roasting	(Hanboonsong & Durst 2014)
		Thailand	Tong-Dem (T)				Frying	(SENS Food 2020)
							Drying	
Apis spp.	Honeybee	Lao PDR	n/a	Y	Imagos		Raw	(Watanabe & Satrawaha 1984)
		Phillipines	n/a		Pupae		Grilling beehive	(Ghosh et al. 2020)
		Thailand	Pung, Rueng Pung (T)		Larvae	37.53 (brood)	Roasting	
		Vietnam	n/a		Eggs		Frying	
							Boiling	
Bombyx mori	Silkworm	Lao PDR	n/a	Y	Pupae	55.6	Raw	(Watanabe & Satrawaha 1984)
		Thailand	Duck Dae Tua Mai (T)		Larvae	71.4	Steaming	(Yu et al. 2008)
		Myanmar	n/a				Roasting	(Tomotake et al. 2010)
		Vietnam	n/a				Frying	
Gryllus bimaculatus	Two-spotted cricket	Lao PDR	n/a	Y	Imagos	64	Roasting	(Watanabe & Satrawaha 1984)
	Field cricket	Thailand	Ching Reed, Ching Klong, Chi Pom (T)				Frying	(Kim et al. 2015)
Hermetia illucens	Black soldier fly	Cambodia	n/a	Y	Larvae	42	Processed	(Wang & Shelomi 2017)
		Lao PDR	n/a					(Unger 2013)
		Malaysia	n/a					
		Myanmar	n/a					
		Thailand	n/a					
		Vietnam	n/a					

Table 16. Species of edible insects in Southeast Asia (continued)

Latin name	English name	Distribution	Local name	Cultivated	Stage of consumption	Protein % dry matter	Preffered peparation	References
Oecophylla smaragdina	Asian green weaver ant	Lao PDR	n/a	Y	Imagos	55.28	Raw	(Offenberg & Wiwatwitaya 2010)
		Thailand	n/a		Pupae	n/a	Steaming	(Hanboonsong & Durst 2014)
		Myanmar	n/a		Larvae	n/a	In curry	(Watanabe & Satrawaha 1984)
					Eggs	n/a		(Raksakantong et al. 2010)
					Queen caste	37.46		
Rhynocophorus ferrugineus	Asian palm weevil	Lao PDR	Dong Mak Prao (L)	Y	Larvae	18-28.5	Raw	(Hanboonsong & Durst 2014)
	Red palm Weevil	Vietnam	đuông dừa (V)				Steaming	(Rugman-Jones et al. 2013)
	Sago Palm weevil						Roasting	(Cito et al. 2017)
							Frying	(Chinarak et al. 2020)
							Processing	
Rhynocophorus vulneratus	Asian palm weevil	Malaysia	n/a	Y	Larvae	18-28.5	Raw	(Hanboonsong & Durst 2014)
	Red palm Weevil	Myanmar	n/a				Steaming	(Rugman-Jones et al. 2013)
	Sago Palm weevil	Thailand	n/a				Roasting	(Cito et al. 2017)
							Frying	(Chinarak et al. 2020)
Rhynochophorus bilineatus	Black palm weevil	Indonesia	Ulat sagu (J)	N	Larvae	n/a	Raw	(Ramandey & Van Mastrig 2010)
							Roasting	

Table 16. Species of edible insects in Southeast Asia (continued)

Latin name	English name	Distribution	Local name	Cultivated	Stage of consumption	Protein % dry matter	Preffered peparation	References
Tenebrio molitor	Yellow mealworm	Lao PDR	Dong Nannok (L)	Y	Imagos	n/a	Raw	(Hanboonsong & Durst 2014)
					Larvae	52.4	Frying	(Grau et al. 2017)
					Eggs	n/a		
Arcididae	Grasshopper	Indonesia	n/a	N	Adults	n/a	Roasting	(Hanboonsong et al. 2013)
	Locust	Lao PDR	Tak Tane (L)				Frying	(Watanabe & Satrawaha 1984)
		Phillipines	n/a					(Van der Meer Mohr 1965)
		Thailand	n/a					
Brachytrupes portentosus	Short-tailed cricket	Indonesia	n/a	N	Imagos	48.69	Roastig	(Raksakantong et al. 2010)
		Lao PDR	Chi Nai (L)				Toasting	(Hanboonsong & Durst 2014)
		Thailand	n/a				Frying	
Buprestidae	Metallic wood borer	Malaysia	n/a	N	Imagos	n/a	n/a	(Watanabe & Satrawaha 1984)
	Jewel beetle	Thailand	Malaleng Tub (T)					
Cicadoidea	Cicada	Indonesa	n/a	N	Imagos	47,23 +-	Raw	(Hanboonsong & Durst 2014)
		Lao PDR	Chak Chan (L)		Nymphs		Frying	(Raksakantong et al. 2010)
		Malaysia	n/a		Larvae			(Van der Meer Mohr 1965)
		Thailand	n/a					(Castro AF 2013)

