ISSN 0258-6150

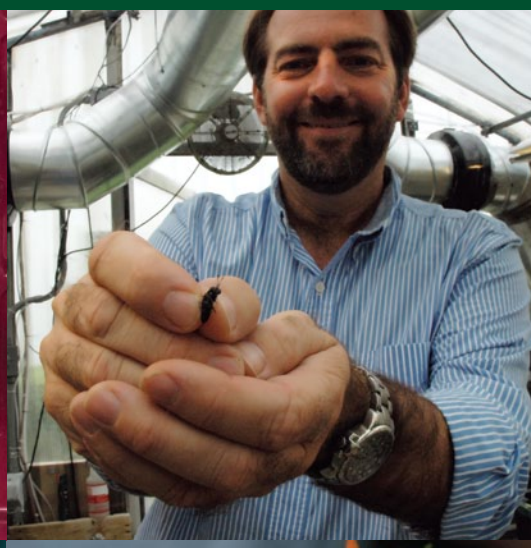
FAO
FORESTRY
PAPER

171

Edible insects

Future prospects for food and feed security






WAGENINGEN UR
For quality of life

FAO
FIAT PANIS

Cover photos, clockwise from top left:
Women selling caterpillars in Bangui, Central African Republic (P. Vantomme)
Gold-painted crickets on top of Belgian chocolates (P. Vantomme)
Black soldier fly in a mass-rearing unit (L. Heaton)
Appetizers prepared with insects (T. Calame)
Coleoptera species used as a food colorant (A. Halloran)
Palm weevil larvae (O. Ndoye)

Edible insects: future prospects for food and feed security

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2013

ISBN 978-92-5-107595-1 (print)
E-ISBN 978-92-5-107596-8 (PDF)

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Foreword

It is widely accepted that by 2050 the world will host 9 billion people. To accomodate this number, current food production will need to almost double. Land is scarce and expanding the area devoted to farming is rarely a viable or sustainable option. Oceans are overfished and climate change and related water shortages could have profound implications for food production. To meet the food and nutrition challenges of today – there are nearly 1 billion chronically hungry people worldwide – and tomorrow, what we eat and how we produce it needs to be re-evaluated. Inefficiencies need to be rectified and food waste reduced. We need to find new ways of growing food.

Edible insects have always been a part of human diets, but in some societies there is a degree of distaste for their consumption. Although the majority of edible insects are gathered from forest habitats, innovation in mass-rearing systems has begun in many countries. Insects offer a significant opportunity to merge traditional knowledge and modern science in both developed and developing countries.

This publication has its beginnings in an effort in FAO's Forestry Department to recognize the traditional practices of gathering insects for food and income, and to document the related ecological impacts on forest habitats. Thereafter, FAO embraced the opportunity to collaborate with the Laboratory of Entomology at Wageningen University in the Netherlands – an institution at the forefront of fundamental and applied research on insects as food and feed. This combined effort has since gained momentum and is unfolding into a broad-based effort at FAO to examine the multiple dimensions of insect gathering and rearing as a viable option for alleviating food insecurity.

This book draws on a wide range of scientific research on the contribution that insects make to ecosystems, diets, food security and livelihoods in both developed and developing countries. We hope that it will help raise the profile of insects as sources of food and feed in national and international food agencies. We also hope that it attracts the attention of farmers, the media, the public at large and decision-makers in governments, multilateral and bilateral donor agencies, investment firms, research centres, aid agencies and the food and feed industries. Above all, it is our hope that this publication will raise awareness of the many valuable roles that insects play in sustaining nature and human life and will also serve to document the contribution insects already make to diversifying diets and improving food security.

