



Edible Insects: Food Safety Considerations

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Preface

- “In entering upon this work, I am fully conscious of the difficulty of battling against a long-existing and deep-rooted public prejudice. I only ask of my readers a fair hearing, an impartial consideration of my arguments, and an unbiased judgement. If these be granted, I feel sure that many will be persuaded to make practical proof of the expediency of using insects as food. There are insects and there are insects. *My* insects are all vegetable feeders, clean, palatable, wholesome, and decidedly more particular in their feeding than ourselves. While I am confident that they will never condescend to eat *us*, I am equally confident that, on finding out how good they are, we shall some day right gladly cook and eat *them*.”

- Vincent M. Holt, “Why not eat insects?,” Field & Tuer. 1885

Food Security Challenges

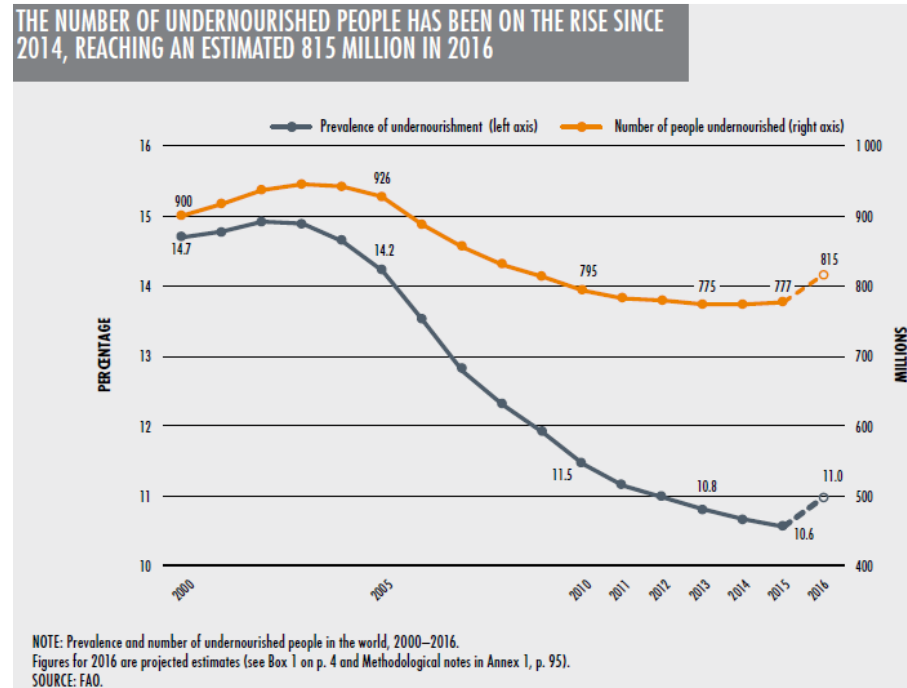
■ World population growing rapidly

- 1885 = 1.3 billion
- 2018 = 7.5 billion
- 2050 = 9.8 billion! (projected)

■ Increase in food production by 2050

- More than double
 - Sub-Saharan Africa
 - South Asia
- 33% elsewhere
- **200 million additional tons of meat**

■ Hunger is on the rise!



Data from 2016:

- 815 million chronically undernourished people
- Wasting affected 52 million children

FAO, 2017. “The state of food security and nutrition in the world.”

FAO, 2017. “The future of food and agriculture – Trends and challenges.”

Trends in Dietary Practices

■ Protein-centric Foods

- Added protein to food and beverages remains a trend.
- Consumers who seek out high protein foods
 - 39% in 2006
 - 60% in 2018

