contaminants. Moreover, there is the potential livelihood implication of farming edible insects that is gaining popularity in the Philippines.

While the traditional collection of edible species in the wild can be continued as an adjunct to the proposed mass production in controlled environments, the former will surely contribute to natural control of the edible species, which are in most cases insect pests as well. Should insects become a popular and widely acceptable food source, then the farmer may be forced to reduce pesticide application and conduct massive collection of these pests instead.

With regard to biodiversity conservation, humans as insect predators are not expected to wipe out any species. For example in mole crickets the stage-specific preference is the adult and therefore the other stages will be spared and allowed to multiply and complete the cycle.

Literature cited

Banjo, A.D. *et al.* 2006. The nutritional value of fourteen species of edible insects in southwestern Nigeria. *African Journal of Biotechnology,* 5(3): 298-301.

Barrion-Dupo, A.L.A., Sheree, A. & Lit, I.L., Jr. 2008. Nutritive value of camaro. *Transactions of the National Academy of Science and Technology Philippines,* 30(1): 199.

Chua, G.S., Palmiere, J.P. & Sullivan, J.T. 1977. Beetle eating: a Malaysian folk medicinal practice and its health implication. *Tropical Geography Medicine,* 29(4): 422-427.

Dacanay, A.C. & Cervancia, C.R. 1989. Biology of *Palembus martianus dermestoides* Chevrolat (Coleoptera: Tenebrionidae). *Philippine Entomologist,* 7(5): 471-477.

Tilde, A.C., Fuchs, S., Koeniger, N. & Cervancia, C.R. 2000. Morphometric diversity of *Apis cerana* Fabricius within the Philippines. *Apidologie,* 31: 249-263.

Yoshida, T. 1974. Rate of oviposition and effect of crowding on egg cannibalism and pre-adult mortality in *Palembus (Matianus) dermestoides* (Chevr) (Fairm), Coleptera L

Tenebrionidae. *Scientific Report, Faculty of Agronomy, Okayama University*, 44: 9-14.

Appendix 1. *Adobong camaru* (mole cricket)

Ingredients:

250 g	mole crickets, washed and drained
1 head garlic	minced
1 pc onion	chopped
2 tbsp	soy sauce
2 tbsp	cane vinegar
2-3 pcs	hot chili
	salt and pepper to taste

Procedure:

1. Remove hard parts of the insects, particularly the extremities. Wash and drain.
2. Heat oil in a sauce pan, sautée garlic and onion and add the crickets.
3. Add soy sauce, vinegar and chopped chili and season to taste with a pinch of salt and pepper.
4. Cover and cook for five to eight minutes over low flame to allow slow cooking to conserve the flavour.
5. For variation, half a cup of pure coconut milk may be added; extend cooking time until the sauce becomes thick.

Sri Lanka as a potential gene pool of edible insects

M.R.M.P. Nandasena,[1*] D.M.S.K. Disanayake[1] and L. Weeratunga[1]

Sri Lanka hosts 11 144 insect species belonging to 30 insect Orders (based only on museum specimens and limited catalogues). The actual number of edible insect species may be much higher than current data suggest. In Sri Lanka, insect eating is only practised among the Vedda tribal people, who traditionally eat bee brood and larvae of Apis dorsata, A. cerana *and* A. florae. *Insects are not eaten by other ethnic groups because the two major religions (Buddhism and Hinduism) do not support the killing of animals for food and this induces a vegetarian diet. On the other hand marine and inland fisheries, along with livestock, provide adequate supplies of protein for society. Forest fragmentation and habitat loss are increasing because of development; thus, insect diversity along with populations of other fauna and of flora is diminishing. Recognition of the island's unique insect biodiversity, coupled with the creation of a programme to protect and conserve the edible insect gene pool, could give Sri Lanka a potential role in the maintenance of an edible insect gene pool for the rest of the world.*

Keywords: bees, conservation, insect biodiversity, religion, Vedda

Introduction

Sri Lanka is a tropical island country in the Indian Ocean with a land area of approximately 65 500 square kilometres. Its unique geoclimatic features support rich biological diversity. Sri Lanka hosts 11 144 insect species belonging to 30 insect Orders (Wijesekara 2006). Insects in Sri Lanka constitute 53 percent of all known organisms (both plant and animal) on the island and 81 percent of the known animal species.

Humans have consumed insects for thousands of years. More than 1 400 insect species are eaten around the world (Johnson 2007), most of which are collected from natural forests. Nowadays, insect consumption is declining in many parts of the world. However, edible insects remain important protein sources for some communities in Asia, Africa and the Americas.

In Sri Lanka insects are only consumed by the Vedda tribal minority (Wijesekera 1964). The Vedda have existed on the island for about 37 000 years and are direct descendants of Sri Lankan Mesolithic prehistoric man (Deraniyagla 1992). The Vedda are accustomed to eating bee brood and bee larvae of *Apis dorsata* (the giant honey bee), *A. cerana* (the common honey bee) and *A. florae* (the dwarf honey bee) (Wijesekera 1964). The ethnic majority groups, i.e. the Sinhalese (ca. 75 percent), Tamils (12 percent), Muslims (8 percent) and Burghers[2] do not consume insects.

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The objective of this study was to determine how many edible insect species consumed worldwide are recorded in Sri Lanka.

Methodology

The results were based mainly on a three-month literature survey. The findings were checked with both the National Entomology collection and insect catalogues available in the national museums of Sri Lanka.

Results

Sri Lanka has a gene pool of 29 species in six Orders *vis-à-vis* insects consumed worldwide (Table 1). Coleoptera (13 spp.) predominate with six Families: Curculionidae (2 spp.), Dytiscidae (3 spp.), Scarabaeidae (4 spp.), Cerambycidae (2 spp.), Hydrophilidae (1 sp.) and Passalidae (1 sp.). One genus from the Family Buprestidae (*Chrysobothris* sp.) is also recorded. The second largest Order is Lepidoptera (7 spp.) represented by three Families: Aretiidae (1 sp.), Bombycidae (1 sp.) and Saturniidae (5 spp.). The Order Orthoptera (4 spp.) includes three Families: Acrididae (1 sp.), Gryllotalpidae (1 sp.) and Tettigoniidae (1 sp.). The genus *Acrida* from the Family Acrididae is also recorded. Other edible insects are represented by Hemiptera (2 spp.), Hymenoptera (3 spp.) and Isoptera, which includes several edible termite species.

Table 1. Insect species recorded in Sri Lanka that are eaten worldwide

Order	Family	Species/genus
Coleoptera	Buprestidae (metallic woodborers)	*Chrysobothris* sp.
	Curculionidae (weevils, snout beetles)	*Hypomeces squamosus* *Rhynchophorus ferrugineus*
	Dytiscidae (predaceous diving beetles)	*Cybister limbatus* *Cybister tripunctatus* *Eretes sticticus*
	Scarabaeidae (scarab beetles)	*Adoretus compressus* *Lepidiota stigma* *Oryctes rhinoceros* *Xylotrupes gideon*
	Cerambycidae (long-horned beetles)	*Neocerambyx paris ?* *Xystrocera globosa*
	Hydrophilidae (water scavenger beetles)	*Hydrophilus olivaceus*
	Passalidae (bess beetles)	*Passalus interruptus*
Hemiptera	Belostomatidae (giant water bugs)	*Lethocerus indicus*
	Pentatomidae (stink bugs)	*Bagrada picta ?*
Hymenoptera	Apidae (honey bees)	*Apis dorsata* *Apis laboriosa*
	Formicidae (ants)	*Oecophylla smaragdina*
Isoptera	Odontotermitidae (wood-eating termites)	*Odontotermes feae ?*
Lepidoptera	Aretiidae (tiger moths)	*Diacrisia obliqua*
	Bombycidae (silkworm moths)	*Bombyx mori*
	Saturniidae (giant silkworm moths)	*Antheraea assamensis* *Antheraea paphia* *Antheraea roylei* *Samia cynthia ?* *Samia ricini*
Orthoptera	Acrididae (short-horned grasshoppers)	*Acrida* sp. *Mecapoda elongata ?*
	Gryllotalpidae (mole crickets)	*Gryllotalpa africana* = (*orientalis*)
	Tettigoniidae (long-horned grasshoppers)	*Holochlora albida*

Discussion

Excepting the Vedda tribal people, other Sri Lankans do not consume insects for two major seasons: (1) marine and inland fisheries afford easy access to large quantities of fish, along with protein from domestic and wild vertebrate animals; and (2) the two major religions, Buddhism and Hinduism, shun the killing of animals for food.

Sri Lanka has diverse habitats for several insect species consumed worldwide. According to the world edible insect list by Johnson (2007), 29 insect species recorded in Sri Lanka are eaten worldwide. Four species of aquatic bugs and beetles can be found in large numbers in hundreds of ancient reservoirs, millions of hectares of paddy fields and natural marsh lands. The other terrestrial insects are found in natural forests (protected and unprotected) and also in native home garden systems, known as “Kandyan home gardens”, which are quite close in structure to the natural rain forest. A few termite species are recorded, but it is not clear which species of termite are consumed by humans worldwide. Most of the edible insects recorded in Sri Lanka are consumed in other countries such as Thailand. In addition, there are two types of honey bee larvae that are consumed by the Vedda, *Apis cerana* and *A. florae*. However, the Vedda are becoming more modernized (living in villages or outside the forest) and they have abandoned some of their old food practices.

Sri Lanka could play a key role in maintaining edible insect gene pools for the rest of the world. Indeed, the number of edible insect species in the country may be much higher than present calculations. Charismatic insect groups such as butterflies and dragonflies have been studied in detail, but other insect groups have received scant research attention apart from initial descriptions. An updated systematic insect checklist for Sri Lanka is also needed. It should be emphasized that present calculations are based solely on museum specimens and limited catalogues in the National Museum of Sri Lanka.

Forest fragmentation and habitat loss are increasing because of development in Sri Lanka, which may well lead to a decrease of insect diversity as well as populations of other native fauna and flora. Therefore, well-planned taxonomic research needs to be carried out, along with a well-executed programme to protect and conserve the edible insect gene pool. With international cooperation and support, Sri Lanka could play an important role in the *in-situ* conservation of edible insects.

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Literature cited

Deraniyagala, S. 1992. *Prehistory of Sri Lanka*. Volumes 1 and 2. Archaeological Survey of Sri Lanka.

Johnson, D.V. 2007. *The contribution of edible forest insects to human nutrition and to forest management: current status and future potential, with emphasis on the Asia-Pacific Region.* Workshop Background Report. 74 pp.

Wijesekara, A. 2006. An overview of the taxonomic status of Class Hexapoda (Insecta) in Sri Lanka. *In* C.N.B. Bambaradeniya, ed. *The fauna of Sri Lanka: status of taxonomy,research and conservation,* pp. 3-11. IUCN-The World Conservation Union, Gland, Switzerland.

Wijesekera, N. 1964. *Veddas in transition*. Colombo, M.D. Gunasena Pub.

Honey and non-honey foods from bees in Thailand

Somnuk Boongird[1]

Thai non-wood forest products are mainly derived from secondary forests because very little primary forest still exists. Primary forest degradation has led to a reduction of bee populations necessary for forest tree pollination and natural regeneration. Stingless bees have distinctive forest habitats. Large stingless bees, Trigona *spp., prefer tree tops; those of medium size feed on flowers at lower canopy levels; the smallest on flowering bushes and ground cover. Stingless bees nest in tree cavities, forming permanent colonies. Arboreal honey bees,* Apis *spp., usually migrate among forest types as nectar sources are exhausted. Collectors typically take the entire nest, rather than the honeycomb only; as a result, adult nurse and guard bees die within one week; occasionally the queen and worker bees attempt to rebuild the nest nearby, but this is seldom successful. Bee nests are collected in forests open for such activities, as well as in restricted forests where collection is prohibited by law. In general, collected bee products are sold at local markets for cash and not consumed for subsistence. Nests are displayed to attract buyers of bottled honey, which is often adulterated. Non-honey food uses include capped brood mixed with pollen, which is cut into pieces and macerated in alcohol to produce a liquid medicine with some food value. Capped brood may also be roasted and eaten directly, except for the pollen. Eating pollen, especially from stingless bees, generally is avoided because of the fear of allergic reactions. Because wild honey production itself is low, sales of brood comb, pollen comb and propolis represent income sources to collectors. Action is needed to discourage honey collecting in restricted forests and the collection of entire nests, to assure sustainable harvesting of bee products and natural forest regeneration.*

Keywords: *Apis*, brood, honeycomb, pollen, propolis, *Trigona*

Introduction

Bees play a significant role in forest ecology. The following introductory material is drawn in part from Boongird and Khomkham (2005) and Santisuk (2004).

The giant honey bee *Apis dorsata* F. and the dwarf honey bees, *A. florea* F. and *A. andreniformis* (Smith) are recognized as major forest pollinators because of their sizeable populations and division of labour, which increases their efficiency in their visits to flowers. Bees are efficient pollinators and – through cross-pollination – can help produce vigorous seed for the next generation of plants. In nature, forest ecological processes, between specific pollinators and the target flowers to be pollinated, have influenced the development of genetic

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resources for survival, after being subjected to competition or predation. Therefore, forest management should not ignore the activities of bee pollination for maintaining plant life for producing vigorous seed growth in the forest environment. Wild bees living in the forest should be one of the major components of sustainable forest management.

Within forests, migration of the wild honey bee such as the giant honey bee, *Apis dorsata* F. and the Indian honey bee, *Apis cerana* F. occurs annually from place to place. Bee trees are necessary for *A. dorsata* to build their colonies for the next mating season. Indian honey bees need a tree cavity for nesting; sometimes they are unsuccessful because a cavity is already occupied by another colony of *A. cerana* or by stingless bees. This is the reason that Indian honey bees are rare in the forest and tend to live in artificial cavities within urban environments. Migration routes of wild honey bees are the same every year. They return to the same site for nesting and then fly back to their usual location when flowers are in bloom. Tropical forest flowers produce large quantities of various types of pollen from different species, which are attractive to specific insect pollinators.

Permanent colonies of stingless bees (*Trigona* spp.) living in the forest normally forage on flowers to gather nectar and pollen. Pollen is the main component of their food mixture. The food ratio of pollen to nectar is about 80 to 20. Nest provisioning food is regurgitated by nurse bees into the cell before the queen lays an egg on the surface of the food and then the cell is closed until the emergence of the adult. Stingless bees occur in every province of Thailand and most of them live in hollow trees.

Bee hunters prefer the nests of the giant honey bee to those of the dwarf honey bees and stingless bees. If they have no option, they will take the bee nests they find. Bee hunters usually have experience in harvesting honey, but the honey quantity of the colonies is decreasing year by year; therefore, they harvest the entire comb to gain more income. Not only can the honey be sold, but the brood comb also fetches a high price. Pollen comb is separated and placed into a bottle of adulterated honey. Harvesting techniques are not being promoted to sustain wild bee colonies. Beekeeping is the ideal solution, alleviating pressures on wild bee populations.

The numbers of native bees in agricultural areas is insufficient for the pollination of the target flowers. As a result, crop yields are quite low in quantity and quality. Orchard growers tried to use the exotic bee, *Apis mellifera* L. to compensate for low numbers of native bees, but this was unsuccessful because some of the flowers were unattractive to these exotic bees. *A. mellifera* has a floral preference. Stingless bee colonies can be used to fill the pollination gap of native flowers which produce some scent. They visit every type of flower that exists while foraging the canopy. However, their flight range is rather limited in distance. This means that the native honey bees are indispensable pollinators and must be conserved to maintain a stable forest ecology. Some fruit growers protect the giant honey bee nests within their orchards and they do not allow honey hunters to collect the honey from the nests. However some landowners agree to allow bee hunters to enter for a share of the honey.

Plate 1. Wedelia flower visited by *Apis mellifera (Courtesy S. Boongird)*

The application of pesticides to field and tree crops has also caused bee populations to decline. An acceleration of detrimental factors such as bee hunting and insecticide spraying also has been reducing bee populations in the natural environment. Similar problems are reported in Africa (Schabel 2006).

Stingless bee colonies have been hunted for many years for propolis as well as honey, but their pollen is not collected. Bee hunters are fearful of the toxicity of stingless bee pollen, which can cause death or at the very least convulsions if eaten directly. But some stingless bee colonies may not contain toxic pollen if benign flower sources occur in the foraging area. Some collectors of stingless bee pollen, to be on the safe side, detoxify it by putting the pollen into traditional whisky and making an alcoholic macerate similar to a traditional medicine, adding certain herbs and liquefying it into a traditional medicine. The alcohol content of this medicine is very high and taking too much can cause intoxification.

Regulations affecting bee hunting

Wild honey bees, *Apis dorsata* F., *A. florea* F. and *A. andreniformis* (Smith) are beneficial insects and should never be classified as insect pests. Bees represent a major component of establishing and maintaining a healthy forest. They are worth much more than their value as producers of human food. A single foraging bee over its lifetime may visit some 270 000 flowers, assuring successful fruit set. Some flowers have evolved to the extent that they require a specific pollinator, as a result of parallel evolution. Simply put, if the specialized insect pollinators are unavailable for pollination of such plant flowers, the result may cause certain species to be in danger of extinction.

There are four official Thai Government acts for forest conservation and protection, which relate to wild bees. These are the Forest Act B.E. 2484[2] (Krongsin Boonboothara 1996), National Park Act B.E. 2504[3] (Krongsin Boonboothara 1993b), National Reserved Forests Act B.E. 2507[4] (Krongsin Boonboothara 1995) and Wildlife Preservation and Protection Act B.E 2535[5] (Krongsin Boonboothara 1993a). These acts establish that wildlife hunting is prohibited and that forest products shall not be collected or harvested at all. But there is an exception for legitimate research by competent officers.

Forest Act B.E 2484, Section 3 states that the following laws and regulations shall be repealed: (14) Rules and regulations allowing the collection of forest products: collection of bee nests, B.E 2464.

The National Park Act B.E 2504, Chapter III, Protection and Maintenance of the National Parks, Section 16 states that within the National Park, no person shall: collect, take out, or alter by any act whatsoever, endanger or degrade orchids, honey, lac, charcoal, bark or guano.

