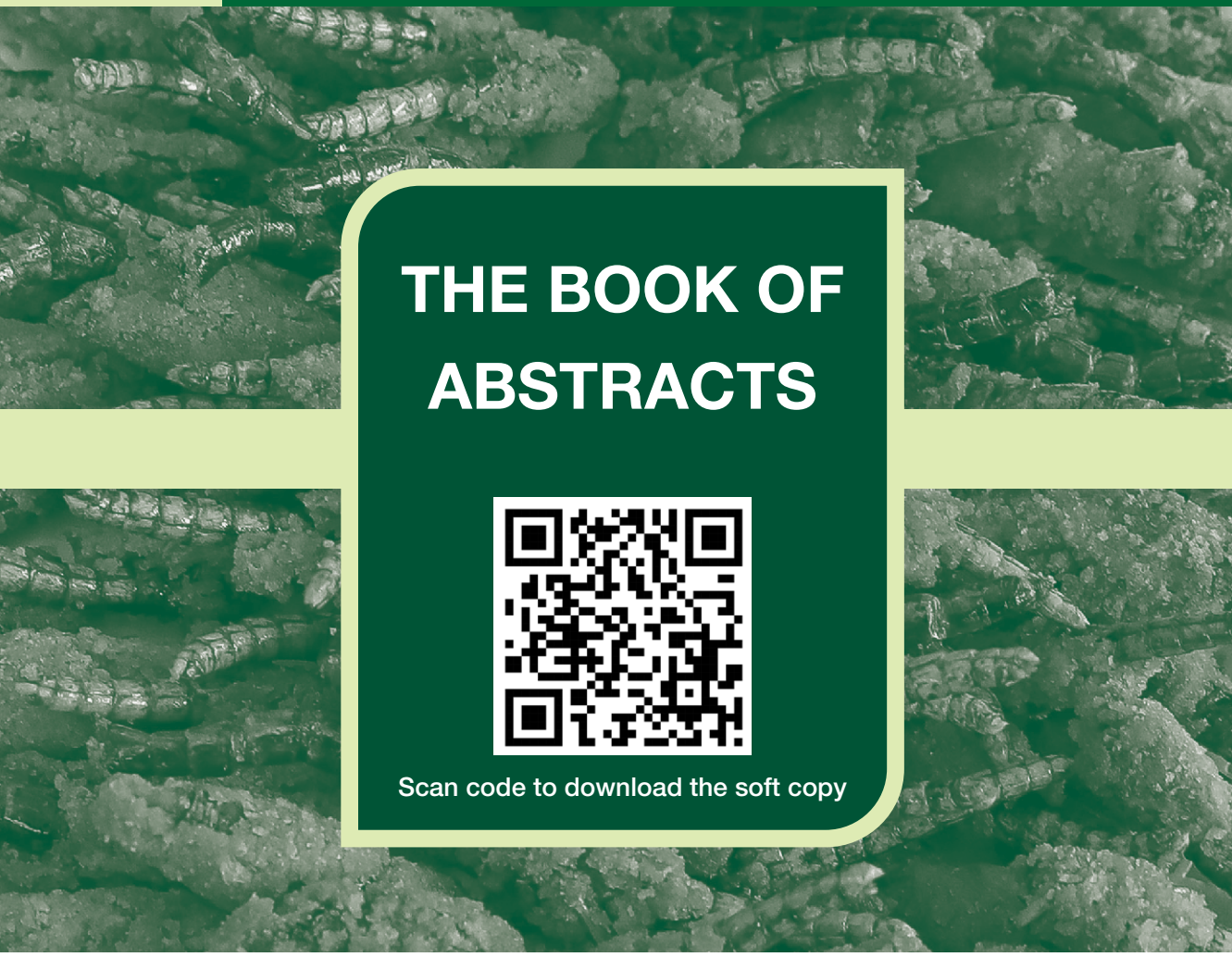
Insects for the Green Economy Conference

Theme: **Sustainable Food Systems and Livelihoods in Africa**

Date **28th – 29th February 2024**

Venue The African Institute for Capacity Development (AICAD) at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya.



THE BOOK OF ABSTRACTS

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FOREWORD

Welcome to the inaugural conference on *"Insects for the Green Economy: Sustainable Food Systems and Livelihoods in Africa,"* hosted by the African Institute for Capacity Development (AICAD) at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya.

As we convene amidst the challenges of climate change, population growth, conflicts, and economic instability, it is crucial to explore innovative, nature-based solutions to address food insecurity across the African continent.

Insects, long overlooked as a valuable resource, are now emerging as a novel livestock in our food systems. With over 500 species contributing significantly to food and nutrition security in Africa, the potential for leveraging insects in sustainable practices is immense. This conference aims to explore how edible insects can *transform our food systems*, emphasizing both the *opportunities* and *challenges* unique to Africa.

Through presentations, discussions, and stakeholder interactions, we will explore the latest research and innovations driving the insect sector forward. From understanding the biology and ecology of relevant species to exploring production systems, applications in food and non-food sectors, and the social and economic contexts surrounding insect utilization, this conference will provide a comprehensive overview of the potential of insects in enhancing food and nutrition security, promoting environmental sustainability, and driving economic growth.

We are honored to have esteemed speakers, researchers, policymakers, entrepreneurs, and stakeholders joining us in this endeavor. Together, let us unlock the potential of insects to create a more resilient and prosperous future for Africa. Welcome to the conversation!

Shaphan Y. Chia

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KEYNOTE LECTURES

KEYNOTE LECTURE 1

Generate knowledge and learning of insect farming for human food and animal feed for increased food security in Sub-Saharan Africa

Dorte Verner
Agriculture and Food, Sustainable Development, The World Bank, Washington DC,
With Line Astrom, UNHCR, Geneva, and teams from Zimbabwe, Malawi, South Sudan, and Kenya.
USA.Dverner@Worldbank.org

The objective is to generate knowledge and learning of insect farming for human food and animal feed for increased food security in Sub-Saharan Africa. The sub-objectives are to: (i) develop approaches to training trainers and farmers and implement pilots aimed at learning about the potential of using farmed insects for food and feed to increase food security by applying a circular economy food production concept, (ii) help to further define Bank activity in the circular economy, (iii) helping to sustainably intensify resilience building through livelihood and jobs for refugees and host community members, (iv) low-carbon and climate-smart insect protein production, processing, and commercialization in Africa, (v) reducing greenhouse gas emission. The task would generate knowledge on insect-based protein production and processing through piloting in Zimbabwe, Malawi, South Sudan, and Kenya. It aims to shed light on the potential to increase local capacity for insect food and feed production and inform World Bank lending. The task provides practical technological solutions to increase food security, jobs, and livelihoods. This task is based on a circular food economy model where organic waste from crops, households, and restaurants feeds insects, which feed people/animals, and the insect manure serves as biofertilizers for crop production - a full circular food economy model. These techniques are more environmentally friendly than most conventional food production systems with a negligible carbon footprint, require no chemicals, and cause no harmful land-use changes or biodiversity loss. The intermediate outcomes include: (i) increased knowledge of insect production for nutritious human food and animal feed and its applicability as a space-saving, food security strengthening measure in urban rural areas, including refugee settlements in Africa; (ii) approaches to training trainers and beneficiaries, focused on women and youth; and (iii) approaches to insect farming pilots that also serve as demonstration sites in Africa.

Keywords: insect farming, food security, livelihoods, refugees, Africa

KEYNOTE LECTURE 2

Prospects of implementing black soldier fly (BSF) selective breeding in Kenya and Uganda: Status from the FlyGene Project

Grum Gebreyesus[1*], Rawlynce Bett[2], Dorothy Nakimbugwe[3], Laura Skrubbeltrang Hansen[1], Hanne Marie Nielsen[1], Henrik Karstoft[1], Kim Bjerge[1], Catherine Kunyanga[2], Chrysantus Tanga[4], Cosmas Mwikirize[3], Roseline Akol[3], Andrew Katumba[3], Fathiya Khamis[4], Johnson Kinyua[5], Sadhat Walusimbi[3], Ssepuuya Geoffrey[6], Nanna Roos[7] and Goutam Sahana[1]

[1]Aarhus University, Aarhus, Denmark
[2]University of Nairobi, Nairobi, Kenya
[3]Makerere University, Kampala, Uganda
[4]International Center for Insect Ecology and Physiology, Nairobi, Kenya
[5]Jomo Kenyata University of Agriculture and technology, Nairobi, Kenya
[6]Kyambogo University, Kampala, Uganda
[7]University of Copenhagen, Copenhagen, Denmark
*grum.gebreyesus@qgg.au.dk

The demand for sustainable and efficient livestock feed production has led to increased interest in insect farming, particularly the black soldier fly (BSF). However, little has been done to improve the quantity and quality of BSF products through selective breeding, despite the potential for significant impact due to the short generation interval and high reproduction rate of insects. The FlyGene project, supported by the Danish Ministry of Foreign Affairs, aims to address the challenges hampering implementation of selective breeding in BSF through research-led knowledge generation and capacity building. The project's objectives include identifying and prioritizing economically important BSF traits in smallholder and commercial production systems in Kenya and Uganda, developing innovative large-scale phenotyping systems using computer-vision approaches, and designing BSF breeding programs with a strategic emphasis on large-scale producers and smallholder farms. The project also aims to develop genomic tools for genetic marker-based monitoring of BSF genetic diversity and pedigree tracing. Significant progress has been achieved, including conducting large-scale surveys in Kenya and Uganda to characterize BSF production systems and identify trait preferences. It has also developed novel computer-vision-based approaches with promising results in phenotyping BSF for larval body traits and sex identification. Additionally, the project anticipates a whole-genome sequence-based study to unveil the genetic diversity of the BSF population in Kenya and Uganda, based on wild and captive BSF sampled from various regions in the two countries. Protocols have been developed for the pilot implementation of mass selection in private-sector partners. Furthermore, two national workshops were organized to bring together stakeholders across the BSF value chain in Kenya and Uganda, facilitating collaboration and knowledge sharing while ensuring the project's outcomes are relevant to the needs of stakeholders. To realize its far-reaching objectives of capacity building, the project has enrolled 4 PhD and 1 MSc students. With multi-disciplinary and multi-sector collaboration the FlyGene project exemplifies a strategic and impactful endeavor poised to revolutionize the landscape of insect rearing and sustainable feed production in Kenya and Uganda.