■ Increased demand for plant and “alternative” proteins

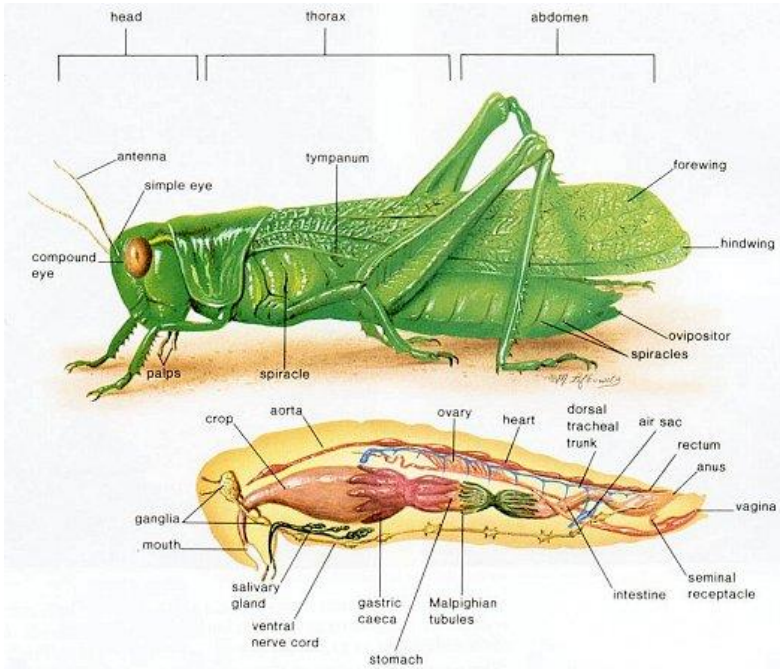
- **Insects!**
- Chickpea, lentil, rice, etc...
- Cultured meat



Hayes, T. 2018. Why We Are Investing in Alternative Proteins. Tyson Foods.

Nunes, K. 2018. Protein to remain on trend in 2018. *Food Business News*.

What is an insect?



- Arthropods
- Three-part body
 - Head, thorax, abdomen
- Three pairs of jointed legs
- Compound eyes
- Two antennae
- 1 million described species
- 6 – 10 million estimated species
- *Relatives:* arachnids and crustaceans

■ Entomophagy

- Technically, “insect eating,” but includes arachnids in practice.
- >1,900 edible insect species

■ Insects are abundant in nature

- 10 quintillion individuals
- 200 million insects for every person!