The National Reserved Forests Act B.E 2507 states that all other laws, rules and regulations shall be replaced by this act. In Section 4, forest products refer to anything that originates from or is found in the forest, for example: carcasses, eggs, hides, horns, tusks, jaws, bone, hair, bird nests, lac, bee nests, honey, beeswax and guano.

Section 15. Logging or collection of forest products in the National Reserved Forests shall be made after permission has been obtained from the competent officer with respect to any particular area of the National Reserved Forests. In granting permission, it shall be given in accordance with the forms, rules and procedures specified in the ministerial regulations.

Section 21. The permission for logging or collection of forest products in the National Reserved Forests, under Section 15, shall be valid for a specified period of time, according to the rules determined by the Director-General, but not to exceed one year from the date of its issue. The renewal of permission shall be in accordance with the forms, rules and procedures specified in the ministerial regulations.

The details of Section 37 in the Wildlife Preservation and Protection Act B.E 2535 set forth that no person other than a competent officer or other officers on duty shall enter a Wildlife Sanctuary, unless written permission has been obtained from the assigned competent officer. Any person obtaining permission to enter a Wildlife Sanctuary shall comply with the conditions as specified in the ministerial regulations.

Despite the legal regulations that apply to the protection of wild bee populations, they have not controlled bee hunting in protected forests. Diminished wild bee populations can negatively affect forest health by allowing other insect populations to increase and to impact

[2] 1941 CE.
[3] 1961 CE.
[4] 1964 CE.
[5] 1992 CE.

detrimentally on host plants. This could affect the species diversity of forest insects, i.e., a decline in the population of certain species, with some insect pests becoming overabundant due to lack of resistance by host plants. Over time, a plant can be eradicated by excessive numbers of a particular pest.

It is estimated that there are more than 100 000 beehives in Thailand. Annual honey production is about 10 000 tonnes, along with some 100 tonnes of bee pollen. Production does not meet demand, although the bee industry has the potential to supply bee products for everyone in Thailand. It is not necessary for consumers to ask for natural pure honey, brood comb and pollen comb, for consumption. The quality of honey from natural wild sources should be the same as industrial honey, but there is a price differential with the industrial product commanding a lower price than wild honey.

Pollen from industrial beekeeping is collected by means of a pollen trap when there is a surplus. Collected pollen is cleaned, dried, packed and kept in a storage room. Pollen comb from wild bees is exposed to air because it is contained in open cells and may become contaminated by airborne fungi that produce aflatoxin.

Bee products from the wild and from beekeeping are available in markets throughout the year. Consumers need to be made aware that collecting bee products from the wild is causing indirect damage to forests. Producing industrial bee products is not linked to any negative environmental impacts.

Plate 2. Inspection of melliferous bee hive at Bhumipol Dam, Tak Province, Thailand *(Courtesy S. Boongird)*

Eating bees and other insects

Excessive hunting of stingless bees in northeastern Thailand is a very serious problem. Nests of stingless bees have disappeared from the wild because hunters have killed off the populations by nest harvesting and consequent destruction of parent stocks of bees as starter colonies for propagation. This has led to a reduction in bee diversity, which is impacting negatively on the ecological processes of the forest. General forest degradation has also exposed more soils to direct sunlight, increased evaporation rates and reduced the amount of soil moisture available for normal plant growth. This phenomenon of drier soil conditions is one of the causes of poverty among local people. Wild food plant resources have declined and people have resorted to the collection of certain insects and amphibians to supplement their basic food source, which is their annual rice crop.

The decrease in forest cover has forced people in northeastern Thailand to change their eating habits. Some insects never eaten before have become food items. Typically, rural people enter the forest to collect wild food and other products. Because there was not enough to eat, people experimented with eating some insects, which later became traditional foods.

Some insect consumption also originated from insect control strategies. The outbreak of a major pest like the grasshopper (*Patanga succinta*) is one example. A successful campaign was mounted to promote the eating of this grasshopper, which led to a reduction of their populations in maize fields, so that the grasshoppers were no longer a serious economic problem. This example of controlling a maize field pest by collecting the grasshoppers for human food was the inspiration for rearing grasshoppers in Wang Namkiew District in Srakaew Province. Maize fields were planted for the express purpose of rearing grasshoppers for food.

Numbers of bees of the genus *Apis* have become smaller and smaller until they are insufficient for effective pollination, mostly because of bee hunting. At the same time that wild bee products are being collected, other insects encountered, such as crickets, grasshoppers, beetles and Lepidopteran larvae, are taken for food. Food insects are popular among the many low-income people in Thailand. Cricket farming is carried out in a similar fashion to beekeeping. But rearing and wild collecting techniques could be improved.

Eating insects in Thailand has become a cottage industry. Wild insect collection for food can be a sustainable forestry activity and not detrimental to forest ecology. Farming certain insects like crickets also has strong potential. Together, wild and farmed insects can play an important role in human nutrition.

Nutritional benefits of bee products

For at least 2 500 years, humans have known about bees and bee products and their high nutritional value. Honey provides superior energy and has become a “sexy” food. Bee pollen is high in protein, amino acids, enzymes and hormones. Propolis is also used as a treatment for some human diseases; bees collect the plant resins, bud glands and essential oils which are attached to the pollen basket. Bees use propolis as a repellent against other insects attempting to enter their nest. Extracted propolis has become a popular natural product that is sold in markets.

Arboreal bees construct a single open comb that can yield honey, pollen and brood. Bee hunters usually take the entire comb, which is later separated into comb honey, comb pollen and the brood nest. Sometimes they soak the honeycomb in a container for display and pour the syrup into another bottle for a prospective buyer**.** Bee brood is nutritious; it is high in protein, fat and carbohydrate.

Bee brood is also a good source of phosphorus, magnesium, potassium and trace elements such as selenium. It also contains essential amino acids, most of the B-vitamins and vitamin C (Finke 2005). Honey bee larvae represent a richer protein source than pork, and their vitamin and mineral content is comparable to chicken (Chen *et al.* 1998).

Research has shown that the quality of wild honey and industrial honey is the same. Therefore, wild bees should be protected and allowed to play their essential role in nature so that forests can produce other non-wood forest products that can be sustainably harvested for general benefit. At present, the forests of Thailand have been degraded or destroyed by human activities and wild fires. Forest recovery from such impacts is a slow process, but is a goal worth pursuing.

Conclusion

The main objective in collecting bee nests is honey. Pollen and brood are by-products of the same comb. Currently in Thailand, collecting entire bee nests is illegal. Nevertheless, bee hunters often take the entire nest and sell it as quickly as possible because it is difficult to keep the honey fresh. Even today, some Thai people still search for wild colonies of giant bees. The typical bee hunter has little education and is poor and jobless. It is difficult to convince bee hunters to stop their activities because they want to be free of restrictions in their livelihood pursuits. Sometimes bee hunters are able to sell honey to the buyers easily, some of whom want only pure wild honey, even though the buyers may not be able to distinguish pure from adulterated honey. This fascination with pure wild honey is the reason why bee hunters still exist. Buyers should be made aware that industrial beekeeping can supply good quality honey and bee food products to consumers; for example, bee pollen, which has a limited shelf life. Consumers should not insist upon trying to obtain wild honey, for the simple reason that there is no pure wild honey in the markets for sale by vendors. Wild honey has largely been replaced by industrial honey, which is harvested, processed and packaged under sanitary conditions that eliminate the causes of unwanted fermentation.

Literature cited

Boongird, S. & Khomkham, A. 2005. *Beekeeping and pollination.* Bangkok, Ramkhamhaeng Printing Inc. (In Thai.)

Chen, P.O. *et al*. 1998. Honey bees and other edible insects used as human food in Thailand. *American Entomologist*, 44(1): 24-29.

Finke, M.D. 2005. Nutrient composition of bee brood and its potential as human food, *Ecology of Food and Nutrition*, 44(4): 257-270.

Krongsin Boonboothara. 1996. Forest Act B.E. 2484 (A.D. 1941). Bangkok, Royal Forest Department, Ministry of Agriculture and Cooperatives.

Krongsin Boonboothara. 1995. National Reserved Forests Act B.E. 2507 (A.D. 1964). Bangkok, Royal Forest Department, Ministry of Agriculture and Cooperatives.

Krongsin Boonboothara. 1993a. Wildlife Preservation and Protection Act B.E. 2535 (A.D. 1992). Bangkok, Royal Forest Department, Ministry of Agriculture and Cooperatives.

Krongsin Boonboothara. 1993b. National Park Act B.E. 2504 (A.D. 1961). Bangkok, Royal Forest Department, Ministry of Agriculture and Cooperatives.

Santisuk, T. 2004. *Forests in Thailand*. Bangkok, Prachachon Printing Co. Ltd. Bangkok. (In Thai.)

Schabel, H.G. 2006. *Forest entomology in East Africa: forest insects of Tanzania.* Dordrecht, the Netherlands, Springer.

Edible insects and associated food habits in Thailand

Yupa Hanboonsong[1]

Insect eating has a long history in Thailand and occurs throughout the country. According to research, more than 150 insect species in eight orders are consumed. Of these, beetles represent the largest group. Insects are consumed at various stages of their life cycles. The preferences of local people vary from region to region. Having an agreeable taste is the main reason for eating insects. Most edible insects are cooked in some way before being eaten; for example deep-fried, fried with spices or roasted. The traditional knowledge of local Thais in the context of insect consumption continues to remain important and provides indicators for future development potential.

Keywords: beetles, collecting, farming, *Patanga* locust, preparation, snack food

Introduction

The inclusion of insects in the human diet is an uncommon, although widespread, practice. Insects are consumed in many countries either as a nutritious food supplement or as a delicacy. For example, Africans eat various grasshoppers, termites and Saturniidae moth caterpillars. Japanese and Koreans eat grasshoppers and silkworm pupae. Hamburger stuffed with crickets and spring rolls stuffed with worms are served as exotic delicacies in some restaurants in the United States. And Mexico's well-known exported edible insect product is the tinned giant skipper larva (Vane-Wright 1991).

Thai people have been eating insects for centuries. In particular, a traditional, well-known delicacy is the giant water bug *Lethocerus indicus,* which is used to make *nam prik maeng daa*, a common Thai dish. Northeastern Thai people favour the silkworm pupae of *Bombyx mori* L., which is a by-product of collecting silk from the cocoons.

Edible insect species are not only associated with local Thai people's way of life or cultural practices. Interestingly, insect consumption is also used as a strategy for insect pest control. For example, 40 years ago there was an outbreak of locust (*Patanga succincta* L.), which was widespread in areas cultivated with maize. Different insect control methods including aerial spraying of insecticide were applied but did not succeed in controlling the outbreak. In the past, the *Patanga* locust was not well-known as an edible species, but from 1978 to 1981 a campaign to promote eating of the *Patanga* locust was initiated (Roffey 1979). Various approaches such as deep-frying, use as a cracker ingredient and fermentation to make a cooking sauce similar to fish sauce were introduced (Amin 1989; Pitug 1986). Currently, *Patanga* locust (deep-fried) is one of the best known and most popular edible insects in Thailand. Consequently, this species is no longer a major pest for farmers. With a

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high demand and price for *Patanga* locust, some farmers even grow a maize crop to feed this insect, rather than to harvest the maize.

Scenarios for eating insect pests have also been suggested for other species such as palm weevil larvae (*Cyrtotrachelus dochrous* F.) and the bamboo caterpillar *Omphisa fuscidentalis* Hampson (Chunram 1993). The latter species has now become a popular edible insect in the northern and northeastern areas of the country. In 2004, a serious outbreak of sugar-cane stem borer (*Chilo tumidicostalis* Hampson) occurred in cane-growing areas of Thailand. One of the successful control methods was biological control by massive human consumption of sugar-cane stem borer caterpillars.

Reasons for eating insects

Insects are commonly eaten in Thailand and their consumption is a particularly symbolic feature of northeastern people's way of life. Moreover, insects are consumed even when other more conventional sources of food are available. Previous research using questionnaires found that approximately three-fourths of the people eat insects because they are *tasty* or make a good *snack*. Less than 1 percent ate insects for pest control purposes.

The reasons for eating insects were surveyed in Northeast Thailand. The results are given in Table 1. Taste appears to be the main motivation. While cost issues were not systematically investigated, cost also appears to play a significant role, as edible insects are easy to find around farms. Such locally available food sources represent a *free supermarket*.

Table 1. Reasons given for eating insects in Northeast Thailand

Reasons for eating insects	Percentage of respondents
Tasty	75
Snack	65
Use as ingredients in cooked meals	48
Traditional medicine	48
As food seasoning	32
Easy to find around the farm	30
Readily available food	22
Accessible for mass production	19
Cultural eating	9
Seasonal food source	2
Local food source	2
Pest control	0.38

Source: Questionnaire survey, Hanboonsong *et al.* (2000).

Edible insect species consumed

Of the millions of insect species known to exist, only a few hundred are eaten by humans around the world. In Thailand, over 150 species from eight insect orders are eaten by the people of the Northeast. Approximately 50 insect species are consumed in the north and about 14 species are eaten by people in southern Thailand (Rattanapan 2000). The different insect-eating habits in various regions may depend on cultural practices, religion or geographical area. The Northeast often encounters natural problems such as drought, infertile soil or flooding, with people living in close proximity to nature. Therefore, natural foods like insects, which are easy to find and harvest, become a part of life and culture.

Although many insect species are eaten by Thai people, some insects are known and consumed only in particular geographic areas, while others such as the giant water bug and grasshoppers are eaten throughout the country. Beetles constitute the largest species group of edible insects. The giant water bug is the most popular edible insect in northern Thailand. Predaceous diving beetles, water scavenger beetles and immature ants are also eaten widely in the country. Bamboo caterpillars and crickets are popular in the northern region. Wasps, bees and termites are well-known edible insects in southern Thailand. The results of an extensive study on edible insect eating in Northeast Thailand are presented in Table 2.

Table 2. Insect species eaten in Northeast Thailand

Order/Family/common name	Scientific name
COLEOPTERA	
Buprestidae	
Metallic wood-boring beetles	*Sternocera aequisignata* Saunders
	S. ruficornis Saunders
Cerambycidae	
Long-horned beetles	*Aeolesthus* sp.
	Apriona germai Hope
	Aristobia approximator Thomson
	Dorysthenes buqueti Guérin-Méneville
	Plocaederus obesus Gahan
	P. ruficornis Newman
Curculionidae	
Snout beetles	*Arrhines hiruts* Faust
	Arrhines 2 spp.
	Astycus gestvoi Marshall
	Cnaphoscapus decoratus Faust
	Episomus sp.
	Genus near *Deiradorrhinus*
	Hypomesus squamosus F.
	Pollendera atomaria Motschulsky
	Sepiomus aurivilliusi Faust

	Tanymeces sp.
	Rhynchophorus ferrugineus Olivier
Hydrophilidae	
Water scavenger beetles	*Hydrobiomorpha spinicollis* Eschscholtz
	Hydrophilus bilineatus Redtenbacher
	Sternolophus rufipes F.
Dytiscidae	
Predaceous diving beetles	*Erectes stiticus* L.
	Cybister tripunctatus asiaticucs Sharp
	C. limbatus F.
	C. rugosus MacLeay
	Hydaticus rhantoides Sharp
	Laccophilus pulicarius Sharp
	Copelatus sp.
	Rhantaticus congestus Klug
Scarabaeidae	
Rhinoceros beetles, Elephant beetles	*Xylotrupes gideon* L.
	Oryctes rhinoceros L.
June beetles	*Adoretus* spp.
	Agestrata orichalca L.
	Anomala anguliceps Arrow
	A. antique Gyllenhal
	A. chalcites Sharp
	A. cupripes Hope
	A. pallida F.
	Apogonia sp.
	Chaetadoretus cribratus White
	Holotrichia 2 spp.
	Maladera sp.
	Pachnessa sp.
	Protaetia sp.
	Sophrops absceussus Brenske
	S. bituberculatus Moser
	S. rotundicollis T. Ihto
	Sophrops 2 spp.
	Sophrops species mean *abscessus* Brenske
	Tribe Sericini 7 spp.
Dung beetles	*Aphodius (Pharaphodius) crenatus* Harold
	A. (Pharaphodius) marginellus F.
	A. (Pharaphodius) putearius Reitter
	A. (Pharaphodius) sp.
	Cathasius birmanicus Lansberge
	C. molossus L.

	Copris (s.str.) carinicus Gillet
	C. (s.str.) nevinsoni Waterhouse
	C. (Paracopris) punctulatus Gillet
	C. (Microcopris) reflexus F.
	C. (Paracopris) sp.
	Gymnopleurus melanarius Harold
	Heliocopris bucephalus F.
	Heteronychus lioderes Redtenbacher
	Liatongus (Paraliatongus) rhadamitus F.
	Onitis niger Lansberge
	O. subopagus Arrow
	Onthophagus orientalis Harold
	O. avocetta Arrow
	O. bonasus F.
	O. khonmiinitnoi Masumoto
	O. papulatus Boucomont
	O. sagittarius F.
	O. seniculus F.
	O. ragoides Boucomont
	O. tragus F.
	O. tricornis Weidemannn
	O. trituber Weidemannn
	Onthophagus sp.
HEMIPTERA	
Belostomatidae	
Water bug	*Diplonychus* sp.
Giant water bug	*Lethocerus indicus* Lepeletier & Sepville
Coriedae	
Leaf-footed bug	*Anoplocnemis phasiana* F.
Stink bug	*Homoeocerus* sp.
Gerridae	
Water strider	*Cylindrostethus scrutator* Kirkaldy
Nepidae	
Waterscorpions	*Laccotrephes rubber* L.
	Ranatra longipes thai Lansbury
	R. varripes Stal.
Notonectidae	
Backswimmers	*Anisops barbutus* Brooks
	A. bouvieri Kirkaldy
Tessaratomidae	
Stink bugs	*Pygopalty* sp.