KEYNOTE LECTURE 3

Investigating pathways to accelerate insect farming and consumption for health and livelihoods in Africa: The HEALTHYNSECT Project

Nanna Roos[1]* on behalf of the HEALTHYNSECT consortium[2]
[1]Dept Nutrition, Exercise and Sports (NEXS), University of Copenhagen, Denmark.
[2]University of Energy and Natural Resources (UENR), Ghana; Makerere University (MAK), Uganda; Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Kenya; Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya; Masinde Muliro University of Science and Technology (MMUST), Kenya; *icipe*, Kenya; Dept Food Resource Economics (IFRO), Dept Plant and Environmental Sciences (PLEN), University of Copenhagen, Denmark.
*nro@nexs.ku.dk

Insect farming in Africa is novel, complementary to the historical supply of wild insects for consumption in many cultures across the continent. Farming insects can secure stable, sustainable and safe supplies of nutrient-dense animal protein beneficial to prevent child malnutrition. Through efficient production and by developing value chains, insect farming can sustain novel pathways to improved nutrition, health and livelihoods. Despite these promises and a decade of efforts, the intensity of insect farming for food remains modest or low. The objective of HEALTHYNSECT project is to investigate drivers for accelerating insect farming and consumption in Africa. The consortium gathers universities in Kenya, Uganda and Ghana. Based on a framework for incentivizing insect farming and consumption, a multisite randomized controlled trial (RCT) across the tree countries is being implemented for assessment of the willingness among farmers to practice insect farming and consumption. Three small-scale farming systems are introduced in randomized selected villages (cricket in Kenya; grasshopper (*Ruspolia*) in Uganda; and palm weevil larvae in Ghana). In parallel, insect-based food on infant nutritional status and gut health is assessed. HEALTHYNSECT support research capacity building through the training of 5 PhD students. The project is supported by Ministry of Foreign Affairs (Danida), Denmark.

Keywords: small-scale farming, farmers adoption, capacity building

KEYNOTE LECTURE 4

From field to fork: edible insect product development and commercialization in Thailand

Yupa Hanboonsong
Entomology Department, Khon Kaen University, Thailand
yupa_han@kku.ac.th

Thailand is a pioneer in insects farming. It accounts for 15 percent of world production or one-third of insect production in the Asia-Pacific region and is a world leader in cricket farming. This activity started from wild collecting and longtime local traditional eating habit in the Northeast region. Farming crickets saw a rapid development during the first decade of the 2000s. The industry is quite mature with both small-scale farms and industrial scale enterprises. Currently, there are 2 forms of processing cricket products: 1) prepared as part of food "Top Up", e.g. fried, roasted, grilled, baked, canned etc. and 2) used as an "Add On" by processing it into powder and use as component of foods such as bakery goods or drinks. Crickets as human food despite many nutritious advantages and being environmentally friendly occupy a very small niche but suffer from lack of demand, overproduction, high cost of feed and production and basic insect products, resulting in relatively low income and the market concentrated in a narrow circle. The future of the industry depends largely on the creativity of entrepreneurs for more added value products. In contrast, black soldier fly (BSF) farming began with not knowing or being familiar with the insect but now, after less than 10 years, it is a promising industry. Despite the farming conditions still being optimized, many farmers have embraced the industry. Currently, BSF farming is rapidly expanding and used by smallholder farmers for feeding livestock and crickets. Moreover, BSF startup companies emerged in the business of processing and production of BSF products for pet food and plant fertilizer. Research is also ongoing to reveal the many benefits of BSF from which added value products might be developed. These include antimicrobial peptides, novel probiotics, lipids with unique properties for skin care and BSF proteins with functional properties as ingredients for human health benefit. The environmental benefits of these insects can also be exploited for income generation.

KEYNOTE LECTURE 5

The global atlas of edible insects: analysis of diversity and commonality contributing to food systems and sustainability

Evanson R. Omuse[1] & **Saliou Niassy**[2*]

[1]International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
[2]African Union Inter-African Phytosanitary Council (AU-IAPSC), P.O Box 4170, Yaoundé – Cameroon
*NiassyS@africa-union.org

The future of the food system on the planet is increasingly facing uncertainties that are attributable to population growth and a surge in demand for nutritious and sustainable foods. Traditional agricultural practices are poised to exert strain on production, as well as natural resources and ecosystem services, particularly under a changing climate. Given their remarkable attributes, including a low environmental footprint, high food conversion ratio, rapid growth and nutritional values, edible insects can play a vital role in the global food system. Nonetheless, substantial knowledge gaps persist regarding their diversity, global distribution, and shared characteristics across regions, potentially impeding effective scaling and access to edible insects. Therefore, we compiled and analysed the fragmented database on edible insects and identified potential drivers that elucidate insect consumption, globally, focusing on promoting a sustainable food system. We collated data from various sources and performed a series of analytics at the country, regional and continental levels. Our study revealed over 2,200 insect species, consumed across 128 countries globally. Among continents, Asia has the highest number of edible insects, followed by North America (mainly Mexico) and Africa. The countries with the highest consumption of insects are Mexico, Thailand, India, DRC, China, Brazil, Japan, and Cameroon. Our study also revealed some common and specific practices related to edible insect access and utilisation among countries and regions. Although insect consumption is often rooted in cultural practices, it exhibits correlations with land cover, the geographical presence of potentially edible insects, the size of a country's population, and income levels. The practice of eating insects is linked to the culture of people in Africa, Asia, and Latin America, while increased consciousness and the need for food sustainability are driving most of the European countries to evaluate eating insects. Therefore, more proactive efforts are required to promote them for their effective contribution to achieving sustainable food production.

Key words: edible insects, culture, food system, world, conservation

Insect species – Biology and Ecology

1.0

Unraveling genetic diversity and population structure of black soldier fly (*Hermetia illucens*) in Kenya and Uganda

Peter Muchina[1,2*], Johnson Kinyua[1], Fathiya Khamis[2], Chrysantus M. Tanga[2], Zexi Cai[3], Grum Gebreyesus[3], Goutam Sahana[3]

[1]Jomo Kenyatta University of Agriculture and Technology (JKUAT)
[2]International Center of Insect Physiology and Ecology (*icipe*)
[3]Aarhus University (AU)
*kimanimuchina@gmail.com

Livestock and fish production in Africa face challenges due to rising feed costs, especially protein ingredients like fishmeal and soybean meal. *Hermetia illucens* L., the Black Soldier Fly (BSF), is an emerging alternative to conventional protein additives in feeds. These insects also contribute to the circular economy via the bioconversion of organic waste into valuable protein biomass and frass fertilizer. Despite the potential benefits, the limited knowledge of the genetic diversity of the wild and mass reared BSF populations in Africa raises concerns about their long-term sustainability. To address this gap, our study investigates the genetic diversity and population structure of BSF populations in Kenya and Uganda. Samples were collected from three agroecological zones in each country, targeting wild and captive BSF populations (n=30 per site). In Kenya, samples were collected from the central, western, and coastal regions, while in Uganda, samples were collected from the central, western, eastern, and northern regions. Additionally, 30 individuals were collected from various commercial partner farms in the two countries. 300 samples were available for DNA extraction and subsequent whole genome sequencing (WGS) and analysis. The single nucleotide polymorphism (SNP) variants called from the WGS data will be used to investigate the genetic diversity and determine the population structure and evolutionary relationships between and within the BSF populations. The nucleotide diversity (π), Tajima's D, the genetic differentiation (FST), the observed heterozygosity (HO), expected heterozygosity (HE), and the inbreeding coefficient (FIS) will be used to investigate the genetic diversity. Principal component analysis (PCA) and admixture analysis will infer the population structure, while the neighbor Joining (NJ) tree will infer the evolutionary relationships. This study will reveal the genetic basis of ongoing domestication and the genomic disparity between the captive and wild individuals. The findings will guide colony management, selective breeding programs, and genetic improvement, ensuring the continued growth and sustainability of BSF farming in Kenya and Uganda. This research contributes to a more sustainable agricultural future in Africa.

Keywords: black soldier fly, genetic diversity, population structure, whole genome sequencing, single nucleotide polymorphisms

2.0

Selective breeding in commercial insects with a house fly model system

Laura Skrubbeltrang Hansen[1*], Stine Frey Laursen[2], Simon Bahrndorff[2], Morten Kargo[1], Jesper Givskov Sørensen[1], Goutam Sahana[1], Hanne Marie Nielsen[1] and Torsten Nygaard Kristensen[2]

[1]Aarhus University, Aarhus, Denmark
[2]Aalborg University, Aalborg, Denmark
*lsh@qgg.au.dk

The rapid expansion of the human population combined with the concerning environmental consequences of resource-intensive agriculture has sparked the interest for alternative protein production from insects. Selective breeding has the potential to optimise insect production through genetic improvement of key traits in commercial insect species, but despite many ongoing efforts, several challenges and questions remain to be solved. We utilise a house fly laboratory model system to reveal and address challenges encountered when implementing selective breeding in commercial insect populations. The research is organised into distinct parts, each addressing a specific aspect of insect breeding such as high-throughput phenotyping, genetic parameter estimation, possibilities and limitations of different breeding plan designs, inbreeding risk and management and, ultimately, the design and implementation of a breeding plan in a house fly population. We present methods that increases throughput of the phenotyping process allowing for rapid acquisition of accurate phenotypic records in house fly larvae, enabling fast selection decisions. We establish a population with known genetic relationship, to unveil important sources of phenotypic variance in larval and adult traits in the house fly, both of biological and environmental origin, and utilise these results to design an optimal insect breeding plan. We demonstrate how selective breeding can be implemented in species with high fecundity and rapid development, such as dipterans, without keeping track of and isolating single individuals. These advances bring us closer to established insect breeding practises which could be an important stride towards advancing sustainable agriculture and ensuring global food security in the future.