■ Insects can be cultivated

- Pet food and bait
- Low to high sophistication

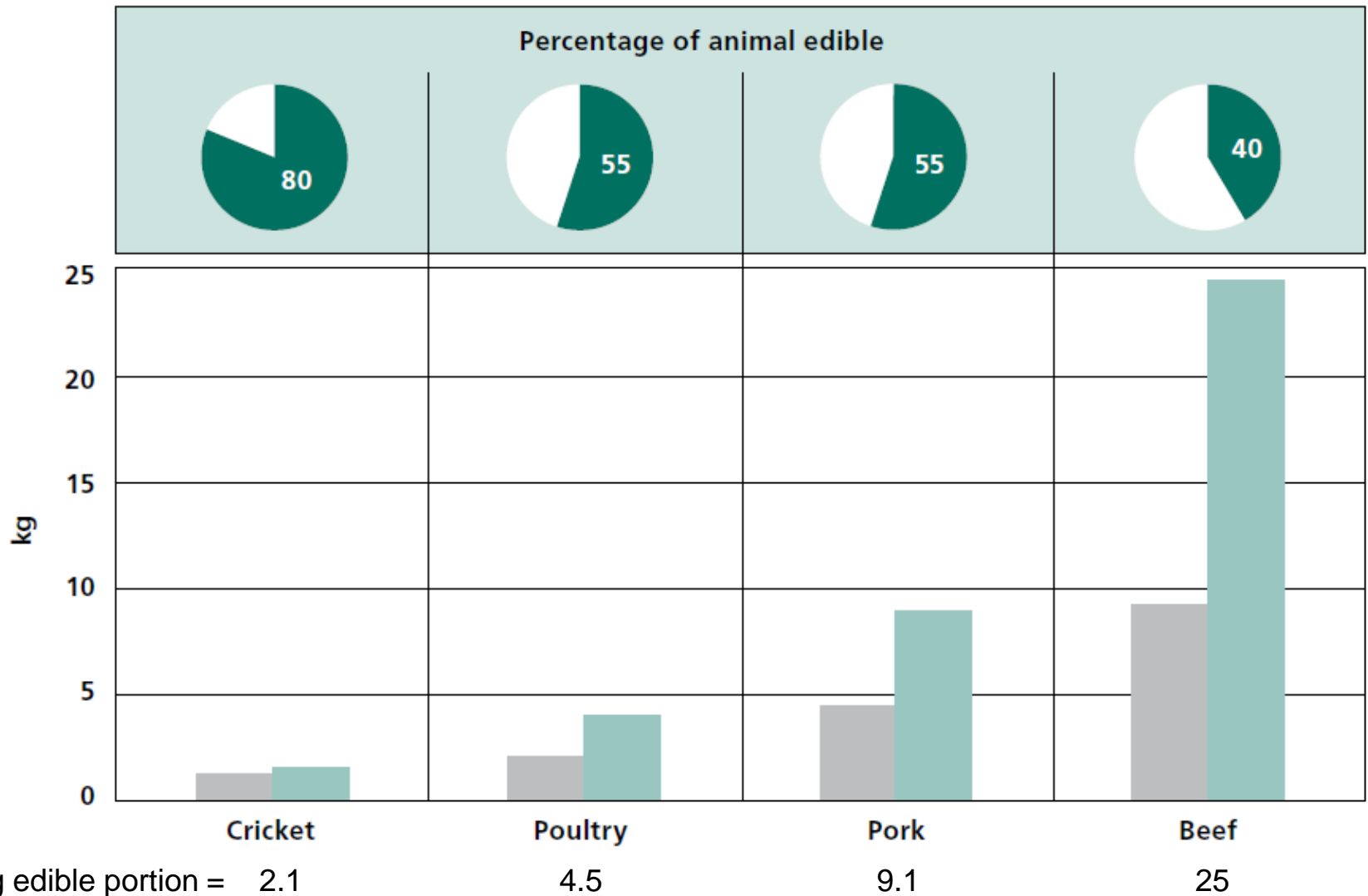


■ Lower greenhouse gas emissions water use, and land use

■ Insect farming for human food

- Farms in Netherlands, France, South Africa, Israel
- United States
 - Several farms in U.S. – mostly cricket producers

Feed Conversion



FAO, 2013. "Edible insects: future prospects for food and feed security."

Types of Insects Eaten

Order	Examples	%
Coleoptera	Beetles	31
Lepidoptera	Caterpillars	18
Hymenoptera	Bees, wasps, ants	14
Orthoptera	Grasshoppers, locusts, crickets	13
Hemiptera	Cicadas, leaf- hoppers, plant- hoppers, true bugs, etc.	10
Isoptera	Termites	3
Odonata	Dragonflies	3
Diptera	Flies	2
Others		6



Kinyuru et al., 2015
Van Huis et al., 2013

Average Nutritional Composition of Insects*

	Coleoptera	Lepidoptera	Hymenoptera	Orthoptera	Hemiptera	Isoptera
	Beetles	Caterpillars	Bees, Wasps	Grasshoppers	Cicadas, etc.	Termites
Protein (%)	41	45	46	61	48	35
Fat (%)	33	28	25	13	30	33
Fiber (%)	11	7	6	10	12	5
Kcal/100g	410	431	450	463	484	509

Comparison: 80/20 ground beef = 45% protein*

*** Dry matter basis**

- **Other nutrients** (influenced by feed and developmental stage)
 - Potentially adequate sources of vitamins and minerals
 - Often good sources of poly- and monounsaturated fats

Sensory Characteristics

- Flavors vary by insect type, feed source, etc.

Insect	Flavor
Ants	Nutty, sweet
Caterpillars	Corn
Wasps	Pine nuts
Mealybugs	Fried potatoes



- Scalding may significantly reduce typical flavors
- Mature insects may be crispy or crunchy
 - Pupae, larva, and nymphs typically are not
- Preparation is a significant influence