Table 16. Species of edible insects in Southeast Asia (continued)

Local name	Cultivated	Stage of consumptio n	Protein % dry matter	Preffered peparation	References			
Cybis spp.	Predacious diving beetle	Thailand	Malaleng Tub Tow	N	Imagos	n/a	Steaming	(Watanabe & Satrawaha 1984)
								(Hanboonsong 2010)
Copris sp, Ontophagus sp., Onitis spp.,	Dung Beetle	Lao PDR	Chud Chii (L)	N	Imagos	54.43+-	Steaming	(Watanabe & Satrawaha 1984)
Heliocopris spp.,		Myanmar	n/a				Frying	(Raksakantong et al. 2010)
Liatongus spp.		Thailand	Kood Chi, Good Gi (T)				Chilli pasting	
							In curry	
Exopotus, Holotrichia,	June Beetle,	Laos	Mieng Chi Noun (L)	N	Imagos	n/a	Steaming	(Watanabe & Satrawaha 1984)
Phylophaga	May Beetle	Phillipines	Salagubang (P)				Roasting	(Hanboonsong & Durst 2014)
	Cockchafer	Thailand	Malaeng Kinoon Mone (dark) (T)				Frying	(Raksakantong et al. 2010)
			Malaeng Kinoon Daeng (metallic) (T)				Dipping	
							In curry	
Gryllotalpa africana	Mole cricket	Indonesia	n/a	N	Imagos	48,69+-	Roasting	(Watanabe & Satrawaha 1984)
		Lao PDR	n/a				Frying	(Van der Meer Mohr 1965)
		Phillipines	n/a					(Adalla & Cleofac 2010)
		Thailand	Malaeng Krachorn (T)					
		Vietnam	n/a					
Hyblaea puera	Teak caterpillar Teak defoliator	Indonesia	Enthung Jati	N	Cocoons	n/a	Frying	(Dwi 2010)

Table 16. Species of edible insects in Southeast Asia (continued)

Latin name	English name	Distribution	Local name	Cultivated	Stage of consumption	Protein % dry matter	Preffered peparation	References
Hydrophilous spp.	Scavenger beetle	Lao PDR	n/a	N	Imagos	n/a	Steaming	(Watanabe & Satrawaha 1984)
		Thailand	Malaeng Nian (T)		Nymphs	n/a		(Hanboonsong 2010)
Hypomeces squamosus	Green weevil	Lao PDR	Meng Xang	N	Larvae	n/a	Raw	(Hanboonsong & Durst 2014)
							Roasted	
							Frying	
Lethocerus Indicus	Giant water bug	Malaysia	n/a	N	Imagos	16,16-19,33	Raw	(Watanabe & Satrawaha 1984).
		Myanmar	n/a				Frying	(Radhakrishore et al. 2015)
		Thailand	n/a					(Watanabe & Satrawaha 1984)
		Vietnam	n/a					
Mantidae	Mantis	Indonesia	n/a		Imagos	n/a	Roasting	(Xiaoming et al. 2010)
		Malaysia	n/a				Frying	
		Myanmar	n/a					
		Thailand	n/a					
Noronectidae	Backwimmer	Malaysia	n/a	N	Imagos	n/a	n/a	(Xiaoming et al. 2010)
		Myanmar	n/a					
		Thailand	Malaeng Muan Won (T)					
			Manghua Qai (T)					
Odonata	Dragonfly	Lao PDR	Miend Naa Gam	N	Nymphs	n/a	n/a	(Watanabe & Satrawaha 1984)
		Phillipines	n/a		Larvae	40-65		(Hanboonsong & Durst 2014)