Key words: housefly, selection, phenotyping, breeding, genetics

3.0

Study into *Hermetia illucens* behaviour in large artificial mating chambers and possible optimizations.

S.P. **Salari***, M.L. de Goede[1]

InsectoCycle, Bronland 10, 6708 WH Wageningen, the Netherlands
*seppe.salari@insectocycle.nl

InsectoCycle has been researching black soldier fly (BSF) reproduction for four years, focusing on adult fly behaviour as a pivotal factor in efficient mating. Recent studies in the field of entomology have shed the first light on numerous aspects of fly mating behaviour, yet many elements remain unknown. Our team has delved into understanding the nuances of the mating dance, rheotaxis, climatic preferences of adult flies at various stages and other behavioural patterns. We performed repeated observations in two-choice experiments to understand the preference for certain conditions. Our research has explored the influence of airflows and their velocities, the segregation of clean and contaminated air, and the strategic placement of additional wall areas to facilitate natural fly behaviours. This pursuit has led to innovative modifications in our mating chambers in which we directed the airflow to come from the top and created two different zones. One with cleaner air for mating and one for stimulating egg laying by providing an attractant. This presentation will offer a comprehensive overview of our observations for optimizing fly behaviour in artificial mating environments, marking a significant stride in the field of insect reproduction.

Keywords: black soldier fly, reproduction, mating.

4.0

Morphological description of Dirhinus sp., a parasitoid of black soldier fly (*Hermetia illucens*) pupae at Bondo, Western Kenya)

Bleu Gondo Douan[1]*, Evans M. Nyakeri[2], Collins K. Mweresa[2] Monica A. Ayieko[3]

[1]Peleforo gon Coulibaly University, Department of Animal Biology, Korhogo, Côte d'Ivoire.
[2]Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Department of Biological Sciences, Bondo, Kenya
[3]Jaramogi Oginga Odinga University of Science and Technology (JOOUST), School of Agricultural and Food Sciences, Africa Center of Excellence in Sustainable Use of Insects as Food and Feeds (INSEFOODS), Bondo, Kenya
* douanbleu@upgc.edu.ci / dgondo7@yahoo.fr

The farming of the black soldier fly as a feed insect is on an increasing trend in Kenya. However the enterprise is now under threat from parasitoids. The objectives of the current work are to create awareness on a recently described wasp parasitoid discovered within the Jaramogi Oginga Odinga University black Soldier fly farm in Bondo; and highlight possible mitigation management strategies. The parasitoid was isolated and characterized using a binocular microscope to measure body length without antennae, antenna length, forewing length, head capsule width, thorax width, and abdomen width. Results indicated that the body length without antennae was 5.15 mm, body length with antennae was 7.97 mm, antenna length was 1.5 mm, forewing length 2.81 mm while the widths of the head capsule, thorax, and abdomen were 1mm each. The parasitoid was subsequently identified by use of dichotomous keys to belong to order Hymenoptera, family Chalcididae, and Genus Dirhinus. The study recommends further characterization of the parasitoid to species level by molecular techniques and use of suggested sustainable management methods to contain the parasitoid menace within BSF farms.

Key Words: insect rearing, black soldier fly

5.0

Effect of communication towers on the performance and behavior of *Apis mellifera L*. (Hymenoptera: Apidae) (the external activity) in Baghdad, Iraq

Alaa Alnaimee[1*], Faiza Salah[2*], Safeldawla Abdallad[2] and Kamila Shaher[1]

[1]Faculty of Agriculture University of Baghdad, Irag
[2]faculty of Agricultural Sciences University of Gezira, Sudan
***** faizaruba2@gmail.com

Beekeeping of honey bee, *Apis mellifera* and the multiplication of this insect is one of the most important branches of agricultural investments. Many factors affect their activities, one of them is electromagnetic radiation. The aim of this study was to investigate the effect of the radiation emitted by communication towers on the behavior of honey bee communities externally. The experiments were conducted in the apiaries of the College of Agricultural Sciences and Engineering in Al-Jadriyah area. The first location was 500 meters, the second location was 150 meters from the telecommunication tower and the third transaction was placed directly under the tower. The height of the tower was 30m and the amount of radiation emitted from it was 925 MHZ. The results of the external activity of the foraging workers recorded the first treatment as highest average followed by the second treatment at an average while the third treatment recorded the lowest average for the foraging bees. The triple overlap between the site, the time and date recorded the second treatment as the highest rate for evening time, followed by the first treatment in the morning. While the third treatment recorded the lowest average for the foraging bees. The activity of collecting pollen was highest in the second treatment, followed by the first treatment. The lowest rate of collection was recorded in the third treatment. The triple overlap between the site, time and date showed significant differences between treatments. The total activity of bee nectar or water collection recorded the highest activity rate in the first treatment, followed by the second treatment and the lowest activity in the third treatment. The triple overlap between the site, the time and date recorded the first transaction on the date of 9/5 pm the highest rate, followed by the second treatment for the morning time on the same date. The lowest rate for the preparation of the workers of the whole nectar or water was recorded in the third treatment for morning. The effect of the radiation emitted by the tower on the ability of bees in the metabolism showed no significant differences between the rates (wet weight, dry weight, protein ratio, fat percentage). The results of the analysis showed significant differences in carbohydrate levels and the ash content). At the end of the experiments, the total weight of honey was calculated for all the cells according to their location. The treatment at the distance of 500 m gave 8 kg for the treatment, while the lowest was in the treatment under the tower (6.99) kg. It could be concluded that communication towers have negative effect on the activities of *Apis mellifera.*

Insect Production Systems

6.0

Insect pathogens and other unwanted organisms in insect production

Jørgen Eilenberg

Department of Plant and Environmental Sciences, University of Copenhagen
Thorvaldsensvej 40, 1871 Frb. C., Denmark
jei@plen.ku.dk

Insect production is subject to challenges because of the presence of unwanted other organisms. Such organisms may directly or indirectly affect the insects in production. Insect pathogens (virus, bacteria, fungi, gregarines, microsporidia, and nematodes) may cause higher mortality or reduce the fitness of the insects. A major issue is to detect the presence of such organisms early to prevent losses in the production. There are other types of unwanted microorganisms occurring in/on the insects, on the substrate for the insects or at other places in the production system. It is important to distinguish between different microorganisms and evaluate the role of these: is it an obligate insect pathogen? is it a facultative insect pathogen? is it a saprotroph? is it of importance for food safety or occupational health? Some of these questions can be addressed initially by careful observation and monitoring in the production units, while specific expertise is often needed to get precise information. The knowledge basis of insect pathogens and other unwanted microorganisms in insect production systems is still in its infancy, so it is urgent that a strong collaboration between insect producers, scientists, food authorities and others is developed. Training courses are essential. In my talk, I will show examples of some of the different organisms and provide advice about diagnostics, monitoring, and management.

7.0

First account of smallholder farmers' experiences in rearing edible grasshopper, *Ruspolia differens* (Serville) (Orthoptera: Tettigoniidae), in Uganda

Nyeko P[1*], Acur A[1] and Malinga GM[1,2]

[1]Department of Forestry, Biodiversity and Tourism, Makerere University, P.O. Box 7062, Kampala, Uganda
[2]Department of Biology, Gulu University, P.O. Box 166, Gulu, Uganda
*pnnyekop@gmail.com or philip.Nyeko@mak.ac.ug

The edible grasshopper, *Ruspolia differens* (Serville), is a popular and highly nutritious insect in east Africa that has the potential to improve food and nutritional security, as well as employment and income opportunities. However, the sole reliance on already low and inconsistent supply of the insect from wild populations is a major drawback to the full realization of this potential. Recently, some protocols for rearing *R. differens* have been developed under laboratory conditions; however, no evaluation of these protocols under smallholder farmers' conditions and management has been done. In an ongoing intervention study to identify and quantify the pathways for enhancing the adoption of insect farming and consumption, we provided *R. differens* production starter kits to 1,024 smallholder farmers: 16 farmers selected from each of 64 villages in Mityana district, Uganda. Here we present experiences of 320 farmers who had kept the insect through periods sufficient for two production cycles. None of the farmers had hitherto attempted rearing the species, let alone knowing its eggs and nymphs. Before the starter kits were delivered, the farmers received trainings on proper rearing techniques. Our preliminary findings indicate that the majority of farmers were able to implement the rearing protocols, but they still need some kick-off on-the-spot guidance. Although most farmers were able to hatch *R. differens* eggs they were given, comparatively few were able to raise their insects to adulthood and through the second cycle of production. A few farmers cited some challenges, including difficulty in moistening egg laying and hatching media, long duration for germinating finger millet feed, and insecticide pollution arising from neighboring gardens. Overall, farmers were excited and eager to expand their *R. differens* production. Our findings indicate a very high potential for adoption of *R. differens* rearing practices by smallholder farmers, but they need to be supported to improve their skills in implementing the rearing protocols.