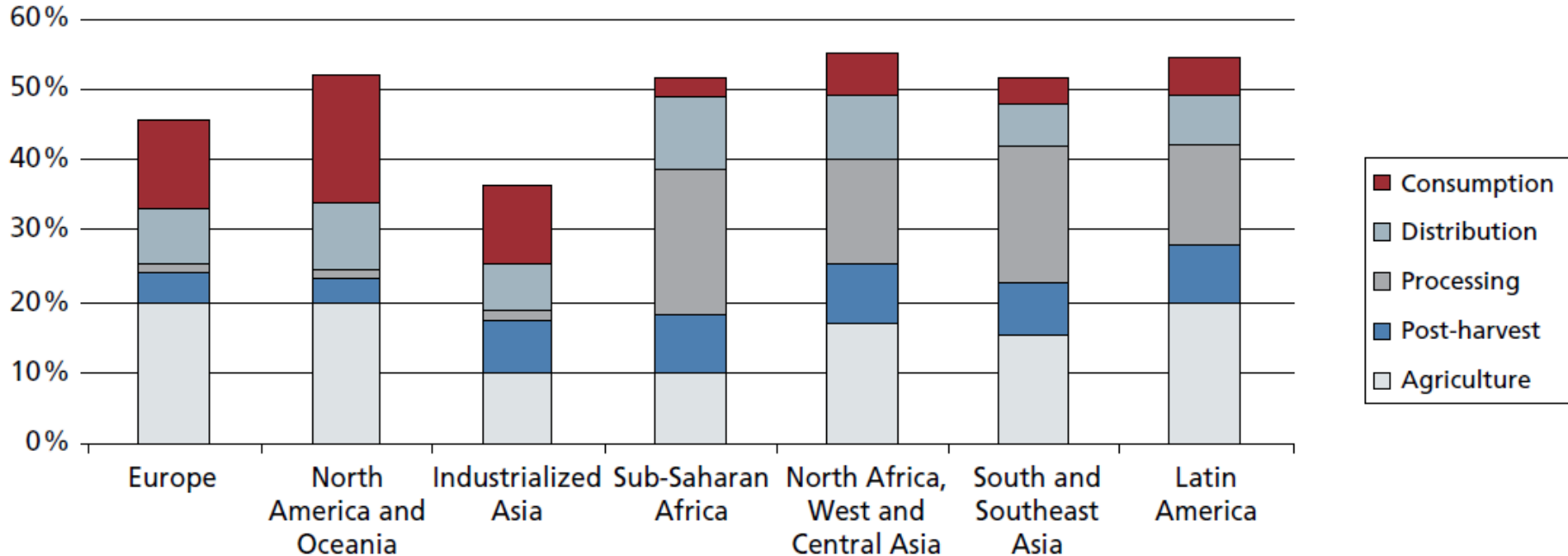


Insect Farming: Production of “Mini Livestock”

- Essentially similar to production of other animals
 - Housing, food, water, air, waste removal, conditions
- Insect farming minimizes inputs and maximizes outputs while minimizing negative environmental effects
- Various production strategies available
 - Straight batch (SB), cyclical SB, cyclical fed batch, parallel fed batch, plug flow continuous, etc...

Part of the Initial Production Lost or Wasted at Different Stages of the Food Supply Chain for Fruits and Vegetables in Different Regions.

Food losses - Fruits and vegetables



FAO, 2011. Global Food Losses and Food Waste.

Insect Processing

■ Slaughtering

- Method may impact sensory properties
 - Study assessed broths made from crickets (Farina, 2017)
 - Frozen or cooked live
 - Panelists scored cooked live crickets higher in overall acceptability, as well as salty and umami flavors.
- Starvation for 24 to 48 h prior

■ Decontamination

- Aerobic Plate Counts of fresh insects
 - 7.2 – 8.6 log CFU/g (4 separate studies)



Farina, MF. 2017. Int. Journal Gastr Food Sci. 8:19–23.

Rumpold et al. 2017. Insects as Food and Feed from Production to Consumption. Wageningen

■ Other processes

- Drying
- Comminution
- Protein extraction
- Fat extraction
- Chitin extraction

■ Ingredients

- Insect proteins
- Insect oils
- Chitin



Recommended uses:

- Smoothies
- Baked goods (replace 10-15% flour)

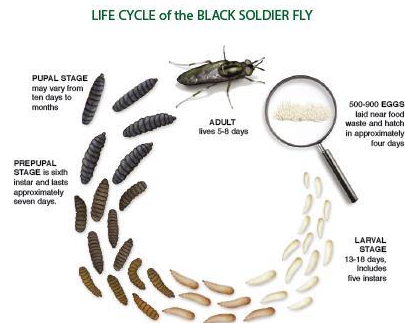
Insects as Feed: The Black Soldier Fly

■ Aquaculture

- Increasing need for aquacultured products
- Pressure to improve sustainability
- Fishmeal expense and availability issues

■ Black Soldier Fly

- Studied for waste treatment
 - Consumes decaying fruits, vegetables, manure, etc.