	Tessaratoma papillosa Drury
	T. javanica Thunberg
ODONATA	
Aeshnidae	
Darner (nymph)	*Aeshna* sp.
Coenagrionidae	
Narrow-winged damselfly (nymph)	*Ceriagrion* sp.
Corduliidae	
Green-eyed skimmer (nymph)	*Epophtalmia vittigera bellicose* Lieftinck
Libellulidae	
Common skimmer	*Rhyothemis* sp.
HYMENOPTERA	
Apidae	
Bees	*Apis dorsata* F.
	A. florea F.
Formicidae	
Ants	*Oecophylla smaragdina* F.
	Carebara castanea Smith
Vespidae	
Wasps	*Vespa affinis indosinensis* Perez
ORTHOPTERA	
Acrididae	
Short-horned grasshoppers	*Acrida cinerea* Thunberg
	Acrida sp.
	Chondacris rosea DeGeer
	Chortippus sp.
	Cyrtacanthacris tatarica L.
	Ducetia japonica Thunberg
	Locusta migratoria L.
	Mecopoda elongate L.
	Oxya sp.
	Parapleurus sp.
	Patanga japonica Bolivar
	P. succincta L.
	Shirakiacris shirakii
	Trilophidia annulata Thunberg
Atractomorphidae	
Short-horned grasshopper	*Atractomorpha* sp.

Catantopidae	
Short-horned grasshopper	*Ratanga avis* Rehn & Rehn
Gryllidae	
Crickets	*Teleogryllus testaceus* Walker
	T. mitratrus Burmeister
	Teleogryllus sp.
	Modicogryllus confirmatus Walker
	Brachytrupes portentosus Lichtenstein
	Gryllus bimaculatus Degeer
	Gryllus sp.
	Gymnogryllus 2 spp.
	Pteronemobius sp.
	Velarifictorus sp.
Gryllotalpidae	
Mole cricket	*Gryllotalpa africana microphtalma* Chopard
Mantidae	
Mantids	*Tenodera ariddifolia sinensis* Saussure
	Mantis religiosa L.
Tettrigidae	
Pygmy grasshopper	*Euparatettix* sp.
Tettigoniidae	
Long-horned grasshoppers	*Euconocephalus incertus* Walker
	Conocephalus maculates LeGuillou
	Conocephalus sp.
	Onomachus sp.
	Pseudophyllus titan White
	Homeoxipha sp.
ISOPTERA	
Termestidae	
Termite	*Macrotermes gilvus* Hagen
LEPIDOPTERA	
Bombycidae	
Silkworm moth	*Bombyx mori* L.
Hesperidae	
Skipper	*Erionata thrax thrax* L.
Pyralidae	
Bamboo borer	*Omphisa fuscidentalis* Hampson

HOMOPTERA	
Cicadidae	
Cicadas	*Chremistica* sp.
	Dundubia sp.
	Orientopsaltria sp.
	Platylomia sp.

Source: Rattanapan (2000).

Occurrence of edible insects

Edible insects can be found in both local markets and in the wild throughout the year. In the northeast, more than half of the species eaten are found during the rainy season from May to July. Thereafter, the number of edible insects gradually decreases from August to April (Hanboonsong *et al.* 2000). Only commercial mass rearing of edible insect species like crickets provides for their availability year round.

Collecting and cooking edible insects

Thai villagers rely on conventional local wisdom to quickly determine which insects are edible as well as where to find and how to catch them. These traditional, highly developed skills have been passed down from generation to generation. This indigenous knowledge has, however, gradually declined with changing socio-economic conditions and dietary habits. Occasionally people have died from eating misidentified poisonous insect species such as the blister beetle (*Mylabris phalerata* Pall, Family Meloidae), which contains the toxic cantharidin substance.

A wide range of edible insect species can be consumed at various stages of their life cycles. For example, silkworms are eaten at both larval and pupal stages. Aquatic insects like dragonflies, predaceous diving beetles and water scavenger beetles are eaten at the nymphal stage. Ants can be consumed at egg, pupae and adult stages.

Local Thai people have used their traditional knowledge for a long time to collect and cook each insect species in a different way. For example, to collect mole crickets which dig holes and make their nests underground, a small hole is made in the ground near the nest and water is poured into it. The crickets come to the surface to avoid being drowned and are easy to collect by hand. Adult cicadas are collected in the early morning when the insect is still resting on grass or low tree branches. If cicadas are resting on grass, they are easy to collect by hand. If they are on higher tree branches, a plastic bag containing some cotton tied to a long stick is used to collect them. The legs and wings of the cicadas come in contact with the cotton which immobilizes them. Dung beetles, which are eaten mostly in Northeastern Thailand, are collected in the early morning by digging them out from cattle and buffalo dung. At that time of day, the beetles are still found around the dung pads and have not yet burrowed deep into the soil to avoid the sun’s heat. Only live beetles are caught and are immediately placed into a container filled with water. To avoid drowning, the beetles must make themselves lighter by releasing all the food contained in their intestine. The beetles are soaked for at least 12 hours in the water or until no more food remains in their intestines before they can be used for cooking. Trapping equipment, like black light, is also popular for collecting giant water bugs.

Healthy insects must be caught alive and processed immediately. Usually the wings, hard exoskeletons and intestines are removed before cooking. Most edible insects are cooked in various ways before being eaten: deep-fried, grilled over an open fire, parched and ground, or steamed in banana leaves and curried. Spices and herbs like garlic, basil leaf, chili and lemon grass are also used to increase flavour and mask unpleasant insects' smell.

Cooked edible insects are not only sold at roadside food stalls in various cities of Thailand, but nowadays can also be found prepared commercially in pasteurized cans. Canned insects are easy to prepare and can be stored for several months or years.

Farming edible insects

Many edible insect species are collected in the wild. The quantity collected and the species found depend on season and location. However, several Thai entomologists, as well as local people, have recently developed techniques for mass rearing on a commercial scale for several edible insect species such as crickets, ants and bamboo caterpillars. For example, cricket farming is an easy source of additional income for farmers in the northeast. Farmers use cement tanks or wooden containers, underlain by a plastic sheet. They then add a sandy loam soil layer covered with dry grasses, bamboo shoots or egg cartons to provide shade for the crickets. Cricket egg masses are introduced and the containers are covered with nylon nets. An artificial diet of chick feed along with grasses or weeds and water is provided. After four to six weeks, the adult crickets are ready to harvest (Jamjanya *et al.* 2001).

Conclusion

Edible insects contribute a small fraction to the nutrient requirements of human populations. They are consumed by Thai people, mainly because of their desirable taste. The potential exists for exploiting insects as a nutrient source by evolving techniques for industrial rearing and by educating local populations on the nutritive value of insects, especially during outbreaks of pests.

Literature cited

Amin, S. 1989. Collecting patanga locust for commerce. *Kasikorn Journal Bangkok*, *62*(2): 13-116. (In Thai.)

Chunram, S. 1993. Bamboo weevil. *Kasikorn Journal Bangkok,* 66(5): 483-484. (In Thai.)

Hanboonsong, Y., Rattanapan, A., Utsunomiya, Y. & Masumoto, K. 2000. Edible insects and insect-eating habits in northeastern Thailand. *Elytra*, 28(2): 355-364.

Jamjanya, T., Thavornaukulkit, C., Klibsuwan, V. & Totuyo, P. 2001. *Mass rearing of crickets for commercial purposes.* Faculty of Agriculture, Khon Kaen University, Thailand.

Pitug, C. 1986. Insect pests: protein resource for local people. *Kasikorn Journal Bangkok*, 59(2): 55-157. (In Thai.)

Rattanapan, R. 2000. Edible insect diversity and cytogenetic studies on short-tail crickets (Genus *Brachytrupes*) in northeastern Thailand. Khon Kaen University, Thailand. M.Sc. thesis

Roffey, J. 1979. *Locust and grasshoppers of economic importance in Thailand*. UK, Her Majesty's Stationery Office.

Vane-Wright, R.I. 1991. Why not eat insects? *Entomology Research,* 81(1): 1-4.

Compendium of research on selected edible insects in northern Thailand

Paitoon Leksawasdi[1]

A survey of edible insects was conducted in 1992 via randomized interviews with residents in Jaehom District, Lampang Province. Their background information was correlated to the consumption of insects, principal cooking methods and edible insects in the study area.

Some edible insects were studied in detail during research in 1983, 1988 and 2005, including three species of ants. The first two species, malang mun *and weaver ants, were the most favoured, while acrobat ants were consumed occasionally. Edible beetles in the chafer group, some scarabs and a species of buffalo or elephant dung beetle were studied during 1990, 2002 and 2006, respectively. Data obtained from a joint research project in 2007 on mosquitoes and black flies revealed that Karen hilltribes considered black fly larvae to be a delicacy. The bamboo borer was studied in 1995 and is generally considered to be one of the most popular insects consumed by Thai people. The outcome of the bamboo borer research led to the organization of several training workshops supported by Chiang Mai University; the purpose was to educate farmers in the eight northern provinces of Thailand who collect and sell this edible insect as a part-time activity.*

Keywords: ants, bamboo borers, beetles, black flies, life cycles, rearing

Introduction

From 1983 to 2007, edible insect research in Thailand encompassed the following ten topics:

- Insect consumption in Jaehom District, Lampang Province
- *Malang mun* (*Carebara castanea* Sm.)
- Weaver ant
- Acrobat ant
- Cock chafer beetle
- Dynastid beetle
- Dung beetle
- Black fly larvae
- The bamboo borer and its morphology
- Farmers' training workshops on the bamboo borer

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Research topics

Topic 1: Jaehom survey

A survey of edible insects was conducted in 1992 via randomized interviews with residents in Jaehom District, Lampang Province (402 out of 1 992 people). They were shown specimens of 128 insect species, which were edible and non-edible, and asked which insects they consumed as food. The five edible insects were: grasshoppers (*Cyrtacanthacris* sp.); red palm weevils (*Rhynchophorus ferrugineus*); scarab beetles (*Xylotrupes* sp.); a species of moth, identified only to the family Pyralidae; and termites (*Odontermes* sp.). Respectively, these insects were eaten by 75-100, 51-75, 26-50, 1-25 and less than 1 percent of the people interviewed. In the age classes of 26-60, 15-25 and 6-14 years, 53, 20 and 17 percent, respectively, of the respondents ate insects. Annual income was another factor influencing insect consumption. In the Thai baht[2] income ranges of 0, less than 2 500, 2 501-5 000 and more than 5 000 per year, 36, 22, 24 and 18 percent, respectively, of the respondents ate insects. Insect consumption by gender showed marginal difference — 52 percent (men) and 48 percent (women). Other popular edible insects included weaver ants (*Oecophylla smaragdina*), *malang mun* ants (*Carebara castanea*), short-tail crickets (*Brachytrupes portentosus*), water bugs (*Belostoma european*), giant honey bees (*Apis dorsata*), Indian hornets (*Vespa cincta*), cicadas (*Dundubia* sp.), butterflies (*Cypris* sp.), water beetles (*Hydrous* sp.) and wasps (*Polistes stigmata*) (Leksawasdi and Tumta 1992).

Topic 2: malang mun

Malang mun (*Carebara castanea* Sm.) is an ant that nests underground. This edible insect emerges from a hole once a year during May and June. A detailed study of the external morphology of the workers and the reproductive castes, i.e., female and male, revealed that each caste had biting mouth parts. Workers administer a painful bite; they have neither wings nor compound eyes nor ocelli and the body size is one-tenth that of the female. Nests were found by excavating holes from which the ants emerged and the holes were then marked. Male and female ants emerged from holes set distantly apart. One to five nests were excavated each month for one year. The nests are made of soil and consist of 7 to 24 levels with a diameter of 12 to 31 centimetres and a depth of 11 to 150 centimetres below the soil surface. During nest excavation, only the immature stages of males and workers were found. The larvae and pupae were vermiform and exarate, respectively. Large populations of immature workers were found (Leksawasdi and Jirada 1983).

Topic 3: weaver ant

Weaver ants (*Oecophylla smaragdina* F.) were sampled and studied for two years at Chiang Mai University campus. Nests of weaver ants were found mostly from April to June on many different shrub and tree species. Population peak occurred in February during the swarming of females and males. Reproductive castes were found in the nests from January to July. After the nests were resettled, worker castes increased to take care of the larvae. Large workers exceeded small workers. Because of their very small size, eggs and the short egg stage were

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[2] US$1.00 = 25 baht (1992).

rarely found. Female larvae castes were larger than other castes. Pupae and adults of the four castes differed (Wongwiggarn and Leksawasdi 1988).

Topic 4: acrobat ant

A study of acrobat ants was carried out at Houy Koh Hang and Huay Poo bamboo forests, San Poo Laew village, Moo 9, Don Pao subdistrict, Mae Wang District, Chiang Mai Province. External morphology was used for species identification of *Crematogaster* sp. Acrobat ants did not exhibit an antennal scrobe on the petiole and the abdomen was also lacking. The post petiole is joined with the upper part of the remaining abdomen and is heart-shaped. Interviews were conducted monthly from May 2002 to January 2003 with 321 individuals from Muang, Mae Rim, Hang Dong, Sampatong, Mae Wang and Samoeng districts. The purpose was to correlate their basic data to familiarity with acrobat ants and the use of this insect as human food. The basic data collected from the interviews included gender, age, education level, occupation and monthly income. The results indicated that both genders were familiar with acrobat ants, but they were mostly consumed by men. Agricultural workers consume acrobat ants more than people in other vocations. However, the availability of larvae is seasonal. Traditionally, the larval stage of the acrobat ant has been used for consumption in a variety of northern Thai dishes such as *jaew*, *jom*, *kang, nam prik* and *abb,* but is now most popular in *jom* (Leksawasdi and Wichai 2005).

Topic 5: cock chafer beetle

More than 40 species of the chafer group are edible beetles. Using fluorescent and black light traps, many species of cock chafer were collected in one year at Jaehom District, Lampang Province. This included *Holotrichia siamensis*, *Anomala chlorochelys*, *Adoreus cribatus*, *H. pruinosella* and *Mimela* sp. — listed in descending order of frequency. The black light trap attracted the cock chafer more than fluorescent light. The external morphology of five species was described as well as the life history of *H. siamensis*. Copulation occurred between 19.00 and 20.00 hours and the average copulation period was 52.3 minutes. During the day, *H. siamensis* was found at 1-5 centimetres beneath the soil where oviposition also occurred. Nine to 21 days elapsed between copulation and oviposition. On average, 31.6 eggs were laid per female over 11 days. Adult females lived for an average of 25.3 days. Eggs had a mean width of 1.8 millimetres and length of 2.1 millimetres and average egg period of 6.3 days. The first instar had a mean head width of 1.1 millimetres and body length of 4.4 millimetres. There were more than six instars of larvae. Levels of infestation of young leaf tips, mature leaves and blossoms of *Tamarindus indica* L. were recorded. Income level and age of the local residents were not related to their preference for eating cock chafers, but more women consumed cock chafers than men. The order of preference of these five species was *H. pruinsella*, *A. chlorochelys*, *Mimela* sp., *H. siamensis* and *Adoreus cribatus* (Leksawasdi 1991-1993).

Topic 6: dynastid beetle

A study on rearing dynastid beetles and their natural enemies was conducted in northern Thailand from September 2001 to September 2003; the species and ecology of elephant beetles were also surveyed. Four species of dynastid beetles were found: *Xylotrupes gideon* L., *Eupatorus gracilicornis* Arrow, *Chalcosoma atlas* L. and *Oryctes* sp. Three methods of rearing elephant beetles were in use: rearing them in the ground in Nan, Payao and Chiang Mai; rearing in cement boxes in Nan, Payao, Lampang, Chiang Rai and Chiang Mai; and rearing in other kinds of boxes in Nan and Chiang Rai, the boxes being half-filled with soil and decaying plants. Host and food plants for the elephant beetles were *Euphoria longan* Steud., *Litchi chinensis* Sonn., *Mimosa pudica* L., *Bambusa* sp., *Sindora* sp., *Cocos nucifera* L., *Castanopsis* spp., *Saccharum officinarum* Linn., *Musa* spp., *Nephelium lappaceum* L., *Psidium guajava* L., *Mangifera indica* L., *Luffa acutangula* Roxb., *Cucumis melo* L., *Cucumis sativus* L., *Citrullus lanatus* Mats, and *Carica papaya* L. A study of the life history of rearing elephant beetles in boxes revealed that one female (*X. gideon* L.) lays 43.18 ± 8.37 eggs. The incubation period of eggs was 17.98 ± 1.39 days; the larval period was 221.60 ± 11.37 days; the pupal period was 34.02 ± 1.82 days; the adult period was 55.82 ± 3.30 days; and the generational period was 337.40 ± 11.30 days. Natural enemies of the elephant beetle in the adult stage are body mites, rats, geckoes, bats and lizards; ants attack the egg and larval stage. Baculovirus and the fungi *Metarrhiziun anisopliae* also destroy larvae and pupae (Leksawasdi and Ramsiri 2003).

Topic 7: dung beetle

The morphology, ecology and behaviour of the dung beetle, *Heliocopris bucephalus,* were studied in Nan Province. The colour of the adults is reddish-brown to black. A large pronotum covers the head with a strong clypeus underneath. The clypeus covers the biting mouth parts. The insects have a pair of compound eyes and lamellate antennae. The front wings are hard and there is a cover sheath of membranous back wings. Females have no horn, the length and width of the body average 4.68 ± 0.23 centimetres and 2.85 ± 0.13 centimetres respectively. The male has three horns, one on the clypeus and two on the pronotum. The length and width of the body average 5.08 ± 0.18 centimetres and 3.08 ± 0.17 centimetres, respectively. Dung beetles were found in areas occupied by water buffalo. The insects made buffalo dung balls and oviposited eggs inside. The overall dimensions of the balls were observed to be 7.08 ± 0.58 centimetres in diameter, 152.20 ± 45.55 grams in weight and 0.64 ± 0.12 centimetres in thickness. The surface of the ball contained an outer area of 1.39 ± 0.14 centimetres in diameter. The observed balls were placed in tunnels with a width of 21.40 ± 2.43 centimetres and a depth of 39.12 ± 4.22 centimetres below fresh dung. The ground surface was porous with a width of 48.30 ± 4.14 centimetres; each tunnel contained six to ten balls. People consume the pupae (Leksawasdi *et al.* 2006).