Keywords: adoption, edible insects, farmer knowledge, mass rearing

8.0

Effects of supplementing agricultural by-product diets on growth and reproductive parameters of the edible grasshopper, *Ruspolia differens*

Acur A[1*], Malinga G. M[1,2] and P Nyeko[1]

[1]Department of Forestry, Biodiversity and Tourism, Makerere University, P.O. Box 7062, Kampala, Uganda
[2]Department of Biology, Gulu University, P.O. Box 166, Gulu, Uganda
*amosacur4@gmail.com

The edible grasshopper, *Ruspolia differens* (Orthoptera: Tettigoniidae) is a delicacy and a source of livelihood for many people in East Africa. Recent studies have demonstrated that it can be successfully reared on germinated finger millet diet. However, long-term mass production on such feeds would be costly. One of the possibilities to lower the production cost is mixing germinated finger millet with locally accessible agricultural by-products. We experimentally evaluated the effect of blending three agricultural by-product diets, dry maize cob, soybean hull meal, and local brew waste with 25 %, 50 %, or 75 % of germinated finger millet by mass on *R. differens* survival, development time, adult fresh weight, and reproductive performance. A total of 390 *R. differens* were individually reared on each of the diet treatments, including germinated finger millet as control, till death. Data was analysed using a generalised linear model and one-way analysis of variance. Performance on a dry maize cob diet supplemented with 75 %, 50 %, and 25 % germinated finger millet was significantly higher than it was on germinated finger millet. Soybean hull meal recorded the lowest performance at all diet supplementation levels. A dry maize cob diet supplemented with 50 % germinated finger millet supplement recorded the shortest pre-oviposition period (10 days) and registered the highest egg hatchability (83 %). The highest adult longevity was recorded on a local brew waste diet supplemented with a 50 % germinated finger millet supplement. Among the tested diets, the dry maize cob diet with 50% germinated finger millet emerged as the most favorable, showing enhanced growth, reproduction, and adult longevity performances.

Keywords: diet, edible insects, mass rearing, performance

9.0

Computer-vision based prediction of body traits and larval sex in black soldier fly

Sarah Nawoya [1,2*], Quentin Geissmann[1], Henrik Karstoft[3], Kim Bjerge[3], Roseline Akol[2], Andrew Katumba[2], Cosmas Mwikirize[2], Grum Gebreyesus[1]

[1] *Center for Quantitative Genetics and Genomics, Aarhus University, C.F Møllers Alle 3, Denmark*
[2]*Department of Electrical and computer Engineering, Makerere University, Uganda*
[3]*Department of Electrical and Computer Engineering, Aarhus University, Denmark*
*snawoya@gmail.com

The growing interest for insect farming as a sustainable protein alternative has given rise to the commercial production of key species like the Black Soldier Fly (BSF), primarily for use in livestock and pet nutrition. Despite the heightened interest in BSF production, there is a need for increased efficiency, particularly in the context of large-scale measurement of various traits for selective breeding as well as management optimization. The unique production system of insects, coupled with the challenges posed by their small size, fragility and metamorphic life cycle underscores the necessity for innovative approaches to streamline production. This study explores the potential of computer vision (CV) in predicting the larval sex and body traits of BSF, offering a non-invasive, rapid, and automated method for trait measurement. The study explores various algorithms, including YOLO, ResNet, and SVM, covering detection, segmentation, classification, and regression tasks. We assess the ability of our models to predict larval weight from images through both feature extraction-based prediction as well as image-regression approaches. A notable aspect of this study is the pioneering effort to predict the sex of BSF larvae through CV and deep learning techniques, which is a cryptic trait. In our analysis of larval weight prediction, we achieved a substantial correlation coefficient of 0.9 between measured and predicted weight using the feature-based approach, along with a commendable coefficient of 0.88 through the image regression approach. Additionally, the sex prediction module demonstrated an F1 score of 0.75 and a prediction accuracy of 74% on validation data. These results underscore the feasibility of leveraging CV techniques for predicting body traits of BSF larvae, representing a significant advancement towards the automation of selective breeding in the context of insect farming. The work presented is supported by the FlyGene project which received funding from the Ministry of Foreign affairs of Denmark under grant 21-09-AU.

Keywords: computer-vision, black-soldier-fly, selective-breeding, automated-phenotyping, deep-learning

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Influence of compound diets on the growth, nutrient composition, and feed conversion rates of the yellow mealworm (*Tenebrio molitor* Linnaeus)

Ssepuuya Geoffrey[1,2], Andrew Kabuye[1], Catherine Ndagire Tamale[1,3], Chrysantus Tanga[4] **Dorothy Nakimbugwe[1*]**

[1]*Makerere University, Kampala, Uganda*
[2]*Kyambogo University, Kampala, Uganda*
[3]*Mountains of the Moon University, Uganda*
[4]*International Center for Insect Ecology and Physiology, Nairobi, Kenya*
*dnakimbugwe@gmail.com

Mealworm, the larvae of *Tenebrio molitor* Linnaeus is one of the most promising insects for food because of its ability to feed on diverse substrates. This study aims to establish the influence of compound diets on mealworm growth, nutrient composition, and feed conversion rates. In triplicate, 5 g of 35-day-old mealworms were provided with 400 g of each of the two compound diets, i.e., the fish meal protein-based diet (FMD) and the black soldier fly larvae protein-based diet (BSFLD); and the control (maize bran) diet (MBD). About 15 g of carrot were provided weekly as a source of water. Weekly individual mealworm weight was obtained by averaging the weight of 50 mealworms until pupation. Feed conversion ratio (FCR) was obtained as a ratio of the total weight of feed consumed to the total weight gained by the mealworms (kg feed / kg of mealworm). The final weight of mealworms raised on FMD (123.8 ± 16.9 mg) and BSFLD (115.0 ± 17.3 mg) weren't significantly different while MBD produced mealworms with the least final weight (100.4 ± 16.8 g). The protein content of mealworm larvae raised on FMD (47.7 ± 1.3 g) was significantly higher than that of mealworms raised on BSFLD (44.4 ± 0.33 g) and MBD (41.3 ± 2.6 g). Diet also significantly affected the mealworm fat and fibre content. Diet didn't have an influence on ash and dry matter content of the mealworms. MBD had a high FCR (2.4 ± 0.2) compared to BSFLD (2.3 ± 0.2) and FMD (2.0 ± 0.4). Information on the effect of diet on growth, nutrient profiles (amino acid, fatty acid and mineral), and economic returns is required to decide on the most suitable rearing feed.

Key words: mealworm, compound feed, growth, nutrient composition, feed conversion

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Rhynchophorus phoenicis Fabricius (Coleoptera: Curculionidae) production: a comparative study of different farming protocols

S.K. Debrah[1*], S. Asomah[1] and J.P. Anankware[1]

[1]Department of Horticulture and Crop Production, School of Agriculture and Technology, University of Energy and Natural Resources, P.O. Box 214, Sunyani-Ghana
*shadrackdebrah@gmail.com

The traditional method of sourcing and semi domesticating of *Rhynchophorus phoenicis* larvae still persists among the inhabitants in Africa. However, the traditional methods disrupt ecosystem functions whiles semi-domestication produces a small proportion of market demands of the larvae in Africa. Containerised system of producing larvae has been found to facilitate the production for socio-economic purposes; thereby contributing to conservation and a sustainable utilisation of the *R. phoenicis* larvae. The life history parameters of *R. phoenicis* were evaluated on three farming protocols that incorporate affordable and available agricultural by-products for production. Larval survival recorded on protocol three was the highest, followed by protocol one and two. Larval mean weight was significantly ($P < 0.05$) different among the protocols with protocol one and three recording a mean weight above 5 g. The *r*m value of *R. phoenicis* reared on protocol two (0.068) was the highest compared to the others. The *Ro* value of *R. phoenicis* reared on protocol two was the highest compared to the others. The mean generational time (*T*) value ranged from 65 to 92 with protocol two recording the lowest. The study suggests that protocol two was the viable rearing technology to facilitate an all-year-round production of *R. phoenicis*.

Keywords: protocol, feed, *Rhynchophorus phoenicis,* farming

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Enhancing attraction and aggregation of desert locusts for efficient harvesting: push-pull approach

Joseph Odhiambo Aguk[1*], Collins Kalwale Mweresa[2], and Monica Awuor Ayieko[1]

[1] School of Agriculture and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, P.O Box 210,40601 Bondo, Kenya;
[2] School of Biological and Physical Sciences, Jaramogi Oginga Odinga University of Science and Technology, P.O Box 210,40601 Bondo, Kenya;
*josephaguk@gmail.com

Despite desert locust being a threat to food security during outbreaks, it is a nutrient rich delicacy in Africa and Asia. This has prompted communities in these two continents to harvest this insect during outbreaks. However, the harvesting methods utilized are traditional and inefficient thus the need to explore more efficient and convenient harvesting techniques. This study investigated preferential selection and feeding behavior of desert locust to identify trap plants that can attract and aggregate them for easy harvesting. At the same time, the efficacy of repellent plants against desert locust was also examined. Four trap plants (cowpea, finger millet, sorghum, and amaranth) and four repellent plants (neem, pencil cactus, garlic, and cayenne red pepper) were assessed through multiple-choice experiments involving mature adults, immature adults, and hopper stages of desert locusts in a randomized complete block design. Cowpea emerged as the most preferred trap plant followed by Finger millet, sorghum and amaranth by the three locust stages. On the other hand, neem exhibited the most potent repellent effect followed by pencil cactus, garlic and cayenne red pepper towards the three locust stages. When neem and cowpea were planted on the same pot to showcase a push-pull system, locust infestation and damage to cowpea was reduced significantly compared to when the plants were grown separately. The push-pull approach attracted 3.7%, 24.3%, and 7.8% of mature adult, immature adult, and hopper locust stages, respectively. However, when cowpea was grown separately from neem, it attracted large numbers of locusts (96.3% mature adults, 75.7% immature adults, and 92.2% hoppers that responded). These findings offer valuable insights into exploiting trap and repellent plants to enhance the aggregation and harvesting of desert locusts for use as food and feed and as eco-friendly pest management strategy.