Table 16. Species of edible insects in Southeast Asia (continued)

Latin name	English name	Distribution	Local name	Cultivated	Stage of consumption	Protein % dry matter	Preffered peparation	References
Odonata	Dragonfly	Thailand	Pong Peng, Malaeng Ngum (T)	n/a	Nymphs	n/a	n/a	(Xiaoming et al. 2010)
		Timor-Leste	n/a		Larvae	40-65		
Omphisa fuscidentalis	Bamboo catterpillar	Lao PDR	To Mir, Daung Nor Mai (L)	N	Larvae	n/a	Raw	(Hanboonsong & Durst 2014)
		Myanmar	n/a				Frying	(Singtripop et al. 1999)
		Thailand	n/a					
Phasmotodeae	Tree insect	Lao PDR	n/a	N	Imagos	n/a	n/a	(Xiaoming et al. 2010)
	Stick insect							
Termitidae	Termite	Lao PDR	n/a	N	Imagos	42,63	Roasting	(Deblauwe 2009)
		Thailand	n/a					(Bignell et al. 2010)
								(Raksakantong et al. 2010)
Tessaratoma spp.	Stink bug	Lao PDR	n/a	N	Imagos	50.54	Roasted	(Hanboonsong & Durst 2014)
		Thailand	n/a				In curry	(Raksakantong et al. 2010)
							Chilli pasting	
Vespa spp.	Wasp, hornet	Indonesia	n/a	N	Brood	36.8–37.9	n/a	(Hanboonsong & Durst 2014)
		Lao PDR	Tor, To Kea (Yellow) (L)					(Van der Meer Mohr 1965)
			To Dun (black) (L)					(Ghosh et al. 2021)
		Malaysia	n/a					
		Myanmar	n/a					
		Thailand	n/a					

Table 16. Species of edible insects in Southeast Asia (continued)

Latin name	English name	Distribution	Local name	Cultivated	Stage of consumption	Protein % dry matter	Preffered peparation	References
Xylotrupes gideon	Hercules beetle	Malaysia	n/a	N	Imagos	n/a	Raw	(Watanabe & Satrawaha 1984)
		Myanmar	n/a		Larvae		Roasting	(Bhattacharyya et al. 2018)
		Thailand	Malaeng Krarm (T)				Frying	
			Duang Ma Prao (T)					

5. Conclusions

Edible insects as alternative source of protein in Southeast Asia were investigated in this thesis. This work analysed eight species of commonly farmed insects and 21 species or groups of species collected from wild with more detailed description of farmed species. Distribution, ontogenetic stages of consumption, preferred ways of processing or amount of protein were investigated as well. Southeast Asia is rich in biodiversity of edible insect species but data on nutritional values of most are not available. Most of research is on already described and well researched species. More research on species foraged from wild is needed.

Insects are highly nutritious and beneficial to humans when incorporated into diet. Insects are source of high-quality protein that is comparable with conventional animal-based protein sources. Some insects have up to 71.4% of protein in dry weight matter (*Bombix mori larvae)* with all essential amino acids present (Tomotake et al. 2010). They are also rich in unsaturated fats and high in minerals and vitamins (Xiaoming et al. 2010). Although, they may trigger allergic reaction in individuals allergic to dust mites, crustaceans, mold or with related cross-allergy (Gour & Lajoie 2016).

Farmed insects have undoubtedly higher nutrient content than the ones that are collected from wild (Chinarak et al. 2020) (Cito et al. 2017). Moreover, insects that are raised on farms are safer to consume, as they do not bioaccumulate toxins and danger of transmission of zoonosis is significantly lower (Jansson & Berggren 2015). Way of preparation can influence the nutrient levels and quality of the nutrients. Lyophilization and hot air drying shown to be the best ways of processing to preserve the nutrient content (Kim et al. 2015).

There has been surge of insect farms in Southeast Asia in past two decades. Farming of edible insects is a promising sustainable way to feed hungry masses and combat food insecurity with minimal harm to the planet. Bigger emphasis, not only in Southeast Asia, but worldwide, should be put on insect farming in near future. More education and awareness need to be spread in the West, to show that bugs are not to be feared and eating them is nowhere close to disgusting or primitive.

Insects offer promising alternative to conventional livestock for human consumption with less negative impact.

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