Topic 8: black fly

Black fly larvae, *Simulium* spp., can be eaten, but apparently this is only done by some Karen hilltribes. The practice was revealed during a joint project on mosquito and black fly. The fly larvae were observed to aggregate in large numbers along a running stream to filter their food. The study was carried out in three areas of Mae Ab Nai village – a rice field and two streams (designated Stream 2 and Stream 3). The last stage of the larval instar was noted. The rice field, which had a different habitat from both streams, possessed only one species of black fly, namely, *Simulium aureohirtum*, while 11 species were detected in the stream habitats. The temperature and pH level differed only slightly among the three habitats. In addition, the number of last-stage larval instar at the rice field exceeded Stream 2 several-fold in each month during 2004 and 2005. However, the number of black flies in Stream 3 was twice that of Stream 2 in each month. Black fly larvae could be found throughout the year, occurring most frequently during the rainy season. It was deduced that adult female black flies, which bite humans, should also be found in large numbers as well (Leksawasdi and Srisuka 2007)

Topic 9: bamboo borer

Omphisa faseidentalis, Family Pyralidae, Order Pipidoptera, has been promoted by the mass media and is the best known edible insect in Thailand. Bamboo borers or *nae* (*Omphisa* spp.) are abundant in the mountains of northern Thailand. The larvae develop inside the stems of bamboo. They are collected and sold by local people and preyed upon by woodpeckers. Forty-seven local people were interviewed about their knowledge of the borer; the market value quoted by hilltribe people was 80-120 baht/kilogram. Frying was the favourite cooking method. Experiments were in progress that involved rearing borers in the mountains. The adult and egg stages are 5 to 14 days during August. Larvae bore a hole in the bamboo stem (*pai hok*), destroying the inner pulp. Then the larvae bore through the internodes moving upwards within the stem. External evidence of their presence includes holes in the stem, shortened internodes and stiffened sheaths. The larval stage is 280 to 304 days, August to May. When almost mature, larvae migrate back down the stem into the old segment where they initially bored in. The pupal stage is 30 to 40 days. Moths emerge from the entrance hole. Collection by humans, rather than predation by woodpeckers, is the most important factor limiting bamboo borer populations (Leksawasdi 1995).

Topic 10: bamboo borer workshops

The author realized that the bamboo borer was a suitable subject for edible insect training workshops, based on natural husbandry. Such training was developed and conducted from 2005 to 2008. Training was intended to stimulate alternative income for some farmers in mountainous areas. This was the last phase of the bamboo borer project that studied this insect as food. Local people have considered the bamboo borer to be a delicacy for a long time. Earlier research focused on detailed information about this insect; subsequently efforts were made to extend the knowledge acquired to the general public by holding training workshops for collectors on bamboo borer husbandry. Since 2006, this activity has extended workshop training to villagers in eight provinces of northern Thailand on ten occasions. Evaluation results indicated that the training was well-received and the participants ranked the training highest on the satisfaction scale. Research on income derived by representative bamboo borer collectors from the Lahu tribe was done by grouping them into four work units: (1) two males, (2) husband and wife, (3) single male and (4) single female. These units were evaluated with respect to the quantity of insects collected as well as the corresponding income. Insects collected amounted to 29, 22, 15 and 13 kilograms, respectively; this represented income of 3 500, 2 637, 1 791 and 1 600 baht. On average, the quantity of insects collected and income were 13 kilograms and 1 588 baht per person. Fifty-six percent of the households in the surveyed villages were bamboo borer collectors (Leksawasdi and Sununta 2008).

Conclusion

The topics presented in this paper summarize an array of studies carried out on edible insects in northern Thailand. Information on nine insect species is summarized. The popularity of food insects and indigenous rearing practices demonstrate the potential for further development of this food resource.

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Literature cited

Leksawasdi, P. & Sununta, R. 2008. Workshop training on the culturing and farmer income from bamboo borers. (Unpublished data.)

Leksawasdi, P. & Srisuka, W. 2007. Black flies *Simulium aureohirtum* population at Mae Ab Nai Village, Chiang Mai Province. *In Proceedings of 3rd Naresuan Environmental Annual Conference, Pitsanulok Province, 20-21 June,* pp. 335-342.

Leksawasdi, P., Tavichai, N., Ramsiri, P. & Chanchai, N. 2006. Morphology, ecology and behavior of dung beetle, *Heliocopris bucephalus*. *In Proceedings of 2nd Naresuan Environmental Annual Conference, 28-29 June,* pp. 323-329.

Leksawasdi, P. & Wichai, J. 2005. *Using acrobat ant as food* The Seventh National Plant Protection Conference, Lotus Pang Suan Kaewn Chiang Mai Province, 2-4 November. 10 pp.

Leksawasdi, P. & Ramsiri, P. 2003. *Rearing the elephant beetles and their natural enemies.* Annual Meeting of National Biological Control Research Center, Pitsanulok Province. 9-31 July. 13 pp.

Leksawasdi, P. 1995. Life history and natural enemy of a bamboo borer (Omphisa sp., Pyralidae: Lepidoptera). *In Second National Plant Protection Conference, Chiang Mai. 9-11 October,* pp. 96-102.

Leksawasdi, P. & Tumta, S. 1992. *Insects for food.* 30th Kasetsart University Conference, Bangkok, 29 January to 1 February.

Leksawasdi, P. 1991-1993. Study on five species of cock chafers (Scrabaeidae: Coleoptera). *Journal of the Science Faculty Chiang Mai University,* 18-20: 30-43.

Leksawasdi, P. & Jirada, P. 1983. *Malang mun (Formicidae: Hymenoptera) Part 1.* 9th Conference on Sciences and Technology for Development of North Eastern Region, Faculty of Sciences, Khon Kaen University, 27-29 October.

Wongwiggarn, R. & Leksawasdi, P. 1988. *Nest, population and development of weaver ant* Oecophylla smaragdina F. 26th Kasetsart University Conference, Bangkhen, Bangkok, 29 January to 1 February.

Edible products from eri and mulberry silkworms in Thailand

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*At least 194 species of edible insects are reported in Thailand. There are 81 species of edible forest insects. In general, insect foods are well-known as a protein source in the country, especially in the north and northeast. Of the edible insects, Coleoptera represents the major group (61 spp.), followed by Lepidoptera (47 spp.), Orthoptera (22 spp.), Hymenoptera (16 spp.), Hemiptera (11 spp.), Homoptera (11 spp.), Odonata (4 spp.), Isoptera (2 spp.) and others. Cooking methods and recipe development are derived from indigenous knowledge of provincial insect consumers. Mulberry silkworm (*Bombyx mori *L.) pupae are popularly consumed as a by-product from silk yarn reeling. Recently, a cultivated wild silkmoth (eri silkworm, *Samia ricini *D.) was introduced into the northeast where cassava (*Manihot esculenta*) is its main host plant. This silkworm has other diverse host plants found generally in the region such as castor bean (*Ricinus communis*), the Ceara rubber tree (*Manihot glaziovii*) and variegated cassava (*Manihot esculenta *var.* variegata*). It is reared easily under northeastern conditions. Because of high protein content (66 percent), eri food products have been developed using more than eight recipes, which have been registered as intellectual property. Eri silkworms are safe "green" edible insects because no chemicals are used in the rearing process. Moreover, eri products could generate supplementary income for farmers. Publicity campaigns should provide more information for consumers. The eri silkworm has the potential to support government food security policies in the context of supplying edible insects as protein sources for communities in Thailand.*

Keywords: *Bombyx*, edible insects, protein, recipes, *Samia*, silk by-product

Introduction

Insects account for the greatest species diversity and the largest numbers of all of the world's fauna. They have been used as human food for millennia. At least 194 species of insects are reported to be edible in Thailand. Among them, Coleoptera is the major group (61 spp.), followed by Lepidoptera (47 spp.), Orthoptera (22 spp.), Hymenoptera (16 spp.), Hemiptera (11 spp.), Homoptera (11 spp.), Odonata (4 species), Isoptera (2 species) and others. Insects as food are most popular in the northern and northeastern parts of Thailand. Cooking methods and recipe development of edible insects were derived mostly from indigenous knowledge of provincial insect consumers. Generally well-known edible insects are sugar-cane white grubs, dung beetles, giant water bugs, bee larvae, red ant eggs (*Oecophylla smaragdina*), wasp

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larvae, crickets, grasshoppers, sugar-cane stem borer pupae, banana leaf rollers, mole crickets, diving beetles, water scavenger beetles, adult termites, green weevils and mulberry silkworm larvae and pupae. The mulberry silkworm is an industrial insect, which has been reared for a long time and can be produced year round. Farmers raise this insect for the weaving of high value textiles. A by-product from yarn reeling is the pupa, a popular food in Thailand, especially in the northeast. Mulberry silkworm rearing is either a principal or alternative economic activity. These activities give rise to silk products that generate income; this amounted to 1 675.28 million Thai baht[3] in 2004 (Chuprayoon 2005). Approximately 136 884 households, mostly in the northeast, raise the silkworms, which account for about 80 percent of the country's production. Thai silk is a well-known product worldwide.

Edible insects in general and silkworm pupae in particular, are low in price, taste good and are high in protein content and nutritional value (Table 1). Produced throughout the year, they are always available on the market, fresh or as processed food. Recently, the wild silkmoth or eri silkworm has become well-known in Northeast Thailand, where cassava, its major host plant, is cultivated extensively.

Eri silkworm is a species of wild silkmoth, which can produce commercial quantities of silk. The eri silkworm in Thailand has been studied for rearing and silk production by several local scientists (Sirimungkararat *et al*. 2005a, 2005b, 2001, 2000, 1994; Attathom *et al*. 1992; Wongtong *et al.* 1980). Other major host food plants of eri silkworm are castor bean, papaya (*Carica papaya*), *kesseru* (*Heteropanax fragrans*), *Evodia fraxinifolia*, *Ailanthus excelsa*, *Sapium* spp. and *Jatropha curcas* (Jolly *et al.* 1981; Sengupta and Singh 1974). Wongtong *et al.* (1980) studied eri culture in the highlands of northern Thailand and used castor bean leaf as the principal food plant. Attathom *et al*. (1992) reported on eri silkworm rearing using different food plants and various cassava varieties. Cassava leaf is suitable for eri silkworm culture. In addition, the research group of Khon Kaen University reported for the first time that the Ceara rubber tree and variegated cassava were new food plants for eri silkworm (Sirimungkararat *et al*. 2005b). Silk yarn production from reeling machines using indigenous knowledge was reported initially by the same research group (Sirimungkararat *et al*. 2005a).

Eri silkworm production provides not only silk yarn but also by-products such as pupae, fertilizer from faeces and sericin from wastewater in the reeling process. Eri larvae and pupae fed with cassava leaf were nutritionally analysed by Sirimungkararat *et al*. (2004b). Results showed that larvae and pupae contained high amounts of protein, approximately 66 percent (Sirimungkararat *et al*. 2004a), which is higher than mulberry silkworm (53-54 percent) and very low content of hydrocyanic acid (6.21-50.47 mg/kgDM) (Sirimungkararat *et al*. 2004b). These favourable properties led to exploitation of eri silkworm as animal feed, aquarium fish food and also as human food. Rearing focused on low cost and applicable techniques for encouraging eri culture as a secondary activity among cassava growers. Removal of up to 30 percent of cassava leaves, used as the sole food of eri silkworms, significantly increased the cassava tuber yield in the northeast (Sirimungkararat *et al*. 2002). Given its high protein content, a simple rearing process that does not use chemicals and a wide range of host plants, eri food was developed as a sustainable high protein food source. It is a safe food with diverse cooking preparations and is ideal as high-protein food for schoolchildren, rural dwellers and local communities.

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[3] US$1.00 = 33 Thai baht (October 2009).

Table 1. Nutritional value of edible insects per 100 grams of fresh weight compared to commonly eaten livestock

Insect/livestock	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Iron (Fe) (mg)	Calcium (Ca) (mg)	Phosphorus (P) (mg)	Potassium (K) (mg)	Vitamin (mg)		
									B1	B2	Niacin
Grasshoppers (large)	95.7	14.3	3.3	2.2	3	27.5	150.2	217.4	0.19	0.57	6.67
Grasshoppers (small)	152.9	20.6	6.1	3.9	5	35.2	238.4	237.4	0.23	1.86	4.64
True water beetles	149.1	21	7.1	0.3	6.4	36.7	204.8	197.9	0.31	3.51	6.85
Mole crickets	125.1	15.4	6.3	1.7	41.7	75.7	254.1	267.8	0.20	1.89	4.81
Red ant eggs (a mix of eggs and pupae)	82.8	7	3.2	6.5	4.1	8.4	113.4	96.3	0.15	0.19	0.92
Silkworm pupae	98	9.6	5.6	2.3	1.8	41.7	155.4	138.7	0.12	1.05	0.89
Giant water bugs	162.3	19.8	8.3	5.5	13.6	43.5	225.5	191.7	0.09	1.50	3.90
Chicken	110	20.8	2.4	0	1.2	11	214	-	0.15	0.16	7.90
Beef (without fat)	150	20	7.2	0	3	9	171	-	0.07	0.34	6.70
Pork (without fat)	376	14.1	35	0	2.1	8	151	-	0.69	0.16	3.70
Pork (with fat)	457	11.9	45	0	1.8	7	117	-	0.58	0.14	3.10

Source: Nutrition Division (1978).

Life cycle of the eri silkworm

The eri silkworm reared in northeastern Thailand completes its life cycle in 47 to 59 days. There are four development stages: egg: 7-8 days; larva: first to fifth instar, 18-24 days; pupa: 15-19 days; and adult: 7-8 days (Plate 1).

Plate 1. Life cycle of the eri silkworm (*Samia ricin*i D.)

Source: Sirimungkararat (2003).

Development of eri food products

Rearing of larvae, prepupae and pupae of eri silkworm was reported by Sirimungkararat *et al.* (2002). Various eri food recipes were developed using late fifth instar larvae, prepupae and pupae as the principal raw materials, combined with herbs, vegetables and spices. The recipes developed by Sirimungkararat *et al.* (1992) were registered as intellectual property in the form of a patent. These recipes comprising larvae, prepupae or pupae are: crispy basil flavour, herb flavour, spicy salad flavour, traditional spicy flavour, *tom yam* crispy flavour, chili paste flavour, original flavour and classic flavour.

Analysis and contents of processed eri food products

Nutritional value and other major constituents of eri processed foods were analysed using the same raw materials employed in the study of eri food product development. The analysed larvae (Duan-KKU) and pupae (Sab-KKU) had good nutritional value and contained high amounts of protein, about 76.22 and 67.64 percent in processed larvae and pupae, respectively. Ash, crude fibre, ether extract, nitrogen free extract and moisture values are given in Table 2. These findings are similar to a previous study by Sirimungkararat *et al.* (2004a, Table 3). Compared to other food insects, the eri silkworm is one of the highest protein producers and a “green” product.

For these reasons, it is suitable for exploitation as a protein source (Jolly *et al*. 1981). In addition, the general characteristics, colour, odour, taste and texture are considered good to very good. The moisture content of Sab-KKU (13.13 percent) was similar to Duan-KKU (13.30 percent), which gives it a smooth texture (Table 3). Regarding micro-organism contamination, there was a low concentration of 1.4×10^3 cfu/gram and 1×10^2 cfu/gram in analysed larvae and pupae, respectively (Table 3). These concentrations in the pupae product were one-tenth of the Thai Community Product Standard (TCPS)’s limit for cricket products, which is not more than 1×10^3 cfu/gram. Moreover, the processed eri products were safe in terms of toxic substances (Table 4). Results revealed the quantities of such toxic substances as hydrocyanic acid (HCN), heavy metals (Pb, Hg, Cd), arsenic, benzoic acid and sorbic acid (Tables 3 and 4). The allowable levels used here were defined by the TCPS for other products, because the standards for eri foods are still not available and need to be developed. The safe level of HCN was previously reported by Sirimungkararat *et al*. (2004b).

Table 2. Analysis of processed eri silkworm larvae and pupae

Chemical composition	Processed material	
	Larvae (Daun-KKU)	Pupae (Sab-KKU)
Moisture (%)	5.325	6.025
Ash (%)	2.72	2.30
CP (crude protein, %)	76.22	67.64
CF (crude fibre, %)	4.621	1.860
EE (ether extract, %)	10.967	16.494
NFE (nitrogen free extract, %)	0.143	6.381

Source: KKU analysis.

Table 3. Evaluation of processed foods of eri silkworm compared to the TCPS

Item	Processed material		Method
	Larvae (Daun-KKU)	Pupae (Sab-KKU)	
Aerobic plate count (cfu/g)	1.4×10^3 EAPC	1×10^2 EAPC†	BAM 2001 (Pour plate methods)
Yeast and mould (cfu/g)	27	3	BAM 2001 (Pour plate methods)
Moisture (g/100 g)	13.30	13.13	AOAC‡
Benzoic acid (mg/kg)	46.91	<5	In-house method based on HPLC¶
Sorbic acid (mg/kg)	ND	ND	In-house method based on HPLC

†EAPC = estimated aerobic plate count; ‡AOAC = Association of Analytical Chemists; ¶HPLC = high performance liquid chromatography. ND = not detectable

Source: KKU analysis.

Table 4. Analysis of HCN and heavy metals from processed eri silkworm food

HCH/heavy metals	Processed material	
	Larvae (Daun-KKU)	Pupae (Sab-KKU)
HCN (ppm)	<2.068	<2.0
Pb (mg/L)	ND	ND
Cd (mg/L)	0.199	0.261
Hg (µg/L)	NA	ND
As (µg/L)	3.008	5.836

ND = not detectable
NA = not analysed

Source: KKU analysis.

Consumer evaluation of eri foods

Eri products derived from larvae (Duan KKU) and pupae (Sab-KKU) with classic flavour were evaluated with regard to consumer preference, compared to other edible insects sold in the markets of Amphoe Muang District, Khon Kaen Province from October 2007 to February 2008. Based on interviews with retailers, the most popular edible insects are bamboo caterpillars, Bombay locusts, white crickets and mole crickets. Comparing price after processing, the most expensive were bamboo caterpillars, white crickets, Bombay locusts and mulberry silkworm (pupae), in descending order (Table 5). Random visitors/buyers were tested, interviewed and their reactions evaluated using a questionnaire. The results showed that there was a distinct difference between the types of consumers.

Farmers prefer to eat giant water bugs, predacious diving beetles/water scavenger beetles, mulberry silkworm (pupae), eri pupae, white crickets, mole crickets, Bombay locusts, short-tail crickets or giant crickets, bamboo caterpillars and eri silkworm (larvae), in descending order. Reasons given for preference related to familiarity with native edible insects, low price, as a main ingredient cooked with rice and other usage. Least popular were bamboo caterpillars and eri larvae because of the unpleasant appearance of the larvae, which inspires disgust. Giant water bugs were the most popular because of their pleasant cooking odour; true water beetles ranked second.