Key Words: trap plants, repellent plants, multiple choice experiment, push-pull

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Characterization of black soldier fly production systems and traits preferences in Kenya

Rawlynce Bett[1*], Grum Gebreyesus[2], Annastacia Maweu[1,3], Catherine Kunyanga[1], Nuna Abigael[1], Tare Philip[1], Ssepuuya Geoffrey[4], Chrysantus Tanga[5] and Goutam Sahana[2]

[1]*University of Nairobi, Nairobi, Kenya*
[2]*Aarhus University, Aarhus, Denmark*
[3]*Kenya Agricultural and livestock Research Organization (KALRO)*
[4]*Kyambogo University, Kampala, Uganda*
[5]*International Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya*
*rawlynce@uonbi.ac.ke

The purpose of this study was to characterize Black Soldier Fly (BSF) production systems and identify the traits prioritized by BSF farmers. A survey was conducted using questionnaires on 54 respondents from selected farms in Kenya. The variables examined consisted of the socio-economic information of the farmers, BSF production and post-harvest handling, marketing, trait preferences, and farming constraints. The findings revealed that a significant proportion of farmers that keep BSF are in the middle age category (48.15%) and have tertiary education (62.96%). Additionally, most farmers involved in BSF farming were males (72.22%) with 1-2 years of experience. Farmers cited many reasons for keeping BSF, which included using it as animal feed (79.63%), earning income from the sale of fertilizer (frass) and utilizing organic waste on the farm (64.81%), producing organic fertilizer for the farm (59.26%), and selling breeding stock (57.41%). The farmers obtained their initial BSF breeding stock from other farmers (53.70%), institutions (24.93%), and the wild (1.85%). BSF operations were primarily conducted in screen houses, with a strong preference for vertical raising systems. The use of off-farm substrate (market waste) for raising larvae is a common practice among farmers. It is preferred due to its accessibility and ability to provide better yields. The optimal substrate was finely shredded and fed to larvae in plastic basins. The depletion of food in containers determined the frequency of feeding. Three weeks after inoculation, farmers typically harvest the larvae using a sieve and basin. Farmers who choose to store larvae typically opt for a dry form with minimal packaging. Most farmers (70.38%) choose not to sell BSF products, either in person or online, because of the changing needs of the market and the absence of a well-established customer base. Farmers proposed enhancing partnerships to address these challenges. The most preferred traits by farmers are the number/volume of eggs laid, the proportion of eggs laid that hatch, and the growth and size/length of the larvae. High protein content was preferred for larvae, while the importance of fat content was relatively lower. The emphasis on the importance of BSF's ability to adapt to different climatic conditions was evident, with temperature and humidity variations identified as key factors. In addition, the prolonged longevity of the flies was preferred by most farmers. Constraints faced by farmers include inadequate substrate supply, weather fluctuations, limited technical expertise, and a lack of government support. Labor problems are also prevalent, with quick hiring of casuals being a common strategy. The findings of this study provide a foundation for the development of BSF genetic improvement programs incorporating traits of economic importance.

Keyword: black soldier fly, traits preferences, sustainable production system, breeding programs

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Danish initiatives in selective breedisng in insects

H.M. Nielsen[1*], L.S. Hansen[1], G. Gebreyesus[1], G. Sahana[1], R.M. Zaalberg[1], M. Kargo[1] M. Slagboom[1], N.K. Noer[2], T.M. Schou[2], K. Jensen[3], J.G. Sørensen[4], S.F. Laursen[5], S. Bahrndorff[5], and T.N. Kristensen[5]

[1] Aarhus University, Center for Quantitative Genetics and Genomics, C. F. Møllers Allé 3, 8000 Aarhus, Denmark;
[2] ENORM Biofactory, Hedelundvej 15, 8762 Flemming, Denmark;
[3] Aarhus University, Department of Animal and Veterinary Sciences, Blichers Alle 20, 8830 Tjele, Denmark;
[4] Section for Genetics, Ecology and Evolution, Department of Biology, Aarhus University, Ny Munkegade 116, 8000 Aarhus C, Denmark
[5] Section for Bioscience and Engineering, Department of Chemistry and Bioscience, Aalborg University, Fredrik Bajers Vej 7H, 9220 Aalborg, Denmark,
*hannem.nielsen@qgg.au.dk

Commercial insect production for food or feed offers a sustainable solution to mitigate the food crisis with the increasing world population. However, to optimize insect production, the large and yet unexploited selective breeding potential should be utilized. In Denmark, work is being performed to develop a selective breeding program in insect species such as house flies and black soldier flies. However, there are several challenges associated with selective breeding in insects. For example, a short generation interval provides only limited time to collect phenotypic records, which necessitates development of accurate and high-throughput phenotyping methods. An important requirement for developing an effective selective breeding program for insects is to estimate economic values and we have done so for important traits in black soldier flies (BSF) such as larval mass on day 15, growth rate, dry mass-, protein- and fat content, development time, eggs per fly, egg hatching rate, and larval mortality to be included in a breeding goal. We have also explored different mating systems for BSF and estimated genetic parameters for traits of economic importance. Based on this information we used stochastic simulation software to evaluate different breeding programs. We simulated a mass selection breeding program where the aim was to increase larval body weight. Further we assessed different breeding programs where we varied to the phenotypic strategy and mating design. A sustainable breeding program for the insect industry will enable insect companies to maintain their own breeding population and increase genetic gain for traits of interest.

Keywords: selective breeding, breeding program, insects, breeding goal

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Effect of substrate type on bioconversion and black soldier fly (*Hermetia illucens*) larvae production

Ssepuuya Geoffrey[1,2], Andrew Kabuye[1], Robert Kayizzi[1], Catherine Ndagire Tamale[1,3], Chrysantus Tanga[4], **Dorothy Nakimbugwe[1*]**

[1]Makerere University, Kampala, Uganda
[2]Kyambogo University, Kampala, Uganda
[3]Mountains of the Moon University, Uganda
[4]International Center for Insect Ecology and Physiology (*icipe*), Nairobi, Kenya
*dnakimbugwe@gmail.com

Black soldier fly (BSF) (*Hermetia illucens*) larvae are known to environmentally manage/ decompose organic waste (substrate). This study aims to investigate the effect of selected organic substrates on BSF larvae (BSFL) and Frass yield. Three substrates (soy residue, brewery waste, maize bran) were used to establish the weight of BSF eggs that should be inoculated to obtain 6-day old larvae (6DOL). The other nine substrates were used to establish adequate substrate depth (either 0.75, 1.50 or 3.0 inches) in a 30 x 27 x 12 cm rearing container, the weight (either 20.8, 26.0, 31.2, 36.4 or 41.6 g) of 6DOL that should be inoculated into 3kg of substrate to obtain larvae, BSFL growth [individual weight (g), girth (mm) and length (mm)], and harvesting period (days). The inoculated weight of BSF eggs (5.0 g Vs 2.5 g) in 2 kg of substrate didn't significantly affect the resultant average weight (364 g) of 6-day old (6 DOL) BSFL. Maize bran resulted in the highest weight (319.7 ± 75 mg) of 6 DOL. BSFL yield from a 3-inch substrate depth was similar to that of other depths but showed the highest compost yield. Brewery waste (408.2 ± 67.6 g) and poultry manure (303.5 ± 28.4 g) resulted in the highest BSFL yield. Beyond an inoculation weight of 31.2 g in 3kg of substrate, BSFL growth and yield significantly reduced. BSFL growth at days 21 and18 wasn't significantly different implying harvesting at day 18. Hence, after inoculation of 2.5 eggs in maize bran, 31.2 g of 6 DOL should be inoculated in 3 kg of a '3 inch high' plant-animal substrate mixture and harvested after 12 days at day 18.

Key words: black soldier fly larvae, egg inoculation weight, substrate depth, harvesting period, 6-day old larvae

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Growth and reproductive performance of edible grasshopper, *Ruspolia differens* (Serville) (Orthoptera: Tettigoniidae) reared on diet of grass grains

Malinga G. Maxwell[1,2*], Acur Amos[1] and Nyeko Philip[1]

[1]Department of Forestry, Biodiversity and Tourism, Makerere University, Kampala, Uganda
[2]Department of Biology, Gulu University, Gulu, Uganda
*malingageoffrey@gmail.com or geoffrey.malinga@gu.ac.ug

Ruspolia differens (Serville) (Orthoptera: Tettigoniidae), known by several names, including edible grasshopper, African edible bush-cricket and *nsenene*, is a commercially important edible insect species that has gained popularity in the food industry. In the laboratory, it has been shown to eat and thrive on grass leaves and inflorescences as well as artificial diets and food industry by-products. However, experiments showing how *R. differens* performs on local grass grains in captive rearing conditions are still lacking. This study experimentally investigated the suitability of eleven local grass grains on the growth and reproductive parameters of *R. differens*. Finger millet (*E. coracana*) grains was utilized as a control diet. We reared newly hatched (1 day old) nymphs on each powdered grass grain that had been gently crushed individually until they reached adulthood. Generalized linear mixed-effects models were fitted to test if *R. differens* performance varied between sexes and among diet treatments. The highest nymphal survival rates were recorded for both sexes when fed *E. coracana* (90.3%), *E. indica* (96.8%), and *C. gayana* (90.3%). When the males and females were examined separately, the nymphal development time in females was significantly shorter in individuals reared on *C. gayana* (mean±SE, 100.12±7.55) and *P. purpureum* (108.91±5.80). Similarly, male development took noticeably less time when individuals were reared on *E. corocana* (100.30±5.47) and *C. gayana* (95.46±4.93). Meanwhile, the highest adult weight was attained when individuals were fed on *E. coracana* (0.526±0.02), *P. maximum* (0.52±0.02), *S. pyramidalis* (0.471±0.02) and *C. gayana* (0.49±0.02) diets. The lifetime fecundity rate (69.71±3.27 eggs) of females fed *P. purpureum* was more than twice that of females fed other diets. Our results demonstrate that local grass grains could be used to feed *R. differens* in insect farming systems. These findings contribute to the development of commercial diets for mass production of *R. differens* for improved food security and income generation.