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Abbreviations

BCE	Before Common Era
BSE	bovine spongiform encephalopathy
CABIN	Central African Biodiversity Information Network
CE	Common Era
CGRFA	FAO's Commission on Genetic Resources for Food and Agriculture
CH_4	methane
CO_2	carbon dioxide
CRGB	Centre de Recherche pour la Gestion de la Biodiversité (Benin)
EFSA	European Food Safety Agency
ESBL	extended spectrum beta-lactamase
EU	European Union
FBF	fortified blended foods
g	gram
GHG	greenhouse gas
GWP	global warming potential
HACCP	Hazard Analysis Critical Control Points system
IFIF	International Feed Industry Federation
INFOODS	International Network of Food Data Systems
IPM	integrated pest management
kg	kilogram
N_2O	nitrous oxide
NGO	non-governmental organization
NWFP	non-wood forest product
PAP	processed animal protein
RDA	recommended dietary allowances
SEPALI	Madagascar Organization of Silk Workers
SPS Agreement	Agreement on the Application of Sanitary and Phytosanitary Measures
VENIK	Dutch Insect Farmers Association
WHO	World Health Organization
WTO	World Trade Organization
WUR	Wageningen University and Research Centre

Authors' preface

Insects are often considered a nuisance to human beings and mere pests for crops and animals. Yet this is far from the truth. Insects provide food at low environmental cost, contribute positively to livelihoods, and play a fundamental role in nature. However, these benefits are largely unknown to the public. Contrary to popular belief, insects are not merely "famine foods" eaten in times of food scarcity or when purchasing and harvesting "conventional foods" becomes difficult; many people around the world eat insects out of choice, largely because of the palatability of the insects and their established place in local food cultures.

In 2008, within the framework of the Wageningen University–FAO partnership, a few researchers came together and began reviewing an extensive array of published and unpublished research and information on insect rearing and consumption. Their intention was to break down the aforementioned misconceptions and contribute positively to the development of the edible insects sector. The subject of edible insects inherently covers a wide range of thematic areas, from the conservation of habitats where insects are harvested to insect ecology, the artificial rearing of insect species, the processing of insects into food and feed products, and the labelling and marketing of insect-based food and feed products. This publication, therefore, draws from a wide range of disciplines and areas of expertise. It is a multidisciplinary effort involving technical experts specializing in forestry, animal farming, nutrition, the feed industry, legislation and food security policies.

This publication marks the first attempt by FAO to document all aspects of the insect food and feed value chain, with the aim of enabling a comprehensive assessment of the contribution of insects to food and feed security. It includes original research from around the world, such as that carried out at Wageningen University. It also incorporates findings from the International Expert Consultation on Assessing the Potential of Insects as Food and Feed in Assuring Food Security, which took place at FAO headquarters in Rome, Italy, on 23–25 January 2012. This meeting marked the beginning of a dialogue between agricultural experts from various backgrounds and fostered an exchange of information on the potential benefits of using insects for food and feed as part of a broader strategy to achieve global food security. The participants at this meeting provided the authors with a wealth of supplementary data and valuable insights. These helped to shape the form and content of this book and its conclusions, which it is hoped can provide a basis for solutions to alleviate food insecurity.

Insect rearing for food and feed remains a sector in its infancy, and key future challenges will likely emerge as the field evolves. As such, readers are encouraged to contact the authors with feedback on this book. Such contributions will undoubtedly assist the future development of the sector.

Since the science of edible insects is still at a relatively pioneering stage, it boasts only a few scientists of renown. One of those, Gene R. DeFoliart (1925–2013), died shortly before this book was published. He spent his long academic career passionately raising awareness of insects as a global food source, and he continued his work in this area long after his retirement in July 1991. He was also the founder of *The Food Insects Newsletter*. The authors dedicate this book to his memory.

Acknowledgements

This book was made possible by the valuable contributions of many people with a variety of backgrounds and from many parts of the world. Their ideas, papers and professional activities all played a fundamental role in shaping this publication. Among them, special thanks are extended to the 75 participants at the Expert Consultation Meeting on Assessing the Potential of Insects as Food and Feed in Assuring Food Security, which was held in Rome on 23–25 January 2012.[1] Special thanks go to those who reviewed specific chapters of this book: Christian Borgemeister, Eraldo Medeiros Costa-Neto, David Drew, Florence Dunkel, Jørgen Eilenberg, Ying Feng, Parimalendu Haldar, Yupa Hanboonsong, Antoine Hubert, Annette Bruun Jensen, Nonaka Kenichi, Andrew Müller, Maurizio Paoletti, Julieta Ramos Elorduy Blásquez, Nanna Roos, Oliver Schneider, Severin Tchibozo and Alan L. Yen.