Farmers' preferences were almost totally different to urban dwellers or those living nearby, including university students and schoolchildren. In this group, 50 percent favoured Bombay locust, eri pupae, mulberry silkworm (pupae) and white crickets. Other insects such as eri silkworm (larvae), mole crickets, crickets, bamboo caterpillars, giant water bugs and true water beetles were preferred by 37.5, 25, 25, 25, 12.5 and 0 percent of those interviewed, respectively (Table 6). In this group, the reasons for preference were: delicious taste, crispiness, ease of buying and availability year round. Disliked were giant water bugs and true water beetles because of their odour and hard body, respectively.

One of the largest edible insect dealers in Thailand related that the most widely distributed insect was the bamboo caterpillar, which is regarded as a delicacy. This correlated with the overall frequency evaluation of international testers who participated in the Chiang Mai edible forest insect workshop – that the most popular edible insects were bamboo caterpillars, white crickets and Bombay locusts, in descending order.

Table 5. Insects sold in the Khon Kaen market during November 2007 to February 2008

Common name	Scientific name	Vernacular name†	Preference†(%)	Price (baht/kg)‡		Family
				Fresh	Processing	
Giant water bugs	*Lethocerus indicus*	*Maeng-dah*	12.5	2-4 baht/piece	5 Baht/piece	Belostomatidae
Mulberry silkworm (pupae)	*Bombyx mori*	*Dak-dae-mai*	37.5	100-150	400-600	Bombycidae
Mole crickets	*Gryllotalpa africana*	*Maeng-gi-son*	50	120	400	Gryllotapidae
Predacious diving beetles, Water scavenger beetles	*Cybister limbatus* *Hydrous cavistanum*	*Maeng-tab-tau*	0	100-120	300	Dytiscidae, Hydrophilidae
White crickets	*Acheta domesticus*	*Maeng-sa-ding, Jing-reed-khao*	50	100-180	600-1,000	Gryllidae
Short-tail crickets orGiant crickets	*Brachytrupes portentosus*	*Ji-pom*	37.5	100-120	400-600	Gryllidae
Bamboo caterpillars	*Omphisa fuscidentalis*	*Rod-duan*	50	190-500	1,000-2,000	Pyralidae
Bombay locusts	*Patanga succincta*	*Tak-ka-taen-mo*	50	260-700	700-800	Acrididae

†Interview with the sellers.
‡US$1.00 = 33 Thai baht (October 2009).

Source: Questionnaire survey.

Table 6. Preference evaluation of eri food compared to other edible insects bought by urban dwellers

Common name	Vernacular name	Family	Preference (%)
Mole crickets	*Maeng-gi-son*	Gryllotalpidae	25
Giant water bugs	*Maeng-dah*	Belostomatidae	12.5
White crickets	*Maeng-sa-ding*	Gryllidae	50
Predacious diving beetles, Water scavenger beetles	*Maeng-tub-tau*	Dytiscidae, Hydrophilidae	0
Mulberry silkworm(pupae) Short-tail crickets or Giant crickets	*Duk-dae-maiJi-pom*	Bombycidae Gryllidae	5025
Bombay locusts	*Tak-ka-taen-mo*	Acrididae	50
Bamboo caterpillars	*Rod-duan*	Pyralidae	25
Eri silkworm (pupae)	*Sab-KKU*	Saturniidae	50
Eri silkworm (larvae)	*Duan-KKU*	Saturniidae	37.5

Source: Questionnaire survey.

Eri recipe contest

Because of the high potential of eri silkworm larvae and pupae for diverse cooked dishes, an eri recipe contest was organized at the Annual Silk Festival in Khon Kaen Province. It had already been confirmed that eri silkworm was a potential industrial insect. Eri silkworm breeders were delighted to take part and demonstrated an excellent ability to develop their own recipes, based on indigenous knowledge of edible insects. This activity served to inculcate the need to promote this high protein source for the community and as a food security resource in the minds of contestants and observers, especially as it represents a green product.

The final results revealed that the three winners with larval recipes were: crispy fried larvae with citrus hystrix (wild lime) leaves; fried larvae with *koki* powder (ginger rhizome?) and tofu stuffed with larvae. The three winners for pupal recipes were: pupae fried with hot chilies, traditional flavour mixed with pupae and pupae fried with basil leaves.

Future prospects for eri food

Eri silkworm has been recognized as an edible insect, especially in Northeast Thailand, for 17 years. To introduce eri food widely to potential consumers, it is necessary to provide them with satisfactory information via displays, tasting opportunities and education. One of the most successful efforts was the eri food recipe contest. Promotional selling of eri food products also allows more people to become familiar with and appreciate this edible insect.

The public sector is an important driving force to promote food safety. One such effort is the One Tambol (subdistrict) One Product (OTOP) campaign. OTOP was developed to increase productivity in districts, subdistricts and provinces. Public universities and government policies support OTOP. Eri food was developed by Sirimungkararat *et al.* in 2006 and was further improved through better processing techniques and improved quality, to achieve a high-quality product. Two eri food products have been nominated as outstanding OTOPs, as shown in Plate 2.

Plate 2. Outstanding OTOP – eri silkworm pupae (Sab-KKU), developed by Sirimungkararat and collaborators in 2006 *(Courtesy the authors)*

Discussion and conclusion

Rearing eri silkworms is relatively easy and can be practised throughout the year in Thailand, including the northeast, using techniques and equipment similar to those employed in mulberry silkworm rearing. Eri silkworms can be fed leaves of the host cassava plant, without any chemical use, thus yielding a green product (Sirimungkararat *et al*. 2002). This silkworm produces thermal property silk yarn, along with high protein larvae and pupae (Sirimungkararat *et al*. 2004a). Most countries in the world are facing rising costs for cereals and other foods. This global situation provides a timely opportunity for the eri silkworm. Due to its high protein content, eri food has excellent potential as a protein source and security food for schoolchildren and people in rural areas. Eri food will become better known when both the private and public sectors provide long-term promotional support. Eri food and eri products should be quickly and widely promoted through consumer publicity campaigns. In this way, the potential of the eri silkworm can be realized to support government food security policies and to broaden the availability of edible insects as commodities in Thailand. The eri silkworm represents one of the potentially commercial wild silkmoths in Thailand and is being promoted in the northeastern region.

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Literature cited

Attathom, T., Kunhasut, V. & Areekul, S. 1992. *Rearing of eri silkworm by different host plants.* Proceeding of the 30th Annual Conference, Plant Science. Bangkok, Thailand, Kasetsart University. (Abstract in English.)

Chuprayoon, S. 2005. *Sericulture in Thailand.* 20th Congress of the International Sericultural Commission: Conference Papers Volume III. Bangalore, India.

Hanboonsong, Y., Rattanapan, A., Waikakul, Y. & Liwwanich, A. 2001. Edible insects survey in northeastern Thailand. *Khon Kaen Agriculture Journal*, 29(1): 35-44.

Jolly, M.S., Sen, S.K., Sonwalkar, T.N. & Prasad, G.K. 1981. *Non-mulberry silks*. Rome, FAO.

Nutrition Division. 1978. *Nutritional value table of 100 grams of Thai food*. Bangkok, Pharmaceutical Organization Printing. (In Thai.)

Sengupta, K. & Singh, K. 1974. *An evaluation of the efficiency of different food plants and their combination for the rearing of eri silkworm* Philosamia ricini *Boisd.* Proceeding of the First International Seminar on Non-Mulberry Silks. Ranchi, India.

Sirimungkararat, S., Kamoltip, S. & Saksirirat, W. 2005a. Reeling of eri cocoon (*Philosamia ricini* B.) for silk yarn production. *International Journal of Wild Silkmoth & Silk*, 10: 35-39.

Sirimungkararat, S., Sangtamat, T., Saksirirat, W. &Waikakul, Y. 2005b. New food plants for eri silkworm rearing. *International Journal of Wild Silkmoth & Silk*, 10: 27-34.

Sirimungkararat, S., Khacharoen, Y. & Polthani, A. 2004a. *Nutritional value of eri silkworm (*Philosamia ricini *B.) fed with cassava leaf.* Presented at Annual Agricultural Seminar, 26-27 January 2004, Faculty of Agriculture, Khon Kaen University, Khon Kaen. (Abstract in English.)

Sirimungkararat, S., Wachirapakorn, C., Waikakul, Y. & Wapugpetr, B. 2004b. *The preliminary detection for hydrocyanic acid content in eri silkworm,* Philosamia ricini *B. fed with cassava leaf.* Presented at Annual Agricultural Seminar, 26-27 January 2004, Faculty of Agriculture, Khon Kaen University, Khon Kaen. (Abstract in English.)

Sirimungkararat, S. 2003. Eri silkworm (*Samia ricini*): a new economic insect. Leaflet.

Sirimungkararat, S., Atthathom, T. & Saksirirat, W. 2002. *Development of eri silkworm rearing technique using cassava leaf as food plant and its textile production.* Proceedings of the XIXth Congress of the International Sericultural Commission, 21-25 September 2002, Queen Sirikit National Convention Center. Bangkok, Thailand.

Sirimungkararat, S., Chalorkpunrat, P. & Waikakul, Y. 2001. *Using eri silkworm larva* Philosamia ricini *Boisd. for aquarium fish feed.* Presented at Annual Agricultural Seminar, 26-27 January 2001, Faculty of Agriculture, Khon Kaen University. (Abstract in English.)

Sirimungkararat, S., Phongam, J., Pattanasettanon, W., Boonchan, S. & Apinakpong, K. 2000. Increasing of cassava and eri silkworm (*Philosamia ricini* B.) yield by management and leaf detaching. Presented at Annual Agricultural Seminar, 24-25 January 2000, Faculty of Agriculture, Khon Kaen University. (Abstract in English.)

Sirimungkararat, S., Thongpak, D. & Saksirirat, W. 1994. Effect of temperature on the development and hatching ability of eri silkworm (*Philosamia ricini* B.) egg. *NEROA Newsletter,* 23(1-2): 29-38.

Wongtong, S., Areekul, P., Onlamoon, A. & Tragoolgarn, S. 1980. *Research on wild silkworm cultivation in the highlands of northern Thailand.* Final Report of Highland Agriculture Project 1976-1980. Bangkok, Thailand, Kasetsart University.

Edible insects in Thailand: nutritional values and health concerns

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Edible insects should be considered not only for their nutrient content, but also for their nostalgic value to consumers. In the past, insects were commonly eaten by people in the north and northeast of Thailand. Nowadays, they are even eaten by urban dwellers throughout the country. In general, there are three main groups of insect eaters: (1) indigenous consumers from the northern and northeastern provinces (some of whom have migrated to other parts of the country); (2) consumers in urban areas who learn about and later develop a taste for insect foods; and (3) foreign tourists attracted by different insects prepared and sold in tourist spots.

Although over 50 species of insects are reported to be commonly eaten in Thailand, not all of them have had their nutritive values determined. The Institute of Nutrition at Mahidol University has analysed the nutrient contents of only those insects that are most commonly eaten. These include groups of ants, bees, beetles, bugs, cicadas, crickets, locusts, moths and termites. Edible insects are good sources of protein, fat, calories and micronutrients. The amino acid score of silkworm pupae reaches 100, followed by bamboo caterpillars (77.5), house crickets (68.7), wasps (59.4), Bombay locusts (55.8) and scarab beetles (34.2). Insects having an optimal ratio of fatty acid are house crickets, short-tailed crickets, Bombay locusts and scarab beetles.

Methods of preparation play a part in determining the nutritional values of insects for consumers. In Thai cuisine, there are 13 techniques for cooking insects, grouped into singeing (precooking), cooking in oil (frying, sautéeing) and oil-free cooking (paste, soup, curry, poaching, steaming and hot salad. Recently, insect fritters, burgers and sandwiches have become popular and in high demand among non-indigenous consumers, especially in urban and tourist centres. These new methods possibly increase the caloric intake of consumers. Excessive consumption of insects may fill the stomach with chitin and chitosan, protein and fat, which carry the risk of urinary tract stone formation and development of chronic degenerative disease.

Keywords: chitin, chitosan, cuisine, nutritive value, protein, stone diseases, traditional food

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Introduction

Insects are commonly used and consumed in a variety of ways: (1) as part of regular diets; (2) as famine or survival foods; (3) for medicinal purposes; (4) for ritual purposes; and (5) as novelties (Sutton 1995). In hunter-gatherer societies, insects are recognized as food. In modern agricultural societies, insects are generally viewed negatively. But in many cultures in Africa, Asia and Oceania and Latin America, pests such as locusts and grasshoppers are important food items (Defoliart 1999). Eating insects is not simply the result of poverty or of protein deficiency. In many parts of the world, eating insects is a matter of preference and tradition (Jach 2003; Pemberton 1999). Worldwide, insects have formed part of the cuisine of 113 entomophagous countries, with almost 1 500 known species of edible insects being consumed by over 3 000 different ethnic groups (MacEvilly 2000). In Thailand, approximately 164 species are edible (Lewvanich *et al.* 2000) and over 50 species are commonly eaten (Watanabe and Satrawaha 1984).

This paper focuses on insects and their role in human nutrition. Grivetti (1997) provides four principles influencing individual food patterns. First, availability of foods, either on a seasonal or regular basis, providing a variety of food supplies to consumers. Second, humans perceive a food item to be edible and become familiar with it. However, familiarity does not necessarily correlate with nutritional quality. Third, individuals select food based upon their personal preferences as to whether they like or dislike it. These are based upon sensory evaluation of past experience with such food. If foods are tasted and liked, consumption is likely to be repeated. The body's reactions and perception of the taste and aroma of food provide valuable indications about whether or not a specific food should be eaten. The crunchy exoskeleton of insects offers a wonderful taste and induces the consumer to eat it in considerable quantity. But not all potential items identified as fit for consumption are selected. Lastly, expectation follows from exposure, that is, taste (sweet, sour, salty, bitter), colour (hue, intensity), texture (smooth, coarse) and odour (pleasant vs. unpleasant). Besides the nutrient content, the nutritional values of edible insects are confounded by eating patterns and behaviours, which are complicated issues. Therefore, this paper is not limited to only nutritive value; the aforementioned principles are also applied. Information presented here was obtained from rapid assessments, observations carried out over several years and published sources.

Edible insects: a contribution to economic empowerment

On average, the monthly household income of a Thai farmer is approximately 9 639 Thai baht[2] (National Statistics Office 2007). Selling insects could improve the economic status of poor farmers. Unlike other agricultural or food products, there are no national data collected on the contribution of insects to the economic status of Thai farmers. As an income source, bamboo caterpillars and silkworm pupae are popular and are normally expensive. A few decades ago, Watanabe and Satrawaha (1984) reported that silkworm pupae sold for 25 baht per kilogram in rural markets. Nowadays, their market price has increased to 200 to 250 baht per kilogram for bamboo caterpillars and 120 to 150 per kilogram for silkworm pupae.

[2] US1.00 = 33 Thai baht (October 2009).

As a primary occupation, selling edible insects can be attractive. One of the pioneers of edible insect selling, Mr Nusu T., who has been in this business for 16 years, related that selling edible insects is a job that can be handled singly. It does not need many labourers. Purchasing insects wholesale requires an investment of about 4 000 baht per day for 13 species. Net profit is approximately 1 200 baht per day (or 30 percent). Mr Nusu T, reported that he sells 70 to 80 tonnes of insects per year, and he estimates that the country's demand may be 2 000 tonnes (Department of Industrial Promotion 2004).

Because of the remarkable increase in demand, supplies of edible insects are even being brought into Thailand from neighbouring countries. For instance, Cambodian farmers collect locusts and trade them at Rong Kluah Market, a large market on the Thai-Cambodian border. The price is 40 baht per kilogram (Hutasingh 1996). It has been observed that the quantities of edible insects being imported through this market have increased. Intermediaries trade the insects from that point to other outlets including Bangkok and Pitsanulok. Bangkok is reportedly the largest market.

Availability of edible insects

In Thailand, insect eaters can be found in all regions of the country. In the past, indigenous insect eaters were known to reside mostly in the north and northeast. These people were attuned to the climate and geographical situation. In these regions, insects can be collected from paddy fields, upland and forested areas, natural ponds and streams; some kinds of edible insects are available all year round (Yhoung-aree and Viwatpanich 2005). However, there may be variations of species and volumes. Grootaert and Kiatsoonthorn (2003) reported that from April to June (peaking in May), ants, termites and beetles are abundant. In this period insects feed on decayed wood and litter. In years of abundant rainfall, the surplus of insects collected from nature adds to the family income of the collectors. Edible insects are commonly found also in urban areas. For instance, Sarapee (2004) listed six Orders, 13 Families and 21 species of edible insects available in urban areas of Surin Province from June 2002 to May 2003. Currently, large quantities, representing 10 to 15 species, are sold in large food outlets such as Klong Tuey and Dhevej markets in Bangkok.

Edible insects are now increasingly being domesticated. This has been accomplished in a number of countries. In Guangdong, China, water beetles sold in the local markets are hatched locally in special nurseries (Jach 2003). In Thailand, commonly farmed species are crickets and locusts. To promote school nutrition, children are encouraged to raise red ants and giant water bugs. Among the few insects being domesticated, mulberry silkworms and crickets are the most successful (Defoliart 1995), whereas red ants and giant water bugs were unsuccessful for commercial-scale production (Chamjanya *et al*. 2008).

Consumption of edible insects

The consumption of insects has evolved over the past decades. Wara-asawapiti *et al*. (1975) published an account of species of insects used in various local recipes in Northeast Thailand. Nutrition researchers consider these consumed insects as an important source of protein for the native people whose nutritional status is poor (Sirichakwal and Sungpuag

1982). Sungpuag and Puwastein (1983) analysed their nutritive values and documented them as an unconventional protein source because they are consumed by native dwellers only, and are not accepted by the Thai people in general. Due to their palatability and status as a delicacy, edible insects have been marketed increasingly in public places. More than 50 species were reported to be eaten in the northeastern region (Watanabe and Satrawaha 1984).