Keywords: edible insects, commercial diet, insect farming, food, and nutrition security

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Production characteristics and constraints of black soldier fly farmers in Uganda

Mark Ojungu[1]*, Bob Mali[3], Geoffrey Ssepuuya[4], Dorothy Nakimbugwe[5], Rawlynce Bett[6], Grum Gebreyesus[7], Sadhat Walusimbi[2]
[1]Department of Pharmacy and comparative Medicine, Makerere University, Uganda
[2]Department of Agricultural Production, Makerere University, Uganda
[3]Department of Wildlife and Aquatic Resources, Makerere University, Uganda
[4]Department of Food Science and Technology, Kyambogo University, Uganda
[5]Department of Food Science and Technology, Makerere University, Uganda
[6]Department of Food Science, Nutrition and Technology, Nairobi, Kenya
[7]Center for Quantitative Genetics and Genomics, Aarhus University, Denmark
* markojungu@gmail.com

Black soldier fly (BSF) larvae production is one of the fastest-growing insect value chains in Uganda, with potential to lift 4.53 million people over the poverty line and provide annual employment to up to 563,302 people. To contribute to the development of the BSF value chain, this study sought to examine the nature of farmers and management processes as well as constraints faced in BSF production. A cross-sectional study was conducted in which BSF farmer-households (n=83) from three AEZs (North-Eastern Savannah Grasslands, Lake Victoria Crescent and Western Savannah Grassland) were interviewed using a questionnaire with semi-structured and structured questions. The main purpose of producing BSF and larvae trait preferred were ranked using Likert scale ranging from 1(not important) to 5 (most important). Association between demographic and other characteristics of farmers with purpose of production and traits preferred were examined using chi-square test. In addition, the constraints faced by farmers were ranked. Sixty percent (60%) of the farmers interviewed were in the Lake Victoria crescent. Farmers participating in BSF production were mostly male (68%), slightly over 50% were youth (age 18-35), mostly educated to tertiary level (74%), trained in BSF production (78%) and produced less than 100kg/week of fresh larvae (75%). Majority of the farmers used the vertical rearing system (69%) compared to the horizontal rearing system (21%), 5 percent practicing both two systems and 5% practiced none, sourced starting material from fellow farmers (59%), and raised both flies and larvae (82%). Among the many reasons for rearing BSF, “feed for own livestock” was ranked highest (Mean rank=4.25) followed by income, while the most preferred larvae trait was larvae girth (Mean rank= 4.47) followed by length (mean rank=4.4). The source, availability and importance of substrates used in feeding larvae differed among the AEZs. Up to 57% of farmers in the different AEZs purchased substrates off-farm, and (76%) preferred shredded substrate. Whereas, in all the three AEZs market waste (39 percent), followed by brewer waste (18 percent) was mentioned as most preferred substrates. Common harvesting methods included sieving (51%) and manual picking (36%). The inadequate supply of substrate was the most noted constraint (21%) followed by weather fluctuation (16%) and market and marketing BSF products (15%). In summary, youth represent a major part of BSF farmers, but most of these farmers are not well distributed across the country and are still producing at a low rate primarily because of inadequate supply of substrate. Therefore, to improve BSF production, initiatives to increase the size of larvae, or provide larvae with larger sizes, and increase diversity substrates should be prioritized and should target the youth.

Keywords: agro-ecological zones, black soldier fly, production characteristics, trait preferences.

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Application of emerging technologies in insect monitoring and rearing

Roseline Akol[2], Andrew Katumba[2], Cosmas Mwikirize[2], Dorothy Nakimbugwe[2], Frank Ssemakula[2], Sarah Nawoya[2], Ssepuuya Geoffrey[6], Grum Gebreyesus[1]

[1]Aarhus University, Aarhus, Denmark
[2]Makerere University, Kampala, Uganda
[3]Kyambogo University, Kampala, Uganda
* nrakol@gmail.com

Insects for food and feed is gaining traction because of high nutritional content. However, in large scale rearing, harvesting and processing insects for food and feed is still a challenge largely due to manual monitoring. Through the advances in technology, computing power and communications, it is now possible to generate and analyze massive data in real time. This lends itself to automation, remote sensing and relaying of massive data using Internet of Things (IoT). Counting, measurements of insects and their traits, modelling which may result into prediction can be successfully done using Machine Learning (ML). Image acquisition and signal processing is made possible through the use of Computer Vision (CV) while the insect content analysis is achieved through the use spectroscopy.

Key words: emerging technologies, IoT, machine learning, computer vision, insect monitoring and rearing

Food and Non-Food Applications of Insects

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Effect of cooking methods on nutritional quality and microbial load of edible rhinoceros beetle grubs (Oryctes sp)

Marliyn W. Muthee[1*], Fathiya M. Khamis, Xavier Cheseto, Chrysantus M. Tanga, Sevgan Subramanian, James P. Egonyu[1,2]

[1]International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
[2]Faculty of Science and Education, Busitema University, Tororo, Uganda
*muthee173@gmail.com

Edible rhinoceros beetle (*Oryctes* sp*)* larvae are popularly consumed in many countries worldwide. They are the fifth most consumed insects in Kenya, majorly in the western region due to their taste, nutritional, cultural and medicinal value. They are cooked using different methods such as boiling, roasting, toasting, and deep-frying. However, little is known about the effect of these cooking methods on nutritional value and microbial safety. This study investigated the effect of these methods on the nutritional integrity and microbial safety of *Oryctes* sp larvae. The grubs were analysed for proximate composition, and fatty and amino acid profiles using standard chemical procedures; and microbial safety using standard culturing procedures. Analyses of variances were carried out to determine the effect of cooking methods on nutritional parameters and logs of microbial counts using IBM® SPSS® Statistics 20 at p = 0.05. Means were separated using Tukey's Honestly Significant Difference (HSD) test. Deep-frying significantly reduced protein and carbohydrate contents, but elevated fat content. Boiling significantly lowered ash content, but increased fiber and carbohydrate composition. Roasting and toasting significantly increased protein and ash contents, respectively. The levels of fatty acids were differentially affected by the different cooking methods. Amino acid profiles and levels were largely comparable across treatments. All the cooking methods eliminated Enterobacteriaceae, *Shigella* sp and *Campylobacter* sp from the grubs. Apart from boiling, all methods reduced total viable counts from 9.78 log cfu/g in the raw larvae to levels of 5.11-5.95 log cfu/g. *Salmonella* sp were only eliminated by toasting and roasting; while boiling promoted growth of yeast and moulds. *Staphylococcus aureus* levels exceeded safety limits in all the cooking methods. We conclude that roasting and toasting are the safest methods of preparing the larvae for human consumption, both for their relatively higher nutritional and microbial quality products.

Keywords: *campylobacter,* fatty and amino acid profiles, proximate composition, *Salmonella, Shigella, Staphylococcus aureus*

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Black soldier fly larvae meal increases profitability in rabbit (*Oryctolagus cuniculus*) farming

Mube K. Hervé[1*]; Manga Manga[2], Gina Djoumessi[3], Shaphan Y. Chia[4]

[1]Faculty of Agronomy and Agricultural Sciences, University of Dschang, Dschang, Cameroon
[2] Institut Agricole d'Obala, Obala, Cameroon
[3]Université de Liège, Liège, Belgium
[4]International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
*mubehervemkh@yahoo.com

The black soldier fly (BSF) larvae, *Hermetia illucens* L. (Diptera: Stratiomyidae) effectively convert organic waste into protein-rich animal feed ingredients. This study assessed the impact of BSF larvae (BSFL) meal on the growth performance, health status, and economic efficiency of rabbits, thereby contributing to sustainable feed production for livestock and mitigating the adverse environmental impacts associated with conventional feeding practices. We evaluated four distinct diets tailored for crossbred rabbits, each featuring incremental levels of BSFL meal at 2.5%, 5%, and 7.5%, denoted as diets BSFL2.5, BSFL5, and BSFL7.5, respectively. A standard commercial diet without insect meal served as the control group (BSFL0). A total of 48 male rabbits were randomly allocated to these diets and monitored over a 14-week experimental duration. Essential parameters including feed intake, body weight, body weight gain, feed conversion ratio, carcass traits, serum hemato-biochemical markers (such as immune cells, creatinine, urea, cholesterol, and blood cells), microbial load, and economic efficiency (in terms of feed intake cost and net return) were determined. Statistical analyses comprised a one-way ANOVA, and LSD test to distinguish significant differences among means at a 5% level of significance. Our study findings showed that dietary incorporation of BSFL meal did not significantly affect gowth performance, caecal microbiota and blood parameters of rabbits. Conversely, the highest carcass yield and low-density lipoprotein cholesterol levels were recorded in the group fed BSFL7.5, containing the highest level of BSFL. Additionally, incorporating the BSFL meal into the feed led to a reduction in the cost per kilogram of rabbit feed, thereby increasing rabbit profitability by 16% compared to the diet without BSFL. This study demonstrates the value of BSFL as a promising feed source in rabbit production, notably enhancing farmer profitability without side effects on health status.