Several FAO staff members kindly volunteered to review chapters relevant to their areas of expertise: Philippe Ankers, Jan Breithaupt, Carmen Bullón, Ruth Charrondiere, Persijn Diedelinde, Patrick Durst, Graham Hamley, Martin Hilmi, Edgar Kaeslin, Blaise Kuemlangan, Harinder Makar, Verena Nowak, Koroma Suffyan, Patrice Talla, Pieter Van Lierop and Philine Wehling. We thank them for their willingness to contribute to such an interdisciplinary effort. Special thanks also go to staff at Wageningen University, including Sarah van Broekhoven and Dennis Oonincx.

The authors are grateful to David McDonald and Alastair Sarre for editing, Yde Jongema for checking the Latin names of the insects, Kate Ferrucci for design and layout, Susy Tafuro and Lucia Travertino Grande for the administrative handling of the manuscript from printing through to distribution, and Maria DiCristofaro and Alison Small for media support. Special thanks are due to Eva Müller, the Director of the Forest Economics, Policy and Products Division at FAO, and Michael Martin, the previous director, who both fully supported the Edible Insects Programme.

Above all, the authors acknowledge all people around the world for whom eating insects is and has always been an integral part of daily life. They have provided time-honoured understandings of edible insects and remain custodians of valuable knowledge on the important roles that insects play in daily lives. These peoples are a key to the continued practice of eating insects and the potential of edible insects as future sources of food and feed.

[1] For futher information, see www.fao.org/forestry/edibleinsects/74848/en/.

Executive summary

This book assesses the potential of insects as food and feed and gathers existing information and research on edible insects. The assessment is based on the most recent and complete data available from various sources and experts around the world.

Insects as food and feed emerge as an especially relevant issue in the twenty-first century due to the rising cost of animal protein, food and feed insecurity, environmental pressures, population growth and increasing demand for protein among the middle classes. Thus, alternative solutions to conventional livestock and feed sources urgently need to be found. The consumption of insects, or **entomophagy**, therefore contributes positively to the environment and to health and livelihoods.

This publication grew from a small effort in 2003 in the FAO Forestry Department to document the role of insects in traditional livelihood practices in Central Africa and to assess the impact of harvesting insects in their natural habitats on the sustainability of forests. This effort has since unfolded into a broad-based effort to examine the multiple dimensions of insect gathering and rearing to clarify the potential that insects offer for improving food security worldwide. The purpose of this book is to bring together for the first time the many opportunities for, and constraints on, using insects as food and feed.

THE ROLE OF INSECTS

It is estimated that insects form part of the traditional diets of at least 2 billion people. More than 1 900 species have reportedly been used as food. Insects deliver a host of ecological services that are fundamental to the survival of humankind. They also play an important role as pollinators in plant reproduction, in improving soil fertility through waste bioconversion, and in natural biocontrol for harmful pest species, and they provide a variety of valuable products for humans such as honey and silk and medical applications such as maggot therapy. In addition, insects have assumed their place in human cultures as collection items and ornaments and in movies, visual arts and literature. Globally, the most commonly consumed insects are beetles (Coleoptera) (31 percent), caterpillars (Lepidoptera) (18 percent) and bees, wasps and ants (Hymenoptera) (14 percent). Following these are grasshoppers, locusts and crickets (Orthoptera) (13 percent), cicadas, leafhoppers, planthoppers, scale insects and true bugs (Hemiptera) (10 percent), termites (Isoptera) (3 percent), dragonflies (Odonata) (3 percent), flies (Diptera) (2 percent) and other orders (5 percent).