Because of socio-economic developments, rural people are increasingly migrating to urban areas and bringing their food habits along. Not surprisingly, edible insects have been included. Furthermore, the migrants gradually introduce edible insects as delicacies to people in the new setting. As can be observed, the edible insect is accepted and becomes popular, especially in poor urban communities where insect-eating migrants reside. As a result, Yhoung-aree *et al.* (1997) propose that edible insects should no longer be considered unconventional.

Currently, Yhoung-aree and Viwatpanich (2005) divide insect eaters into three groups: (1) indigenous insect eaters, who may reside either in their native areas or have migrated to new locations. (The latter are observed to be deeply attached to insect dishes, considering them to be nostalgic food.); (2) the new insect eaters – people who belong to families of insect-eating migrants and have been introduced to insect-eating customs by their parents or relatives (It was observed that young family members more easily accept insect dishes prepared by frying and frittering because they are more delicious.); and (3) many migrants from neighbouring countries and tourists scattered around various parts of the country. The former are known to be indigenous insect eaters and the latter are traditional insect eaters as well as new consumers.

Cooking methods and recipes

Collected insects die and spoil quickly and are therefore generally prepared live. Preparation and cooking methods vary with the cultural group (Sutton 1995). In traditional Thai cuisine, indigenous knowledge relates that edible insects should be prepared without using oil. Especially in the northern and northeastern regions, people eat sticky rice as a staple food. In this instance, oil-free dishes are prepared because they are most compatible with their standard meal. Traditionally, oil-free insect recipes include roasting, smoking (or baking), steaming (or *homoke*), poaching, with chili paste, as a hot salad (half cooked) and uncooked/raw. Typically, among the rural poor, insects are incorporated into a ragout or vegetable dish as well as an ingredient in plain or spicy soups (Yhoung-aree *et al.* 1997).

Oil-cooking of insects, including frying, sautéeing and frittering, is considered to be modern Thai insect cuisine, because these cooking techniques have been recently introduced. In addition, they have been disseminated to non-indigenous insect eaters through markets. The oil-based recipes make insect dishes tastier resulting in their becoming more popular in urban areas and tourist destinations. These cooking methods are also commonly used in other cultures as well (Ramos-Elorduy *et al.* 1997).

Culinary efforts in the preparation of new insect recipes are directed toward modifications to overcome prejudices against insects. Frittering is a new form of cooking in Thailand and creates a pleasant aroma. Among younger generations of Thai insect eaters, frittering helps to banish the squeamish feelings of the consumer. Flavour is one of the essential determinants by which insects are considered most edible (MacEvilly 2000). Fried and frittered insects are further improved by sauces that enhance their delicacy and palatability, especially when they go well with beverages like beer or wine. In addition, edible insects are being prepared in the form of sandwiches, burgers and pizza in order to serve westerners who are familiar with and appreciate these styles of cooking.

It is evident that insect dishes available in Thailand are not only prepared using traditional but also western styles. However, traditional styles such as soup, paste, steaming, etc. are still used for main meals. The western style of preparing edible insects is directed more towards their being consumed as snacks.

Nutritional values of edible insects

Data on the nutritive values of insects are important, for they inform consumers about the quality and quantity of their intake. For international comparison, a common yardstick to assess the nutritional value of food is the weight of food, along with its nutrient content (Grigg 1995). Because food analysis is costly, the available data on the nutritive values of edible insects in Thailand have focused on those species which are most commonly eaten.

Nutritive values of insects vary depending upon species, habitats, the growth stage of the insects and methods of cooking. Characteristics of consumers such as gender and food habits contribute to their preferences. Many publications state that edible insects are rich in protein, fat and calories, as well as being good sources of minerals such as iron, calcium and vitamins A, B_1, B_2 and D. Ramos-Elorduy *et al*. (1997) conducted protein analysis of 78 species of edible insects. On a dry weight basis, protein content was determined to be 15 to 81 percent. Protein digestibility varied from 76 to 98 percent. Wasps had the highest protein content.

Jongjaithet *et al* (2008) collected samples of seven common edible insects sold in various public markets in Bangkok (Klong Tuey and Dhevej), Khon Kaen and Sakaew (Rongkuah). These markets are well-known as large insect outlets. The results showed high protein content in bamboo caterpillars, silkworm pupae and wasps (Table 1).

Qualitatively, the protein of insects such as silkworm pupae has been analysed and found to be safe for human consumption (Zhou and Han 2006). The contribution of protein to overall human intake varies with the stage of the insect eaten and the time period of its availability. In the palm weevil, the mature stage has higher protein content than when it is immature (Omotoso and Adedire 2007). In the northwest Amazon, insects provide approximately 5 to 7 percent of total protein intake during the year. Their contribution increases to 12 to 26 percent during May to June when availability peaks (Dufour 1987). This period coincides with the mature stage of insects. Sutton (1995) studied gender differences in insect consumption and found that men consumed more insects than women, contributing to more than three times the protein intake (men: 69 percent, women: 31 percent).

In relation to protein quality, the amino acid profile of edible insects is relevant. Some species may contain enough amino acid to provide the requirements of an adult, such as Mexican

Table 1. Calories, protein and fat content in common edible insects by cooking methods

Vernacular name	English name	Scientific name	100 g raw(1)			100 g blanched(2)			100 g fried(2)			Per 100 g paste(3)		
			Cal Kcal	Prot. G	Fat G	Cal Kcal	Prot. G	Fat G	Cal Kcal	Prot. G	Fat G	Cal Kcal	Prot. G	Fat G
Mang tub-tao	Predaceous diving beetles	*Cybister limbatus* F.				180	21.0	7.1	301	24.3	18.6			
Mang ki-noon	Scarab beetles	*Holotrichia* sp.	98	18.1	1.8	98	13.4	1.4	215	15.5	12.9			
Jing-rheed	House crickets	*Acheta testacea* Walker	133	18.6	6.0	134	12.9	5.5	465	14.9	17.0	79	4.6	1.3
Ji konke	Short-tailed crickets	*Brachytrupes portentosus* Licht	188	17.5	12.0	125	12.8	5.7						
Mangkachon	Mole crickets	*Gryllotalpa africana* Beauvois				136	15.5	6.3				101	11.7	4.3
Mang-dana	Giant water bugs	*Lethocerus indicus*				182	19.8	8.3	303	22.9	19.8	90	4.3	1.3
Patunkka	Bombay locusts	*Patanga succincta* L.	157	27.6	4.7	169	20.6	6.1	221	16.6	14.8			
Tukkatan E-moh	Spur-throated grasshoppers	*Chondracris roseapbrunner* Uvarov				105	14.3	3.3	290	23.8	17.6			
Rod-duan	Bamboo caterpillars	*Omphisa fuscidentalis*	231	9.2	20.4				644	25.5	55.3			
Mod daeng	Red ants	*Oecophylla smaragdina* F.							231	16.1	15.0			
Non-mhai	Silkworm pupae	*Bombyx mori* L.	152	14.7	8.3	127	12.2	7.0	241	14.1	18.5			
Toh	Hornet grubs	*Vespa* sp.	140	14.8	6.8	140	14.8	6.8				108	12.1	2.6

(1) Jongjaithet *et al.*: http://nutrition.anamai.moph.go.th/temp/main/view.php?group=3&id=120
(2) Institute of Nutrition, Mahidol University, Food Composition Database for INMUCAL Program, 2002.
(3) Yhoung-aree and Viwatpanich (2005).

Table 2. Amino acid content in common species of edible insects

Common name	Scientific name	Essential amino acid: mg/gram protein									Non-essential amino acid: mg/g protein							
		Isoleucine	Leucine	Lysine	Methionine &Cystine	Phenylalanine &Tyrosine	Threonine	Tryptophan	Valine	Amino acid score	Arginine	Histidine	Alanine	Aspartic acid	Glutamic acid	Glycine	Proline	Serine
House crickets	*Acheta testacea Walker*	29.8	60.9	46.1	30.9	62.4	29.0	24.4	34.4	68.7	45.1	15.4	78.0	69.2	96.8	47.2	45.2	35.9
Scarab beetles	*Holotrichia* sp.	32.1	51.8	18.8	44.6	49.3	26.9	27.1	29.3	34.2	32.3	16.1	58.3	61.2	97.6	52.8	47.0	31.3
Bombay locusts	*Patanga succincta* L.	32.7	59.5	35.7	20.9	60.0	22.3	17.3	35.6	55.8	36.0	13.5	92.7	48.8	76.4	48.8	48.7	23.9
Bamboo caterpillars	*Omphisa fuscidentalis*	33.9	60.0	56.0	41.7	100.7	34.9	41.1	38.8	77.5	47.9	23.3	37.7	88.2	93.2	32.7	40.7	41.3
Silkworm pupae	*Bombyx mori* L.	46.1	70.6	77.2	36.3	122.0	45.3	19.0	52.2	100	58.8	35.4	39.4	88.9	107.3	29.7	44.4	37.9
Hornet grubs	*Vespa* sp.	42.6	78.5	59.0	20.8	165.0	45.3	10.1	53.7	59.4	41.0	35.3	43.5	79.6	180.6	48.2	56.8	3.8
Scorpions*		21.1	50.0	31.1	24.6	76.5	19.4	22.3	24.4	48.4	41.2	18.8	50.1	52.0	67.6	70.8	26.2	25.8

* The scorpion is not an insect.

Source: Jongjaithet *et al*.: http://nutrition.anamai.moph.go.th/temp/main/view.php?group=3&id=120

edible insects (Ladron de Guevara *et al*. 1995). Jongjaithet *et al.* (2008) published amino acid profiles of six common species of insects eaten in Thailand. Table 2 shows that different species of insects have different profiles of both essential and non-essential amino acids. Among the essential amino acids, leucine is relatively high in all species (50.0-78.5 mg/gram protein). Silkworm pupae contained the most lysine. According to WHO (1985), the amino acid score of silkworm pupae reached 100, followed by bamboo caterpillars (77.5), house crickets (68.7), wasps (59.4), Bombay locusts (55.8) and scarab beetles (34.2).

Fat content: Fat components (crude fat, cholesterol and fatty acids) in edible insects show a similar pattern to protein. Not all edible species of insects are high in fat. Ramos-Elorduy *et al*. (1997) reported on fat in 78 species of insects and found it ranged from 4.0 to 77.2 percent. Ekpo and Onigbinde (2007) document unsaturated fatty acid in termites (*Macrotermis bellicosus*) at 51.02 percent. Jongjaithet *et al.* (2008) determined the fat content of seven sample insect species (Tables 1, 3). Bamboo caterpillars and short-tailed crickets are high in fat, followed by silkworm pupae and wasps. As far as nutrition is concerned, fat intake is interpreted based on the optimal ratio among saturated and unsaturated fatty acids. In principle, the optimal ratio of saturated fatty acid to monounsaturated fatty acid and polyunsaturated fatty acid informs the appropriate fat intake. It is recommended that this ratio should be 1:1:1 for these respective components (Whitney and Rolfes 1999). As such, the study shows that fatty acids in house crickets, short-tailed crickets, Bombay locusts and scarab beetles meet the optimal ratio. Apart from fatty acids, cholesterol was analysed. Cholesterol per 100 gram sample is high in house crickets (105 milligrams), followed by Bombay locusts (66 milligrams), scarab beetles (56 milligrams) and bamboo caterpillars (34 milligrams).

Caloric content: As a result of the protein, fat and carbohydrate contents, caloric values can be determined either by calculation or by direct assessment of insect samples. Insects high in fat provide more calories. This was also demonstrated by Ramos-Elorduy *et al.* (1997) from 78 species of edible insects analysed with caloric content ranging from 293 to 762 Kcal/100 grams. The same patterns were confirmed by Jongjaithet *et al.* (2008). The cooking method plays a role in increasing the caloric content of cooked insects. As noted by Banjong *et al.* (2002), frying insects adds fat to the cooked products, amounting to approximately 13 to 17 grams per 100 grams of insects. Table 1 (columns 2 and 3) shows the remarkable increases of calories in fried insects. It is noted that cooking insects as paste does not contain as many calories because insects are but one of the ingredients in a spicy mix.

Table 3. Fatty acid and cholesterol content in common species of edible insects

Common name	Scientific name	Saturated fatty acid (% fatty acid)	Unsaturated fatty acid (% fatty acid)		Cholesterol (mg)
			MUFA	PUFA	
House crickets	*Acheta testacea*	36.5	30.1	31.1	105
Short-tailed crickets	*Brachytrupes portentosus*	35.0	32.3	29.6	NA
Scarab beetles	*Holotrichia* sp.	33.3	30.0	32.4	56

MUFA: Monounsaturated fatty acid
PUFA: Polyunsaturated fatty acid
NA: Not analysed
Source: Jongjaithet *et al*. (2008, Table 4): http://ora.kku.ac.th/res_kku/Abstract/AbstractView.asp?Qid=634858900/
http://nutrition.anamai.moph.go.th/temp/main/view.php?group=3&id=120

Micronutrients: Insects are also rich in vitamins and minerals such as vitamins A, B_2, C and iron (Banjo *et al.* 2006). Black ants (*Polyrhachis vicina* Roger) are rich in vitamin E and minerals. In the Thailand Food Database (Institute of Nutrition, Mahidol University 2002), when compared to pork and chicken, the groups of beetles, crickets and locusts/grasshoppers have comparable levels of phosphorus, potassium, iron, calcium and vitamins B_1 and B_2. However, the level of these micronutrients varies with the insect species.

Advantages and disadvantages of insect consumption

Despite a positive perception of edible insects as delicacies, and scientific evidence of their nutritive values, edible insects need to be considered in terms of the potential negative consequences of their consumption. In this regard, issues related to the chitin, protein and fat content of edible insects are important.

Chitin is a naturally abundant mucopolysaccharide found in the supporting exoskeletal material of crustaceans, insects, etc. Chitosan is the N-deacetylated derivative of chitin. Chitin and chitosan have a wide range of applications (Majeti and Kumar 2000). Chitin is digested by chitinase. There are two chitinase: acidic mammalian chitinase (AMCase) and chitotriosidase (chit). Chit is a hydrolytic enzyme produced by macrophages. In tropical populations with a higher rate of entomophagy, AMCase activity is high and could confer increasing resistance against parasitic infection (Paoletti *et al.* 2007). Chitin and chitosan also have a protective effect on candida, an infection caused by yeast (Koide 1998). Chitin and chitosan can bind dietary lipids, resulting in the reduction of plasma cholesterol and triglycerides. Consequently, the intestinal absorption of lipids is reduced (Koide 1998). Majeti and Kumar (2000) also confirm that chitosan is a fat trapper in the stomach, thereby preventing the trapped fat from absorption. In contrast, chitosan forms gel and traps lipids and other nutrients including fat-soluble vitamins and minerals. As for long-term effects, chitosan may interfere with and lead to calcium reduction. As a result, bone metabolism and possibly vitamin D absorption may be impaired. In this case, pregnant mothers are at high risk.

There is hearsay among medical practitioners working in hospitals in Northeast Thailand that urinary tract stone diseases may be associated with the consumption of edible insects. The mechanism of urinary stone formation is unclear. At the beginning of the twentieth century the percentage of bladder stones was as high as 90 percent in countries such as China and Thailand. In the last few decades the frequency of bladder stones occurrence has sharply decreased (Hesse and Siener 1997). However, health professionals working in entamophagous provinces observe that urinary stone diseases have persisted, for example in Northeast Thailand.

Urinary stone diseases are a painful and costly medical condition to treat (Curhan *et al*. 1996). About 40 percent of urinary stone sufferers need in-patient treatment, with a relatively high rate of surgery (12.2 percent). Of all urinary tract stones, more than 76 percent consist of calcium oxalate (Hesse and Siener 1997). Most of all, calcium oxalate stones have gained increased importance. Halstead and Valyasevi (1967) reported the urinary stone situation in Ubon Ratchathani Province (the lower northeast) where insects have been eaten commonly. In a sample population of 20 860, 3.8 percent, at one time in their lives, had active urinary stone disease, and 2.6 percent had one or more symptoms suggestive of the disease. The prevalence of urinary stones in urban areas in Ubon Ratchathani was 4.7 per 1 000. Sriboonlue *et al*. (1992) documented the prevalence of urinary tract stones in an administrative subdivision of Khon Kaen Province (the upper northeast) as 3.76 per 1 000. The lower rate does not correspond to an improvement of nutrition in this region.

Halstead and Valyasevi (1967) also determined factors associated with urinary tract stone diseases. As far as nutrition is concerned, symptoms of bladder stones occur at a greater rate in water-deprived villages than in villages with ample year-round water supply (20 per 1 000 and 12.8 per 1 000, respectively). A positive correlation also was found between the abundance of fish and the prevalence of bladder stones. The authors note that the problem was inversely related to economic status. In the better-off villages, the rate of bladder stones is higher than in moderate or poor villages (20.4 per 1 000, 10.4 per 1 000 and 8.6 per 1 000, respectively). Halstead and Valyasevi (1967) also observed that the people in the areas studied ate large quantities of vegetables, which may be rich in oxalate, such as wild spinach (*pak kome*), *pak kadone*, *pak tiew* and the leaves of the naturalized leucaena.

In normal individuals, only small amounts of ingested oxalate (about 6 to 14 percent) are absorbed (Hasse *et al*. 1999). Thus, ingestion of vegetables of high oxalate content in combination with a misbalancing of other nutrients might contribute to the occurrence of the stone diseases. Halstead and Valyasevi (1967), however, do not highlight the quantity of insect intake which has been commonly eaten in the region studied. Not all species of edible insects are high in calcium. Thus, increased dietary oxalate intake (from indigenous vegetables) coupled with low calcium intake leads to a high risk of kidney stone formation (Holmes and Assimos 2004). Moreover, if a person consumes high calcium-containing species, chitosan does not reduce intestinal oxalate absorption (Wolf *et al*. 2006). Curhan *et al.* (1993) ascertained that a high calcium diet is associated with a decreased risk of kidney stone formation. The role of dietary oxalate in calcium oxalate kidney stone formation remains unclear.

The influence of animal protein on the risk of calcium kidney stone formation is uncertain. Robertson *et al*. (1979) report the overall relative probability of forming urinary stones markedly increased throughout the period of high animal protein ingestion. Curhan *et al*. (1993) show a positive association between animal protein intake and kidney stones. Hesse and Siener (1997) found that ingesting high levels of animal protein led to the increased metabolism of phenylalanine, tyrosine, tryptophan and hydroxypyroline. Consequently, oxalate excretion was observed to increase. Age and gender may contribute to urinary stone formation. Taylor *et al.* (2004) found a positive association between animal protein intake and kidney stones in men of 40 to 59; however, no association was found in men over 60. Young women are noted to have a low risk of kidney stones (Curhan *et al*. 2004).