Black soldier fly is being investigated as a replacement for fishmeal for a number of fish species.



Challenges to Use of Insects as Food and Feed

- **Potential antinutritional properties of chitin**
 - Decreased protein digestibility
- **Microbial risks**
 - Generally, high microbial load
 - Few studies on microbial risks from feed materials
- **Allergen potential for those with shellfish allergies**
- **Regulations lack clarity**



FOOD SAFETY CONSIDERATIONS FOR EDIBLE INSECTS

Undesirable Conditions or Contaminants

- In HACCP, “hazards” refer to conditions or contaminants in foods that can cause illness or injury. It does not refer to undesirable conditions or contaminants such as:
 - Hair
 - Filth
 - Spoilage
 - Economic fraud
 - Insects
 - Violations of regulatory food standards not directly related to safety

Common Insect Bacterial Genera

- *Staphylococcus*
- *Streptococcus*
- *Bacillus*
- *Proteus*
- *Pseudomonas*
- *Escherichia*
- *Micrococcus*
- *Lactobacillus*
- *Acinetobacter*
- *Enterobacter*
- *Citrobacter*
- *Klebsiella*
- *Yersinia*
- *Bacteroides*
- *Fusobacterium*
- *Actinobacillus*
- *Propionibacterium*
- *Serratia*
- *Dermabacter*
- *Brachybacterium*
- *Clavibacter*
- *Exiguobacterium*

Agabou and Alloui, 2010; Amadi et al., 2005; Belluco et al., 2013; Braide et al., 2011; Giaccone, 2005; Liu et al., 2011; Ulrich et al., 1981

Common Insect Mold Genera

■ Mopane caterpillar (*Imbrasia belina*), which is commonly consumed in African countries

- *Aspergillus*
- *Cladosporium*
- *Fusarium*
- *Penicillium*
- *Phycomycetes*



Gashe et al., 1997

Foodborne Pathogens in Insects

■ *Salmonella* and *Listeria monocytogenes* **not found** in farm-raised:

- Superworm (*Zophobas morio*)
- Yellow mealworm (*Tenebrio molitor*)
- Wax moth (*Galleria mellonella*)
- Butterworm (*Chilecomadia moorei*)
- House cricket (*Acheta domesticus*)

Giaccone, 2005

■ Processed caterpillars & lesser meal worms (*Alphitobius diaperinus*) **shown to have** potential human pathogens:

- *Escherichia coli*
- *Bacillus cereus*

Gashe et al., 1997

Parasites in Insects

- Trematode families *Lecithodendridae* & *Plagiorchiidae*
- Chagas disease (*Trypanosoma cruzi*)
- Liver fluke (*Dicrocoelium dendriticum*) transmission due to ingestion of ants
- Protozoa in cockroaches
 - Entamoeba histolytica*
 - Giardia lamblia*
 - Toxoplasma* spp.
 - Sarcocystis* spp.

Mechanical Transmission of Human Protozoan Parasites by Insects

Thaddeus K. Graczyk,* Ronald Knight, and Leena Tamang

*Department of Molecular Microbiology and Immunology, Bloomberg School of Public Health,
Johns Hopkins University, Baltimore, Maryland*

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Relevance of Insect Parasites?



Tachinid flies (left) parasitize many types of insects. Tachinid eggs laid on the caterpillar at right will hatch and, as larvae, bore into the host. Some tachinids lay eggs on plants and enter their insect hosts by being eaten.