CULTURE

Entomophagy is heavily influenced by cultural and religious practices, and insects are commonly consumed as a food source in many regions of the world. In most Western countries, however, people view entomophagy with disgust and associate eating insects with primitive behaviour. This attitude has resulted in the neglect of insects in agricultural research. Despite historical references to the use of insects for food, the topic of entomophagy has only very recently started to capture public attention worldwide.

INSECTS AS A NATURAL RESOURCE

Edible insects inhabit a large variety of habitats, from aquatic ecosystems and farmed land to forests. Until recently, insects were a seemingly inexhaustible resource obtainable by harvesting from nature. However, some edible insect species are now in peril. A number of anthropogenic factors, such as overharvesting, pollution, wildfire and habitat degradation, have contributed to a decline in many edible insect populations. Climate change will likely affect the distribution and availability of edible insects in ways that are

still relatively unknown. This publication includes case studies from several regions on the conservation strategies and semi-cultivation practices of rural people to protect insect species and their host plants. Such efforts contribute to improved habitat conservation.

ENVIRONMENTAL OPPORTUNITIES

The environmental benefits of rearing insects for food and feed are founded on the high feed conversion efficiency of insects. Crickets, for example, require only 2 kilograms of feed for every 1 kilogram of bodyweight gain. In addition, insects can be reared on organic side-streams (including human and animal waste) and can help reduce environmental contamination. Insects are reported to emit fewer greenhouse gases and less ammonia than cattle or pigs, and they require significantly less land and water than cattle rearing. Compared with mammals and birds, insects may also pose less risk of transmitting zoonotic infections to humans, livestock and wildlife, although this topic requires further research.

NUTRITION FOR HUMAN CONSUMPTION

Insects are a highly nutritious and healthy food source with high fat, protein, vitamin, fibre and mineral content. The nutritional value of edible insects is highly variable because of the wide range of edible insect species. Even within the same group of species, nutritional value may differ depending on the metamorphic stage of the insect, the habitat in which it lives, and its diet. For example, the composition of unsaturated omega-3 and six fatty acids in mealworms is comparable with that in fish (and higher than in cattle and pigs), and the protein, vitamin and mineral content of mealworms is similar to that in fish and meat.

FARMING SYSTEMS

Most edible insects are harvested in the wild. However, some insect species, such as bees and silkworms, have a long history of domestication because of the value of their products. Insects are also reared in large numbers for the purposes of biological control (e.g. as predators and parasitoids), health (e.g. maggot therapy) and pollination. The concept of farming insects for food is, however, relatively new; an example of rearing insects for human consumption in the tropics is cricket farming in the Lao People's Democratic Republic, Thailand and Viet Nam.

In temperate zones, insect farming is performed largely by family-run enterprises that rear insects such as mealworms, crickets and grasshoppers in large quantities, mainly as pets or for zoos. Some of these firms have only recently been able to commercialize insects as food and feed, and the part of their production intended for direct human consumption is still minimal.

A few industrial-scale enterprises are in various stages of start-up for rearing mass quantities of insects such as black soldier flies. They are mainly for consumption as whole insects or to be processed into meal for feed. Critical elements for successful rearing include research on biology, rearing condition control and diet formulas for the farmed insect species. Current production systems are expensive, with many patents pending. A major challenge of such industrial-scale rearing is the development of automation processes to make plants economically competitive with the production of meat (or meat-substitutes like soy) from traditional livestock or farming sources.

INSECTS AS ANIMAL FEED

Recent high demand and consequent high prices for fishmeal/soy, together with increasing aquacultural production, is pushing new research into the development of insect protein for aquaculture and poultry. Insect-based feed products could have a similar market to fishmeal and soy, which are presently the major components used in feed formulae for aquaculture and livestock. Available evidence suggests that insect-based feeds are comparable with fishmeal and soy-based feed formulae. Live and dead insects already have established niche markets, mainly as feed given to pets and at zoos.

PROCESSING

Insects are often consumed whole but can also be processed into granular or paste forms. Extracting proteins, fats, chitin, minerals and vitamins is also possible. At present, such extraction processes are too costly and will need to be further developed to render them profitable and applicable for industrial use in the food and feed sectors.