Keywords: black soldier fly-based feed, rabbit farming, feed supplementation, livestock profitability, sustainable animal nutrition

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Growth performance and food safety concerns associated with edible cricket (*Gryllus bimaculatus*) raised on a diet enriched with heavy metals

Susan Mwelwa[1*], Mohanadoss Ponraj[1], Donald Chungu[2], Frank Tailoka[3], Dennis Beesigamukama[4] and Chrysantus M. Tanga[4]

[1]Department of Biological Sciences, School of Mathematics and Natural Sciences, Copperbelt University, Kitwe, Zambia
[2]Cavendish University, Corner of Great North and Washama Roads, Villa Elizabeth, Zambia
[3]Mukuba University, Kitwe, Zambia
[4]International Center of Insect Physiology and Ecology, Nairobi, Kenya
*susan.mwelwa@cbu.ac.zm

Entomophagy has recently gained impetus globally due to it's environmental, health, and nutritional benefits. In many African communities, insects are wild harvested from environments with a risk of heavy metal pollution, yet the impact of metals on insect growth, nutritional quality, and safety for consumption is unknown. This study investigated the effect of dietary heavy metal concentrations (cadmium [Cd], copper [Cu], iron [Fe], and zinc [Zn]) on the growth performance and nutrient profile of edible cricket (*Gryllus bimaculatus*) when compared to WHO recommended limit (2.2mgkg^{-1}, 30mgkg^{-1}, 100mgkg^{-1}, and 150mgkg^{-1} for Cd, Cu, Fe, and Zn respectively). One-month-old *G. bimaculatus* were collected from the Hugel and Tanga stock culture and randomly placed in transparent Perspex cages, each cage consisting of 360 individuals (180 males and 180 females). Three cages were provided with wheat bran with Cd, Cu, Fe, and Zn concentrations below WHO-recommended limits. Others were fed on wheat bran spiked independently with Cd, Cu, Fe, and Zn at WHO limits, twice WHO limits, and thrice WHO recommended thresholds in triplicate. Heavy metal analysis was done using ICP-MS while proximate analysis was conducted for nutritional profile. Results revealed that increasing the dietary metal concentrations reduced the body weights by 30% – 60%, survival by 66 – 82%, and reproductive capacity by 17 – 58%. It was noted that increasing dietary metal concentrations increased the bioaccumulation of heavy metals in cricket's biomass by 23 – 100 folds, particularly for Zn. The crude protein of crickets increased up to 40% with increased dietary heavy metal concentrations, while crude fat and free fatty acids reduced by 29 – 74%. However, sulfur, arsenic, molybdenum, and cobalt levels did not vary with feed inclusion levels of heavy metals. This study demonstrated the bio-transfer and bioaccumulation patterns of different heavy metals by edible crickets, thereby indicating their pollution status at exposure along the food chain. Excessive levels of metal accumulation in the cricket's body is a matter of concern not to be neglected and thus establishing a regulatory framework for quality control of insects and insect-based food products should be taken seriously.

Keywords: crickets; heavy metals; pollution; bioaccumulation, food safety

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Exploring consumer acceptability and allergic reactions of cereal-based porridges enriched with edible insects: A multi-country study

Jeremiah Ng'ang'a[a*], Samuel Kiiru[a], Nicky Okeyo[b], Shadrack Debrah[c], Amos Acur[d], Evans Nyakeri[e], Geoffrey Malinga[d], Philip Nyeko[d], Jacob Anankware[c], Monica Ayieko[e], Silvenus Konyole[b], Nanna Roos[f], John Kinyuru[a,g]

[a] Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Kenya
[b] Department of Nutritional Sciences, Masinde Muliro University of Science and Technology, Kenya
[c] Department of Horticulture and Crop Production, University of Energy and Natural Resources, Ghana
[d] Department of Forestry, Biodiversity and Tourism, Makerere University, Uganda
[e] Department of Plants, Animals and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, Kenya
[f] Department of Nutrition, Exercise and Sports, University of Copenhagen, Denmark
[g] African Institute for Capacity Development, Nairobi, Kenya
* Kandojeremies@yahoo.com

The potential of edible insects to address food and nutrition insecurity is receiving an increasing amount of attention due to their nutritional contribution, and it is possible to incorporate them into conventional food products. The aim of this study was to evaluate consumer acceptability of nutrient-dense cereal-insect powder porridges in three sub-Saharan countries. The flours containing maize, millet and insect powders were prepared as follows: Cricket-enriched porridge (CEP) flour in Kenya, *Ruspolia* grasshopper-enriched porridge (REP) flour in Uganda, and palm weevil-enriched porridge (PWEP) flour in Ghana, whilst commonly consumed porridge (CCP) flour consisting of millet and maize only was used as the control. In each country, respective porridges and control were prepared using local methods, and the participants consumed each of the two porridges on separate days with a one-day washout between porridges. The sensory attributes of the porridges were evaluated using a five-point hedonic scale and a Just About Right (JAR) scale. The formulated flours (CEP, REP and PWEP) had elevated levels of protein, fat, micronutrients and energy contribution compared to CCP. In Kenya, both porridges had an overall acceptability score of > 4.6 (like extremely); however, texture (3.71) in CEP was the least preferred. All organoleptic properties of REP were rated above 4.3 except for texture (3.38) in Uganda, while in Ghana, an overall acceptability score of > 4.2; however, texture (3.04) in PWEP was the least preferred. Based on JAR scale, more than 50% of the respondents indicated that all sensory attributes of formulated porridges were just about right compared to what they normally consume at household levels. In the three countries, only two participants experienced food allergic effects after consumption of insect-enriched porridges. We demonstrated the possibility of producing acceptable complementary foods based on the utilization of commonly consumed cereals supplemented with edible insect powders with no adverse health effects.

Keywords: edible insect; complementary food; acceptability; sensory attributes; health effect

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Fertigro (BSFF fertilizer) combined with good agricultural practices improves farmer yields on selected crops in Bomet and Meru Counties, Kenya

Mary M. Mutisya[1*], Maurice Kimani[1], Martha Arinaitwe[1], Steve Soh Baleba[2], Doreen N. Oguttu[1] and Talash Huijbers[1]
[1]Insectipro Company Limited, P.O BOX -00100, Julian Road, Limuru, Kenya
[2]Max Planck Institute for Chemical Ecology, Department of Evolutionary Neuroethology, Hans-Knöll-Straβe 8, 07745 Jena, Germany
* marymutisya@insctipro.com

Lack of access to farm inputs (especially organic fertilizers) and little to no knowledge on good agronomic practices among farmers in Kenya is a major contributor to decreasing crop yields, return on investment, food and nutritional security. We evaluated the effect of improved access to Fertigro (an organic fertilizer produced by Insectipro using black soldier fly frass (BSFF) coupled with comprehensive farmer training on its utilization and other good agricultural practices (GAP) on crop yield in Bomet and Meru counties, Kenya. To improve access to fertigro, distribution hubs were established in strategically mapped out locations-one in every subcounty. Lead/star farmers were used to set up demo plots and key crops grown in the regions such as tea, maize, beans, potatoes and avocadoes set up. The selected farmers were supplied with fertigro and guided on good agricultural practices. Control plots were treated to conventional farming practices i.e, use of synthetic fertilizers/pesticides or none. Training of farmers on good agronomic practices was conducted through farmer field schools by field agents. Crop yield, prevalence of pests and diseases, improved knowledge on good agronomic practices, physical qualities of the selected crops and profitability were evaluated over a period of 5 months. In comparison to the use of conventional fertilizers and farming methods, the study revealed that Fertigro accelerated the growth of avocado trees by almost 40%. Farmers reported improved physical properties (size, mass, shape and true density) of their produce (vegetables and fruits). Yields in tomatoes, tea, potatoes, avocados and coffee increased by between 30-50%. The prevalence of pests and diseases was drastically reduced with the incidence of nematodes and *Tuta absoluta* reducing by 50-80% in tomato plots treated with fertigro compared to those that were treated with commercial pesticides and those that had none. The results of our survey using a well-structured questionnaire indicated that in both counties, agricultural extension services, and farmer knowledge on good agronomic practices is still very low. The conclusion of the study was that augmenting farmers access to fertigro alongside education on good agronomic practices can substantially increase farmer yields, improve their return on investment, and ultimately contribute to achieving Sustainable Development goal 2, zero hunger.

Keywords: fertigro, gap, insects, food and nutritional security, smallholder farmers

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Unlocking soil enhancement potential: black soldier fly frass amendments in circular agriculture

Shaphan Y. Chia[1, 2*], Pedro B. da Costa[2], Joop J.A. van Loon[2], Marcel Dicke[2]

[1]International Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya
[2]Laboratory of Entomology, Wageningen University & Research, Wageningen, The Netherlands
*schia@icipe.org

Modern agriculture heavily relies on external inputs like fertilizers and protein sources. Addressing the tandem challenges of soil degradation and fertilizer management is paramount, ensuring sustainable practices that mitigate environmental impact and enhance long-term productivity. Prior studies showcased black soldier fly (BSF) *Hermetia illucens* L. larval meal's potential to replace fishmeal and soy meal in livestock feed, generating frass as a by-product rich in nutrients and beneficial microbes. However, frass quality can vary. In greenhouse pot experiments, we explored BSF effects, assessing source (X and Y), composting treatment and dosage (2 and 5 g/kg soil) of application as soil amendments to enhance *Brassica rapa* L. growth, addressing knowledge gaps on soil and plant health impacts. Amplicon sequencing of 16S rRNA and ITS genes was conducted on bulk soil and rhizosphere samples using NovaSeq technology. Partial least square discriminant analyses of chemical properties of frass indicated clear distinctions based on source and composting, notably highlighting Nitrogen, Calcium, Iron, Aluminium, Sodium, and Potassium as pivotal elements affecting separation. Frass composting increased nutrient concentration. The impact of composted frass on growth parameters varied; while it improved shoot dry biomass at 5 g/kg, leaf size remained unaffected. Factors like frass source, composting, and dosage influenced *B. rapa* growth, with frass dosage playing the most crucial role. Soil amendments with frass notably influenced microbial communities, affecting beta diversity, and normalising alpha diversity of bacteria across different frass sources in *B. rapa*-based soil samples. Bacillales, Chitinophagales and Paenibacillales were key drivers of frass-treated soil microbial community shifts. Intriguingly, frass incorporation reduced fungal diversities compared to unamended soil. Permutational multivariate analysis of variance revealed significant effects of frass composting, source, and dosage on rhizosphere and bulk soil communities, indicating their roles in shaping microbial communities. Our findings highlight the fertilizer potential of frass. Showcasing its role in crop enhancement, bridging waste utilisation, livestock, and crop production in circular agriculture.