Consuming edible insects that are rich in fat and calories may imply a risk of urinary stone diseases. Overconsumption of fat calories and fat intake leads to obesity, which brings with it the risk of gallstones (Pixley and Mann 1988). Among women, the risk was more than 75 percent greater for those in the highest BMI (Body Mass Index) categories ($\geq$ 32 kg/m^2) (Curhan *et al*. 1998a). Thijs *et al.* (1990) reported that hyperlipidemia is related to gallstones through an elevated triglyceride and cholesterol level. Haffner *et al.* (1990) showed that diabetes carries a risk of gallstones, even if an individual is not obese.

Publications concerning risk of stone formation due to the effects of vitamins are rarely available. Only Curhan *et al.* (1999) published a study that supports the theory that the risk of stone formation rises with increasing vitamin C intake.

To date, urinary stone disease has gained increasing significance due to the changes in living conditions, that is, industrialization and malnutrition (Hesse and Siener 1997). However, an industrialized society does not necessarily influence the lifestyle of people in a negative manner. Curhan *et al.* (1998b) showed that the risk of urinary tract stone formation decreased with the intake of each 240 millilitre serving of beer, wine, coffee, or tea. In contrast, an increase in risk was seen for each 240 millilitre daily serving of grapefruit juice. Taylor *et al.* (2004) discovered that a low risk of kidney stone formation was found in men younger than 60. This group is assumed to be active alcohol drinkers. As observed, fried and frittered insects are commonly eaten with beer or wine. Optimistically, perhaps this food and beverage consumption pattern contributes positively to lower the chance of stone formation. Overall, the genesis of stone diseases is a complex process. No single factor explains an evident apparent cause. Another warning of concern from MacEvilly (2000) relates to insects causing allergies; his study suggested that insects should not be eaten with nuts or shellfish as both have been shown to trigger allergic responses in hypersensitive individuals.

In summary, edible insects are generally viewed as good sources of protein, fat, calories, vitamins and minerals. These nutrients, along with chitin, may imply an influence on urinary tract stone diseases directly or indirectly. Although the mechanism is unclear, metabolic disorders as well as malnutrition could be major contributory factors of urinary tract stone formation.

Conclusion

Eating insects has both advantages and disadvantages. Insects are often incorporated in and cooked with other ingredients. If the recipes are properly prepared, they will increase their total nutritional value. For instance, bees can be part of a balanced diet. While edible insects are perceived as an excellent source of protein, fat and vitamins and minerals, many insect eaters today may disregard them as a source of these nutrients. Rather, they enjoy edible insects to satisfy the preferences of their palates and as a social function. Many are no longer personally squeamish about eating insects when more modern cooking methods (frittering, frying, etc.) are used that add to their taste. The eating behaviour of individuals is influenced by background, cultural traditions and social values. As a result, in general, insect eaters balance the quality of their diet. Well-balanced nutrition is the ideal to strive for. In particular, the nutritional value obtained from insect consumption depends on the species, environmental factors (season, habitat, climate), culture and socio-economics. Unbalanced intake of edible insects possibly brings about obesity, chronic degenerative diseases and urinary stone disease.

In developing countries, agro-ecosystems change rapidly in response to the farmers' perceptions of opportunities and constraints. In most cases, the result of changes leads to apparent vulnerability for environmental abuse. In the past, the insect fauna in Thailand were rich in certain areas such as Na Haew (Grootaert and Kiatsoonthorn 2003), an area of high biodiversity. This was due to the people's indigenous knowledge derived from their local culture to value the environment. They realized that insects could provide not only daily food, but simultaneously aid in maintaining diversity of habitats for other life forms. In return, this helps native people survive and sustain their local environment. In remote areas, insects have considerable potential for alleviating nutritional inadequacies. Moreover, some local people can make use of them to generate income.

Criticisms have been leveled about edible insects playing a somewhat mutually exclusive role in both ecosystems and as human food. The fact is that Thailand imports edible insects from neighbouring countries to satisfy domestic demand and consumption. The edible insect scenario presents one of demand exceeding supply. To a degree, the explanation of the combined issues includes the following: (1) As forests provide shade and habitats to organisms, any reduction of the forest cover poses a threat to the insect fauna. So when forestry areas are destroyed, a normal ecosystem becomes unbalanced. As a consequence, the insect fauna are negatively impacted and their availability is diminished. (2) Overharvesting of insects for economic purposes in order to close gaps brought about by urban demand. (3) In certain more remote forest areas, insects may be abundant; however, there may be a lack of insect collectors because many have migrated to the city.

Edible insect consumption is a good example of the interaction between human nutrition and biodiversity. There will be ongoing future use of insects for human nutrition. The question is: How can we ensure supplies, perhaps through development of economically feasible methods of mass rearing edible insects, in combination with efficient and sustainable harvesting of wild insects? The maintenance of biodiversity is important to human health and nutrition (Wahlqvist and Specht 1998). As proposed by Toledo and Burlinggame (2006), nutrition and biodiversity initiatives provide the very foundation for reducing by half the proportion of people suffering from hunger by 2015 as envisaged in the Millennium Development Goals.

Literature cited

Banjong, O., Viriyapanich, T. & Chitchang, U. 2002. *Manual of dietary assessment: food conversion factors*. Institute of Nutrition, Mahidol University. (In Thai.)

Banjo, A.D., Lawal, O.A. & Songonuga, E.A. 2006. The nutritional value of fourteen species of edible insects in Southwestern Nigeria. *African Journal of Biotechnology,* 5 (3): 298-301.

Chamjanya, T, Tawornanukoonkij, C. & Uttamavetin, P. 2008. *Cricket production for economic and nutrition of community.* Research report submitted to Khon Kaen University. http://ora.kku.ac.th/res_kku/Abstract/AbstractView.asp?Qid=634858900/ (accessed 5 January 2008).

Curhan, G.C., Willett, W.C., Knight, E.L. & Stampfer, M.J. 2004. Dietary factors and the risk of incident of kidney stones in younger women: nurses' health study II. *Archives of Internal Medicine,* 164: 885-891.

Curhan, G.C., Willett, W.C., Speizer, F.E. & Stampfer, M.J. 1999. Intake of Vitamin B_6 and C and the risk of kidney stones in women. *Journal of the American Society of Nephrology,* 10: 840-845.

Curhan, G.C., Willett, W.C., Rimm, E.B., Speizer, F.E. & Stampfer, M.J. 1998a. Body size and risk of kidney stones. *Journal of the American Society of Nephrology,* 9: 1645-1652.

Curhan, G.C., Willett, W.C., Speizer, F.E. & Stampfer, M.J. 1998b. Beverage use and risk for kidney stones in women. *Annals of Internal Medicine,* 128 (7): 534-540.

Curhan, G.C., Willett, W.C., Rimm, E.B., Spiegelman, D. & Stampfer, M.J. 1996. Prospective study of beverage use and the risk of kidney stones. *American Journal of Epidemiology,* 143 (3): 240-247.

Curhan, G.C., Willett, W.C., Rimm, E.B. & Stampfer, M.J. 1993. A prospective study of dietary calcium and other nutrients and the risk of symptomatic kidney stones. *New England Journal of Medicine,* 328: 833-838.

Defoliart, G.R. 1999. Insects as food: why the Western attitude is important. *Annual Revue of Entomology,* 44: 21-50.

Defoliart, G.R. 1995. Edible insects as minilivestock. *Biodiversity and Conservation,* 4: 306-321.

Department of Industrial Promotion. 2008. http://www.dip.go.th/Product/ PreviewProduct/. asp?WebSiteID=12&ProductID=65&FMonth=5&FYear=2004/ (accessed 5 January 2008).

Dufour, D.L. 1987. Insects as food: a case study from the Northwest Amazon. *American Anthropologist,* 89: 383-397.

Ekpo, K.E. & Onigbinde, A.O. 2007. Characterization of lipids in winged reproductives of the termite *Macrotermis bellicosus*. *Pakistan Journal of Nutrition,* 6 (3): 247-251.

Grigg, D. 1995. The geography of food consumption: a review. *Progress in Human Geography,* 19 (3): 338-354.

Grivetti, L.E. 1997. Social determinants of food intake. *Annals of the New York Academy of Sciences,* 819(1): 121-131.

Grootaert, P. & Kiatsoonthorn, V. 2003. Insects of Na Haeo: a preliminary survey and seasonal dynamics of Dolichopodid and Empidid flies. *In* L. Ampornpan & S.S. Dhillion, eds. *The environment of Na Haeo, Thailand. Biodiversity, non-timber products, land use and conservation*. Bangkok, Thailand, Craftsman Press Ltd.

Haffner, S.M., Diehl, A.K., Mitchell, B.D., Stern, M.P. & Hazuda, H.P. 1990. Increased prevalence of clinical gallbladder disease in subjects with non-insulin dependent diabetes mellitus. *American Journal of Epidemiology,* 132: 327-335.

Halstead, S.B. & Valyasevi, A. 1967. Studies of bladder stone disease in Thailand: III epidemiologic study in Ubol Province. *American Journal of Clinical Nutrition,* 12: 1329-1339.

Hasse, A., Schneeberger, W., Engfeld, S., Unruth, G.E.V. & Sauerbruch, T. 1999. Intestinal hyperabsorption of oxalate in calcium oxalate stone formers: application of a new test with [$^{13}C_2$] oxalate. *Journal of the American Society of Nephrology,* 10 (Suppl 14): S329.

Hesse, A. & Siener, R. 1997. Current aspects of epidemiology and nutrition in urinary stone disease. *World Journal of Urology,* 15: 165-171.

Holmes, R.P. & Assimos, D.G. 2004. The impact of dietary oxalate on kidney stone Formation. *Urology Research,* 32: 311-316.

Hutasingh, O. 1996. Thousands of Khmers seek jobs in Thailand. Bangkok Post Review. 20 September 1996. (Cambodia:Acrididae.)

Jach, M.A. 2003. Fried water beetles – Cantonese style. *American Ethnologist,* 49 (1): 34-37.

Jongjaithet, N., Wacharangkoon, P., Paomueng & Prapasiri, P. 2008. Online. Protein quality and fat content in common edible insects. Division of Nutrition, Ministry of Public Health. (MOPH). http://nutrition.anamai.moph.go.th/temp/main/view.php?group=3&id=120/(accessed 5 January 2008).

Koide, S.S. 1998. Chitin-chitosan: properties, benefits and risks. *Nutrition Research,* 18 (6): 1091-1101.

Ladron de Guevara, O., Padilla, P., Garcia, L., Pino, J.M. & Ramos-Elorduy, J. 1995. Amino acid determination in some edible Mexican insects. *Amino Acids,* 9: 161-173.

Lewvanich, A., Chunram, S., Chareontesprasit, N. & Hanboonsong, Y. 2000. *Edible insects in Thailand.* 12th Entomology & Zoology Division Conference, Bangkok, Thailand.

MacEvilly, C. 2000. Bugs in the system. *Nutrition Bulletin,* 25: 267-268.

Majeti, N.V. & Kumar, R. 2000. A review of chitin and chitosan applications. *Reactive and Functional Polymers,* 46: 1-27.

Mathus-Vliegen, E.M.H., Van Ierland-Van Leeuwen, M.L. & Terpstra, A. 2004. A. Determinants of gallbladder kinetics in obesity. *Digestive Disease Sciences,* 49 (1): 9-16.

Mbata, K.J. 1995. Traditional uses of arthropods in Zambia: I. the food insects. *The Food Insects Newsletter,* 8 (3): 5-7.

National Statistics Office, Thailand. 2007. http://service.nso.go.th/nso/nsopublish/service/survey/socio_6m50.pdf/(accessed 28 December 2007).

Omotoso, O.T. & Adedire, C.O. 2007. Nutrient composition, mineral content and the solubility of the proteins of palm weevil, *Rhynchophorus phoenicis* F. (Coleoptera:Curculionidae). *Journal of Zhejiang University Science,* B 8 (5): 318-322.

Paoletti, M.G., Norberto, L., Damini, R. & Musumeci, S. 2007. Human gastric juice contains chitinase that can degrade chitin. *Annals of Nutrition and Metabolism,* 51:

244-251.

Pemberton, R.W. 1999. Insects and other arthropods used as drugs in Korean traditional Medicine. *Journal of Ethnopharmacology,* 65: 207-216.

Pixley, F. & Mann, J. 1988. Dietary factors in the aetiology of gallstones: a case control Study. *Gut,* 29: 1511-1515.

Ramos-Elorduy, J., Pino, J.M., Prado, E.E., Perez, M.A., Otero, J.L. & de Guevara, O.L. 1997. Nutritional value of edible insects from the State of Oaxaca, Mexico". *Journal of Food Composition and Analysis,* 10: 142-157.

Robertson, W.G., Heyburn, P.J., Peacock, M., Hanes, F.A. & Swaminathan, R. 1979. The effect of high animal protein intake on the risk of calcium stone-formation in the urinary tract. *Clinical Science,* 57: 285-288.

Sarapee, N. 2008. *Edible insects in Surin Province.* Rajabat University, Surin. http://dcms.thailis.or.th/object/21/html_metadata/21_132.html/(accessed 6 January 2008).

Sirichakwal, P. & Sungpuag, P. 1982. Insects as source of protein. Mahidol University Annual Research Abstracts. Bangkok, Thailand, Mahidol University. p. 90.

Sriboonlue, P., Prasongwatana, V., Chata, K. & Tungsanga, K. 1992. Prevalence of upper urinary tract stone disease in a rural community of North-eastern Thailand. *British Journal of Urology.* 69 (3): 240-244.

Sungpuag, P & Puwastein, P. 1983. Nutritive values of unconventional protein source: insects. *Journal of the Nutrition Association of Thailand,* 17: 5-12.

Sutton, M.Q. 1995. Archaeological aspects of insect use. *Journal of Archaeological Method and Theory,* 2 (3): 253-298.

Taylor, E.N., Stampfer, M.J. & Curhan, G.C. 2004. Dietary factors and the risk of incident of kidney stones in men: new insights after 14 years of follow-up. *Journal of the American Society of Nephrology,* 15: 3225-3232.

Thijs, C., Knipschild, P. & Brombacher, P. 1990. Serum lipids and gallstones: a case control Study. *Gastroenterology,* 99: 843-849. Cited by Mathus-Vliegen *et al.* (2004).

Toledo, A. & Burlinggame, B. 2006. Biodiversity and nutrition: a common path toward global food security and sustainable development. *Journal of Food Composition and Analysis,* 19: 477-483.

Wara-asawapiti, W., Wisuthipat, J. & Maneethorn, C. 1975. *Edible insects in Northeast Thailand.* Research Report No. 7. Srinakarintharawiroj University, Mahasarakham Campus. (In Thai.)

Wahlqvist, M.L. & Specht, R.L. 1998. Food variety and biodiversity: econutrition. *Asia Pacific Journal of Clinical Nutrition,* 7(3/4): 314-319.

Watanabe, H. & Satrawaha, R. 1984. A list of edible insects sold at the public market in Khon Kaen, northeast Thailand. *Journal of Southeast Asian Studies,* 22: 316-325.

Whitney, E.N. & Rolfes, S.R. 1999. The lipids: triglycerides, phospholipids, and sterols. *In Understanding nutrition,* pp. 124-159. 8th Edition. Belmont, CA, West/Wadsworth.

Wolf, J., Asplin, J.R. & Goldfarb, D.S. 2006. Chitosan does not reduce post-prandial urinary oxalate excretion. *Urology Research,* 34: 227-230.

World Health Organization (WHO). 1985. *Technical Report Series 724: energy and protein requirements.* Report of a Joint FAO/WHO/UNU Expert Consultation. World Health Organization, Geneva.

Yhoung-aree, J. & Viwatpanich, K. 2005. Edible insects in the Lao PDR, Myanmar, Thailand
and Vietnam. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock.* NH, USA, Science Publishers, Inc.

Yhoung-aree, J., Puwastein, P. & Attig, G.A. 1997. Edible insects in Thailand: an unconventional protein source? *Ecology of Food and Nutrition.* 36: 133-149.

Zhou, J. & Han, D. 2006. Online. Safety evaluation of protein of silkworm (*Antheraea pernyi*) pupae. *Food and Chemical Toxicology,* 44: 1123-30. http://www.manataka.org/page160.html/ (accessed 18 December 2007).

Filling the plates: serving insects to the public in the United States

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Entomophagy is shunned by most people in the United States, although a growing number of Americans are ready to sample insects that are prepared in the manner of other foods, and without the use of chocolate or similar coatings. Entomophagy has a slowly growing presence in the general culture: insects are eaten on television shows, insect dishes are menu items at a few fine restaurants and many children are able to recognize the facts regarding the environmental impact related to food production. While it is clear that advocating entomophagy means fighting the momentum of American food practices, there are good reasons to be optimistic about the future. The changes and the opportunities for insects as food are discussed.

Keywords: ants, crickets, entomophagy, food practices, insect festivals, microlivestock

Introduction

There is indeed recognizable interest in entomophagy in the United States, and even a small niche market for edible insects in the country. While this paper addresses the status of entomophagy in the United States, other fundamental points will also be made.

Discussion

I am convinced that in addition to research, it will be through our efforts in education and the raising of public awareness on entomophagy – both among the peoples of Southeast Asia and throughout the rest of the world – that we can make the greatest progress. Research and education are like two hands that achieve the most when they work together. I am fundamentally an educator and my focus is the social aspect and how people do and do not perceive insects. These perceptions will have a great impact on the public’s willingness to consider insects as a viable food choice. Since 2001, I have served insects to many hundreds of people and in so doing I have planted the seeds of this good idea in people’s minds. I give educational seminars at libraries, museums and nature centres. In addition to slide shows and the display of specimens, I serve crickets, silkworm and ant pupae, *Lethocerus*, cicadas and a few other types of insects cooked with rice and vegetables. They are never coated in chocolate.