FOOD SAFETY AND PRESERVATION

The processing and storage of insects and their products should follow the same health and sanitation regulations as for any other traditional food or feed items in order to ensure food safety. Because of their biological makeup, several issues should be considered, such as microbial safety, toxicity, palatability and the presence of inorganic compounds. Specific health implications should also be considered when insects for feed are reared on waste products such as manure or slaughterhouse waste. Evidence of allergies induced through the ingestion of insects is scarce, but does exist. Some cases have been reported of allergic reactions to arthropods.

LIVELIHOOD IMPROVEMENT

Insect gathering and rearing as minilivestock at the household level or industrial scale can offer important livelihood opportunities for people in both developing and developed countries. In developing countries, some of the poorest members of society, such as women and landless dwellers in urban and rural areas, can easily become involved in the gathering, cultivation, processing and sale of insects. These activities can directly improve their own diets and provide cash income through the selling of excess production as street foods. Insects can be directly and easily collected from nature or farmed with minimal technical or capital expenditure (i.e. for basic harvesting/rearing equipment). Rearing insects may also require minimal land or market introduction efforts, as insects already form part of some local food cultures.

Protein and other nutritional deficiencies are typically more widespread in disadvantaged segments of society and during times of social conflict and natural disaster. Because of their nutritional composition, accessibility, simple rearing techniques and quick growth rates, insects can offer a cheap and efficient opportunity to counter nutritional insecurity by providing emergency food and by improving livelihoods and the quality of traditional diets among vulnerable people.

ECONOMIC DEVELOPMENT

Gathering and farming insects can offer employment and cash income, either at the household level or in larger, industrial-scale operations. In developing countries in Southern and Central Africa and Southeast Asia, where demand for edible insects exists and where it is relatively easy to bring insects to market, the process of insect gathering, rearing and processing into street foods or for sale as chicken and fish feed is easily within reach of small-scale enterprises. With only a few exceptions, international trade in insects for food is insignificant. The trade that does exist to developed countries is often driven by demand from immigrant communities or because of the development of niche markets that sell exotic foods. Border trade in edible insects is significant, mainly in Southeast Asia and Central Africa.

COMMUNICATION

The polarity of views surrounding the practice of entomophagy necessarily requires tailormade communication approaches for each of the various stakeholders. In the tropics, where entomophagy is well established, media communication strategies should promote edible insects as valuable sources of nutrition to counter the growing westernization of diets. Western societies require tailored media communication strategies and educational programmes that address the disgust factor. Influencing the public at large as well as

policymakers and investors in the food and feed sectors by providing validated information on the potential of insects as food and feed sources can help to push insects higher on political, investment and research agendas worldwide.

LEGISLATION

Regulatory frameworks governing food and feed chains have expanded tremendously in the last 20 years; however, regulations governing insects as food and feed sources are still largely absent. For developed countries, the absence of clear legislation and norms guiding the use of insects as food and feed is among the major limiting factors hindering the industrial development of farming insects to supply the food and feed sectors. In developing countries, the use of insects for human or animal food is, in practice, more tolerated then regulated. The feed sector seems to take the lead in pushing for the development of more insect-encompassing norms, while the "novel food" concept seems to be emerging as a leading instrument for setting rules and standards for the use of insects in human foods.

THE WAY FORWARD

Any effort to release the huge potential that insects offer for enhancing food security requires that the following four key bottlenecks and challenges are addressed simultaneously. First, further documentation is needed on the nutritional values of insects in order to more efficiently promote insects as healthy food. Second, the environmental impacts of harvesting and farming insects must be investigated to enable comparison with traditional farming and livestock rearing practices that may be more environmentally damaging. Third, clarification and augmentation of the socio-economic benefits that insect gathering and farming can offer is needed, in particular to enhance the food security of the poorest of society. Finally, a clear and comprehensive legal framework at (inter)national levels is needed to pave the way for more investment, leading to the full development (from the household to the industrial scale) of production and international trade in insect products as food and feed sources.