Examples of Toxins Produced by Insects

■ **Scorpions** (especially *Centruroides* sp)

- Neurotoxic (most), Na channel open longer; K and Cl channel effects
- *Symptoms*: neurological effects, roving eye, miosis, hypertension, increased heart & respiratory rate, muscle fasciculations, weakness, ataxia, excessive salivation, opisthotonos, restlessness (kids), tense/anxious (adults); impaired initial depolarization of the action p in nerve and muscle



■ Centipedes (*Scolopendra* sp)

- High MW proteins, proteinases, esterases, 5-hydroxytryptamine, histamine, polysaccharides, lipids; (maxillipeds = first pairs of legs are poison jaws)
- *Symptoms:* Cardiovascular changes due to acetylcholine release. Bleeding, redness, swelling at bite; severe envenomations cause nausea, vomiting, changes in heart rate, vertigo, headache, mental disturbances
- Two case of rat lungworm disease due to consumption of Chinese red-headed centipedes.
 - Used in Chinese medicine



■ Hemiptera/ Heteroptera (ex: *Belostomatidae* sp)

- Apyrase activity, proteases; Lack 5'-nucleotidase, pyrophosphatase, phosphatase, adenylate kinase
- *Symptoms*: Inhibits collagen-induced platelet aggregation



Giant Water Bug



Fried Giant Water Bugs

Tarantula Popper: Is This a Physical Hazard?





Allergens and Insects

■ We know that some consumers have **adverse physical reactions to insects**, such as external exposure to dust mites or internal exposure to injected venom

We know all consumers eat insect parts due to incidental food contamination – mandibles, legs, wings, etc.

Does insect feed source (ex, soybean) remain potentially allergenic if you eat intestinal content with serving, such as whole crickets?

What is true food safety impact of insect consumption?



Allergenic Potential of Insects

■ Potential cross-reactivity with other allergens

- Crustacean(shellfish) vs insects
 - Appears to be clinically relevant
- House dust mites vs insects
 - Relevance currently unknown

■ Insect Allergens

- Tropomyosin
 - Shares high degree of biological similarity with the crustacean allergen
- Arginine Kinase
- Others

Regulatory Status for Edible Insects

- “The term ‘food’ means (1) articles used for food or drink for man or other animals, (2) chewing gum, and (3) articles used for components of any such article.”
 - Whole insects consumed as food are food
 - Label should include scientific name of insect
 - Raised specifically for human food, not animal feed
 - Cannot be harvested from the wild (pesticides, etc.)
- Use of insect components, such as proteins and lipids, in foods is not clear
 - Food additive or GRAS status not apparent
 - Fish protein isolate regulated as a food additive (21 CFR 172.340)

“Cricket Soup: A Critical Examination of the Regulation of Insects as Food.” Yale Law & Policy Review’ 2017

■ “FDA should specifically affirm that insects used as food are ‘food’ under the Federal Food, Drug and Cosmetic Act’s (FDCA) broad definition of that term. In addition, FDA should distinguish between insects as ‘food’ and insects as ‘filth.’ In light of its substantial regulation of insects as ‘filth,’ FDA’s regulatory inaction with respect to insects as food is not neutral and it may reflect and reinforce predominate cultural conceptions of food, which do not include insects. Culturally, insects may not be commonly regarded as food, in part, because they have been generally regulated as defects and not as food. By recognizing insects as food and regulating them as such, FDA may help to erode the stigma surrounding these products and may help to advance the study and development of insects as food and as an alternative to conventional animal proteins. This would be consistent with FDA’s mission to protect and promote the public health.” – Marie C. Boyd

Why Eat Insects?

■ Health

- Insects are nutritious
 - Excellent sources of proteins and fats, calcium , iron, zinc
- Commonly consumed in many countries

■ Environment

- Fewer greenhouse gas emissions
- Lower land use
- High feed conversion ratio
- Can be fed waste

■ Social and Economic

- Increased protein production needed
- Expanded agriculture business opportunities



Culinary Adventure!

Food Safety Questions for Edible Insects

- **Influence of insect production practices on food safety?**
 - Insect food sources – food waste, etc
 - Waste removal
- **Insect processing for food safety**
 - Validated processing measures
 - Removal of physical hazards
 - Whole insects vs insect products (protein, fats, etc.)
- **Potential for allergen cross-reactivity**
 - Primary concern for shellfish cross-reactivity
- **Unique insect toxins and physical hazards**
- **Regulatory clarification**

Bon Appétit!