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Regarding the United States and, I believe, many Western European nations, although commercial demand for edible insects might never compare to the same demand for edible mammals and birds, it is important to note that the current level of demand for these insects already surpasses currently available supply. I would like to see this situation change and I believe that my actions and those of others may well increase this demand in the coming years. In nearly every week of the year, an edible insect event is taking place somewhere in the United States, and people – especially children – are opening their eyes to the logic of entomophagy. Lastly, there is the very real possibility that the mass production of beef, pork, chicken and fish (the standard protein sources for many millions) might not be possible indefinitely. This implies that entomophagy could become a very viable option for meals despite the general cultural resistance to the practice of eating insects.

Those who attend my presentations are full of questions. Many come without the intention or willingness to sample insects, yet they try them at the end of the programme. There are several reasons why such people initially resist the practice or why they might change their minds, but they can be explored at another time. One of the questions people often ask is, “If insects are such a perfect food source, why have they been shunned by so many people?” I tend to reply that not so many people actually condemn insects as food, but this does not address the real question: Since we are intelligent beings, why did all of us fail to adopt this most logical food source long ago? I indicate that there are a variety of reasons, none of which include the insects’ taste. I also describe society’s separation from nature and that our jobs have distanced us from agriculture; our remoteness from the soil and its products has made us ignorant about and suspicious of animals such as insects.

As a teacher I find it helpful to use a variety of rhetorical approaches to introduce the notion of entomophagy to the public. One method is comparative example. The case of the lobster is quite useful. I often show people images of a lobster juxtaposed by a grasshopper, while explaining that one consumes vegetation and the other eats trash and carrion. The answer to, “Which should be the logical food choice?” usually surprises them. Today lobster is both an expensive food item and a carefully regulated harvest, but for much of American history lobsters were condemned as trash, and fed only to pigs and prisoners. How did this change? One reason is that the lobster was “discovered” as a gourmet food for the rich. It became equated with haute cuisine, and that was crucial. Although some might say that this could never happen with insects, this cannot be known for certain.

I cite this example not to suggest that insects should become the food for a society’s wealthy citizens, but simply to illustrate that a culture’s food perceptions can evolve – and the general perception of insects has been evolving in very positive ways. Insects have always surrounded us, but now they are becoming increasingly present in our culture. The number and variety of insect festivals has risen greatly in the last 20 years, and more zoos now feature insect houses. Also, the amount of insect and arthropod husbandry in the pet industry has expanded considerably. There are even children’s books on entomophagy. Most of all we can witness entomophagy on reality TV shows, which are fairly popular in the United States. While it is unfortunate that the people on these programmes are most distressed about eating insects and are doing so only to try to to win money, the practice still exposes entomophagy to the public, and catalyses conversations on the subject. Negative representations are still better than none at all, for they stir a sense of curiosity in some viewers.

Yet it is unlikely that there will be a quick change regarding the acceptance of entomophagy in the United States. Cultural norms are usually slow to change, but they do change like other fashions. In my area there are several small stores that specialize in foodstuffs for Southeast Asian cuisines and they sell frozen insects. I buy these products frequently for my seminars. I have chatted with many of the Thai and Cambodian owners there, either the clerks or other customers, who smile and chuckle when I ask them if they eat these foods. “No, no,” they tell me. “When I was little, back home, we ate this. Not anymore.” I am always tempted to ask them why, and sometimes do, but I get no real answer.

While entomophagy remains a significant component of humanity’s diet, research indicates that the eating of insects may well be declining in many parts of the world, including within societies that have long embraced edible insects as part of their diets. What could be the reason? I have not found any comprehensive studies of this phenomenon, only a host of anecdotal reports and commentary; in this case, educated guesses must be considered at least as a starting point. Gene DeFoliart and others have observed and described how communication technology has influenced a given group’s perception of themselves by showing them how other, seemingly more prosperous people, live. The global spread of television and other media in the last 40 years has meant that nearly everyone on the planet can see how everyone else lives. This becomes important when we consider that tourism, for example, has developed among more industrialized nations and moved towards their lesser industrialized counterparts, in a single direction. Therefore, it is not surprising that citizens of a less industrialized nation might seek to emulate the habits of others, and that various traditions might be discarded in the process.

None of this is intended to suggest that the United States or Western European nations are cultural leaders. Yet the decline in worldwide entomophagy, however slight and gradual it might be, is real cause for concern, and it has been sufficiently commented upon to be taken seriously. If this decline in entomophagy worldwide can be attributed to what might be called *acquired food source bias*, then one way to address this bias would be efforts at its source: among the people of the developed world. This is one of the bases for my work.

Another issue is the possibility that we do not have much time. Though a great many people enjoy the low food prices and other conveniences of our modern world, progress has been causing ever greater threats to our future. While it may be true that the public is generally disinterested in considering these threats, this does not stop my efforts to create positive change. When describing the vast amounts of wasted resources involved in the production of large vertebrate food sources, I tell the public, “Sometimes I hear my four-year-old daughter say that she would like to eat only cake and ice cream. That sounds nice, doesn’t it? After all, these foods are delicious and eating them gives us great pleasure. But we adults know what would happen to someone if he or she ate only cake and ice cream. The person would get fat, and his or her overall health would suffer greatly because vital nutrients – protein, vitamins and minerals in meat and vegetables – would be missing. An individual’s health will improve if he or she eats these foods sparingly.” The same could be said of the impact of large vertebrate food sources on the planet. Just as eating only desserts would harm the body, producing vast numbers of environmentally damaging food species is harming the planet. Anyone who doubts this logic would do well to read *Livestock’s long shadow*, an exhaustive report compiled and published by FAO (Steinfeld *et al.* 2006).

Clearly, vehicle and industrial emissions pose one of the greatest threats to the planet. But immediately behind these concerns are the cumulative effects of our food production. One reason that the mass production of cows, pigs, horses and other animals involves particularly catastrophic environmental impacts is that they are inherently wasteful in their consumption of grain, water and other resources. While many of us enjoy eating beef or pork, we may well sense that the days of consuming these animals are numbered.

A massive and ever-increasing body of research indicates that as global population continues to rise, and as climate and economics continue to change, the demands of food production and resource use will have a major effect on how we feed ourselves. It is distinctly possible that the large animal food sources that we have taken for granted for so long will be impractical to produce. This will make microlivestock, particularly insects, a desirable choice compared to other paradigms. It may well be that many people will embrace insect foods only when their usual food choices become problematic. However, we can do more than to passively wait for this to happen. In the meantime, there are people who see the logic – not only the logic of direct insect consumption, but also of utilizing insects in other forms of agriculture. It is clear that the more humanity is able to use insects in any form of food production, the more we reduce potential damage to the planet. Therefore, it is not an exaggeration to say that our work in entomophagy serves humanity as much as the work of those who seek new methods for attenuating malaria and other insect-borne diseases.

As we have seen, much of the developed world views insects as nothing more than pests. Moreover, even those academics who work with insects are not immune to biases against entomophagy. Many American entomologists appear to be resistant to any research or participation on the subject of entomophagy. Time and again I have approached these professionals for advice or assistance with information and resources for edible insects; few of these attempts have met with success. For this reason, I turn to the international community. While it is true that most of the United States is not ready to accept insects as food, the door is opening slightly, and more can be done. I feel sure that working together, we can make progress not only in Southeast Asia, but all around the world.

Literature cited

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & de Haan, C. 2006. *Livestock's long shadow: environmental issues and options*. Rome, FAO.

Workshop recommendations: summary

Drawing from the workshop presentations and discussions related to international, regional and country experiences with entomophagy, and specific technical insights, participants conducted extensive deliberations on three main aspects of edible forest insects:

- Taxonomy and ecology;
- Harvest practices and management implications; and
- Postharvest processing, shipping and marketing.

The three working groups each examined their respective topics in relation to three sets of issues: 1) the current status of edible insects in Asia and the Pacific; 2) key constraints to future development; and 3) recommendations for near- and long-term actions.

Key recommendations

The following key recommendations resulted from the working group and plenary session discussions:

Taxonomy and ecology

- Support and provide funding for scientific collection of key insects and the training of insect taxonomists.
- Develop a protocol for recording data on edible insects and establish a centralized database, or establish a collaborative link to an existing database such as the Bureau for Exchange and Distribution of Information on Minilivestock, to aid in species identification and information sharing.
- Conduct further research on the ecology and life cycles of edible insects.
- Carry out further research on the nutritive value of edible insects, possibly including the health benefits of medicinal uses.
- Promote the involvement of local people who eat insects, and therefore capture indigenous knowledge in research and collection.
- Promote a wider acceptance of *entomophagy* and *ethnoentomology* as scientific subdisciplines of entomology.

Harvest practices and management implications

- Conduct research on the management potential of wild edible insects to enhance harvests, to ensure sustainability in nature and to assess potential for rearing of promising species.

- Document consumption, local names and traditional harvest and management practices of edible insects, including any competing uses such as for medicine.
- Establish a mechanism such as a newsletter to share relevant information on these subjects.

Postharvest processing, shipping and marketing

- Enhance promotion, marketing and awareness raising, focusing on human nutritional values and the direct environmental benefits of insect eating.
- Improve public perception of insect eating through education (particularly targeting children), cook books, exhibitions, festivals, articles and interviews.
- Improve quality control (addressing concerns over pesticide residues, parasites, diseased insects and the production processes).
- Improve product appearance, packaging and labeling, provide value-addition.
- Assess the economic feasibility of rearing manageable insects, examining its potential to contribute to rural food stocks and development.
- Promote the adoption of edible insects as an element of government strategy for rural development and agricultural diversification where applicable.

An overarching recommendation was for FAO to strengthen information sharing related to edible forest insects in general, perhaps through a regional newsletter for Asia and the Pacific.

The working groups were structured to deal only with issues surrounding the future development of edible forest insects in general, not with specific insects. Collectively, however, the workshop participants identified a list of the insects considered to be the most important as food in the Asia-Pacific region (Table 1). The workshop recommended that future research and development focus on these priority insects. Among the species listed, highest priority should be given to those that have short life cycles and are therefore most suitable for mass rearing.

Table 1. Most important edible insects of the Asia-Pacific region[†]

Common names	Scientific Order, genus and species[‡]
Bamboo borer caterpillars	Lepidoptera *Omphisa fuscidentalis*
House crickets	Orthoptera *Acheta domesticus*, *A*. spp.
Sago grubs	Coleoptera *Rhynchophorus ferrugineus*
Grasshoppers	Orthoptera *Acrydium* spp*., Aelopus tamulus,Euconocephalus* spp*., Patanga succincta*
Dung beetles	Coleoptera *Heliocopris bucephalus*
Cicadas	Hemiptera *Cosmopsatria* sp., *Dundulia* spp., *Pomponia imperatoria*
Giant water bugs	Heteroptera *Lethocerus indicus*
Silkworms, eri silkworms	Lepidoptera *Bombax mori, Samia ricini*
Vespa wasps	Hymenoptera *Vespa* spp. *Vespula* spp.
Weaver ants	Hymenoptera *Oecophylla smaragdina*
Bee brood	Hymenoptera *Apis* spp. *Trigona* spp.

[†]In no particular ranked order.
[‡]Does not include all possible genera/species.
Source: Workshop participants.

Bottlenecks

The conference recommendations addressed several bottlenecks to future development, which were commonly identified. First is the lack of information and research, and the need to integrate and document local knowledge that is being lost in many parts of the region. The lack of mechanisms for sharing existing information – which is often in local languages – was also recognized. Second are promotional and educational aspects. Ensuring quality and safety of edible insect products, changing perceptions and raising awareness are continuing challenges in this regard. Food regulatory issues in some countries are also potential impediments that must be taken into account. Finally, moving insect eating from a fringe subject to a mainstream strategy for rural development will require a multifaceted effort. Enhancing the acceptance of *entomophagy* in practice and as a scientific discipline will be an important first step in promoting insects as food in the Asia-Pacific region, as well as on a global scale.

Appendix 1. Internet information sources (listed alphabetically by subject)

Bureau for Exchange and Distribution of Information on Minilivestock (BEDIM). Secretariat: Mrs Goorickx Muriel. FUSA, Bibliothèque Centrale, Passage des Déportés, 2. B-5030 Gembloux, Belgium. E-mail: Goorckx.m@fsagx.ac.be Web site: http://www.bib.fsagx.ac.be/bedim

Beekeeping. Glossary of terms. http://maarec.cas.psu.edu/bkCD/glossary.html

Bee Research. International Bee Research Association. http://www.ibra.org.uk

Butterfly Farming. The Amani Butterfly Project in Tanzania. Web site details for the commercial raising of butterfly pupae. http://www.amanibutterflyproject.org

Caterpillars. Good source of general information on caterpillars, including a database, breeding, etc. http://www.saturniidae-moths.de

Centipedes. Comprehensive information on all aspects of centipedes except food use. http://www.earthlife.net/insects/chilopod.html

Edible insect candy. Butterflies, scorpions and larvae in candy; chocolate covered ants and crickets. McKeesport Candy Co., USA. http://www.mckandy.com

Edible insect snack food and candies. Hotlix Company, USA. Insects in hard candies; chocolate covered insects; fried larvae snacks. http://www.hotlix.com

Edible insects from Thailand. Recipes and other information; spiders included; numerous links. http://www.thaibugs.com

Endangered insects. To determine if an insect may be under threat, it is possible to search the Species of Conservation Concern Database of the UNEP-World Conservation Monitoring Centre. http://www.unep-wcmc.org

Entomology. Information and links on all aspects of the subject. http://www.insects.org

Entomology journals. The Entomology Society of America publishes several journals, including *Annals of the Entomology Society of America*, *Environmental Entomology*, and *Journal of Economic Entomology*. Tables of contents can be viewed at Web site. http://www.entsoc.org

(The) human use of insects as a food resource: a bibliographic account in progress. Prof G. DeFoliart's online book; nearly complete. http://www.food-insects.com

Insect candy. Kathy's Critters Co., USA. Hard candy with insects; chocolate covered insects; fried larvae snacks. http://www.insectcandy.com

Insects. Wonderful world of insects. Information on insect Orders, a glossary of entomology, societies related to insects, etc. http://www.earthlife.net/insects

Insects as food. Most comprehensive Web site for information on insects as food. Site edited by Prof. G. DeFoliart. Site partially updated in October 2006. http://www.food-insects.com

Insects in general. Web site primarily for insect collectors, but with links to broad range of related subjects from how to raise insects to insect-inspired jewelry and T-shirts. http://www.insectnet.com

International Butterfly Breeders Association, Inc. Organization has 134 active members, most in the United States. http://www.butterflybreeders.org

International Centre of Insect Physiology and Ecology, Nairobi, Kenya. Chief research activities are pest management and disease vectors. http://www.icipe.org

International trade in insects. Monitors trade in insects with particular attention to threatened species. http://www.traffic.org

Millipedes. Comprehensive information on all aspects of millipedes except food use. http://www.earthlife.net/insects/diplopoda.html

Scorpions. Current information on all living scorpions and their taxonomy. http://www.ub.ntnu.no/scorpion-files

Spiders and their relatives. Technical information on the Arachnids, including mites and ticks, spiders, tarantulas, scorpions, etc. http://www.arachnology.be

Appendix 2. Taxonomy of insects and their relatives

Phylum	Class	Order	Number of named species
Arthropoda	Insecta or Hexapoda	Odonata: darners, dragonflies and damselflies	5 500
		Orthoptera: grasshoppers and crickets	20 500
		Hemiptera: water boatmen, bed bugs, seed bugs	40,000
		Homoptera: cicadas, treehoppers and aphids	45 000
		Diptera: flies, mosquitoes, midges	120 000
		Coleoptera: beetles	400 000
		Lepidoptera: butterflies and moths	150 000
		Hymenoptera: wasps, ants and bees	130 000
		Ephemeroptera: mayflies	2 100
		Phasmatodea: stick and leaf insects	2 500
		Grylloblattodea: rock crawlers	10
		Dermaptera: earwigs	1 800
		Isoptera: termites	2 300
		Blattodea: cockroaches	3 700
		Mantodea: praying mantids	1 800
		Plecoptera: stoneflies	2 000
		Embiidina: webspinners	150
		Thysanoptera: thrips	5 000
		Anoplura: lice	250
		Phthiraptera: crab louse	3 000
		Neuroptera: lacewings and ant lions	5 000
		Megaloptera: alderflies	180
		Trichoptera: caddis flies	10 000
		Mecoptera: scorpion flies	400
	Arachnida	Araneae: spiders and tarantulas	35 000
		Scorpions: burrowing scorpions	1 300
	Chilopoda	Scolopendromorpha + 4 others: centipedes	2 500
	Diploda	Julida + 13 others: millipedes	10 000

Appendix 3. Insect terminology and definitions

Term	Definition
Adult	Insect in its final adult stage, sexually mature and typically with wings.
Apiculture	Keeping of bees for honey and other products.
Brood	Bees not yet emerged from their cells: eggs, larvae and pupae.
Bug	Insect or other creeping or crawling invertebrate; in entomology, an insect in the order Hemiptera.
Caterpillar	Elongated wormlike larva of a butterfly or moth.
Chrysalis	Pupa of a butterfly.
Egg	First stage in life history of an insect.
Entomology	Study of insects.
Entomophagy	Eating of insects.
Ethnoentomology	Applications of insect life in traditional, aboriginal, or non-industrialized societies.
Frass	Caterpillar or other larvae droppings.
Grub	Soft, thick, worm-like larvae of an insect.
Imago (pl. imagines)	Insect in its final adult stage, sexually mature and typically with wings.
Insect	Any of numerous small invertebrate animals; in entomology, insects in the class Insecta with 3 pairs of legs and 1 or 2 pairs of wings.
Larva (pl. larvae)	Immature insect after emerging from the egg; second stage in life history of many insects.
Maggot	Legless larva, especially of a fly.
Nymph	Immature growing form of an insect such as the grasshopper.
Oviposit	To lay eggs, term used especially for insects.
Ovum (pl. ova)	Egg; first stage in the life history of an insect.
Propolis	Sap or resinous materials collected from trees or plants by bees and used to reinforce the comb; also called bee glue.
Pupa (pl. pupae)	Third stage in the life history of insects like beetles.
Sericulture	Silk production, principally from the moth *Bombyx mori*.
Silkworm	Larvae of Asian moth in the genus Bombyx, and other taxa, which are the source of silk.
Worm	Naked, soft-bodied adult animal; also insect larvae, especially those that are destructive.

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