Key words: insect frass, soil amendments, circular agriculture, soil microbial communities, plant growth

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Cost-effective aquafeed enriched with *Hermetia illucens* larvae meal improves the growth and fillet quality of Sagana strain of African catfish (*Clarias gariepinus*)

Menaga M[a*], Maina A. N[a,c], Osuga, I. M.[a,b], Munga, L. K.[c], Munguti, J. M.[d], Subramanian, S.[a], Barwani, D. K.[b,g], Van Loon, J. J. A[e], Dicke, M.[e,] R. Yossah, Ekesi, S.[a], Liti. D. M.[f] and Tanga, C. M.[a]

[a]International Centre of Insect Physiology and Ecology, Nairobi, Kenya;
[b]Department of Animal Sciences, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya;
[c]Department of Animal Science, Kenyatta University, Nairobi, Kenya;
[d]Kenya Marine and Fisheries Research Institute, Sagana, Kenya;
[e]Laboratory of Entomology, Plant Sciences Group, Wageningen University, Wageningen, The Netherlands;
[f]Department of Biological Sciences, University of Eldoret, Kenya;
[g]Department of Animal Production, Université de Kalemie, DR Congo.
*mmenaga@icipe.org

The utilization of black soldier fly larvae (*Hermetia illucens* L.) meal, has gained global attention as a viable protein-rich alternative. This study investigates the effects of replacing fishmeal with black soldier fly larvae meal (BSFLM) in varying proportions in isonitrogenous, isolipidic and isoenergetic diets on water quality, growth performance, fillet quality, and cost-effectiveness of producing the Sagana strain of African catfish (*Clarias gariepinus*) on fixed net cages in earthen ponds. Five diets (D) were formulated, replacing fish meal (FM) with full fat BSFLM in different proportions as follow: Diets with 0% BSFLM and 100% FM (C – control diet), 25% BSFLM and 75% FM (D1), 50% BSFLM and 50% FM (D2), 75% BSFLM and 25% FM (D3), 100% BSFLM and 0% FM (D4). Catfish (3.5-4g) were stocked at a density of 10/ m^3 per cage (2x2x2m) in triplicates installed in earthen ponds for 168 days of culture. Water quality parameters remained within optimal levels in all treatments. Diets D2 and D3 exhibited significantly higher growth performance (1.8-fold increase) with feed conversion ratios (FCR) of 2.56 and 2.65, respectively. Survival rate was 100%, except for D1 and C. Fish fillets from fish fed D2 (5-8%) and D3 (9-11%) exhibited a high protein content. Essential amino acids, particularly lysine and methionine were elevated by 11-18g/kg and 11-27g/kg in fillets from fish subjected to D2 and D3, respectively. Fillets from fish provided D2 and D3 showed 11.4 – 16.7% increase in lauric acid concentrations and 19-folds increase in omega-6 fatty acid (linoleic acid) compared to fish fed on the control diet. Fish fed diet D2showed the best benefit–cost ratio [1.05] and return on investment [105.2%]. These findings demonstrated that replacing FM with BSFLM up to 50% and 75% enhance the growth performance, fillet quality, and profitability of catfish farmers. This study suggest that BSFLM has the potential to be a promising and sustainable alternative fish ingredient for catfish production systems.

Keywords: black soldier fly larvae, African catfish, weight gain, fillet characteristics, profitability

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Total zinc absorption from maize-based meals enriched with edible house crickets in Kenyan pre-school children

Tele Boit[1*], Nikolin Hilaj[2], Pauline Andang'o[3], Christophe Zeder[2], Martin N. Mwangi[1], Marijke Hummel[1], Ornella Nececea Valazco[4], Joop J.A. van Loon[5], Marcel Dicke[5], Michael B. Zimmermann[2], Alida Melse-Boonstra[1]

[1]Division of Human Nutrition and Health, Wageningen University and Research, the Netherlands
[2]Human Nutrition Laboratory, Institute of Food, Nutrition and Health, ETH Zürich, Switzerland.
[3]Department of Public Health, Maseno University, Kenya
[4]Food Quality and Design Group, Wageningen University and Research, the Netherlands
[5]Laboratory of Entomology, Wageningen University and Research, the Netherlands
*tcb@nexs.ku.dk

Zinc deficiency is prevalent globally, with adverse consequences particularly for children. Edible insects are sustainable and nutrient-dense, however, lack well-established evidence on the *in vivo* absorption efficiency of their nutrients. This study investigated zinc absorption from edible house crickets (*Acheta domesticus*) in 2- 3-year-old Kenyan children. The study employed a randomized cross-over design, utilizing the double-isotopic tracer technique to measure fractional and total zinc absorption in 25 children. The test meals comprised of four maize porridges complemented with (a) intrinsically labelled (^{67}Zn) whole house cricket flour (*Acheta domesticus*) or (b) intrinsically labelled (^{67}Zn) fractionated (low chitin) house cricket flour; (c) highly enriched with labelled $^{68}ZnSO_4$; and (d) low enriched with labelled $^{68}ZnSO_4$. The data was analysed using linear mixed models. The mean serum zinc was 58.0 ± 13.3 µg/dL, with 65% of the children identified to be zinc deficient. Geometric mean (95% CI) of total absorbed zinc (TAZ) from the maize meal enriched with whole crickets (0.35; 0.30 - 0.40 mg) was 2.5-fold greater than maize meal low enriched with $ZnSO_4$ (0.14; 0.12 - 0.15 mg) ($P < 0.001$) and did not substantially differ from low chitin cricket flour (0.32; 0.25 - 0.39 mg). TAZ from meals with whole and chitin-free cricket flour was 1.5 and 1.3-fold higher, respectively than that from the meal highly enriched with $ZnSO_4$ (0.24; 0.18 - 0.32 mg) ($P = 0.042$ and $P = 0.365$, respectively). We conclude that zinc from edible house crickets is well absorbed by children, and chitin does not significantly affect zinc absorption. Thus, increased consumption of edible house crickets could potentially play a role in mitigating zinc deficiency.

Keywords: zinc deficiency, edible insects, house crickets, stable isotopes, pre-school children

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Insect frass fertilizer as circular economy solution for profitable insect farming and improved crop productivity

Dennis Beesigamukama*, Subramanian Sevgan and Chrysantus M. Tanga

International Centre of Insect Physiology and Ecology, Nairobi (*icipe*), Kenya
*dbeesigamukama@icipe.org

Globally, insect farming has largely focused on the production of insect-based food and feed, resulting in a knowledge gap regarding the exploration of insect frass fertilizer (IFF), a byproduct with potential to boost economic returns to insect farming and improve crop production through circular economy. This study determined the quality of IFF generated from nine insect mass-rearing systems and assessed its impacts on soil health, crop yield, nutritional quality, and pest suppression. Data were collected through laboratory, greenhouse and field experiments involving IFF, commercial fertilizers, and various test crops in Kenya. Our findings revealed that all the nine insect species require ≤5 weeks to recycle organic waste into mature and stable fertilizer, compared to 12 – 24 weeks for conventional composting methods. The concentrations of nitrogen, phosphorus and potassium in IFF were 3 – 9 fold higher compared to levels of the same nutrients in conventional organic fertilizers. The utilisation of IFF as an additional value-added product increases net income by 5 – 15 fold compared to insect farming alone. Agronomic studies revealed that application of IFF significantly increased the yields of maize (6 – 27%), kales (20 – 27%), tomatoes (22 – 135%), French beans (38 – 50%), spinach (13 – 56%), bell pepper (8 – 151%), and *Amaranthus dubius* (10 – 11%) compared to commercial fertilizers. We found that IFF increased crude protein, (6 – 190%), mineral contents, and net income (10 – 154%) of maize, tomatoes, kales and French beans better than commercial fertilizers. Furthermore, IFF application significantly increased soil water storage, nutrient availability, microbial populations, and reduced soil acidity compared to conventional fertilizers. The IFF also suppressed nematodes, cabbage, and onion root fly pests by up to 100%, and 65%, respectively. These findings indicate that adoption of high-quality, affordable, and multipurpose fertilizers such as IFF will immensely contribute towards the increasing the profitability of insect farming enterprises and improving food security through circular economy.

Keywords: insect frass fertilizer, waste recycling, circular economy, regenerative agriculture, food security

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Antioxidant and antibacterial activity of metabolites of invitro-digestion and fermentation of chitin

Alex Ndiritu[1, 3*], Arnold N. Onyango[1], Carolyne Kipkoech[4], John Kinyuru[2, 5]

[1]Department of Human Nutrition and Dietetics, Jomo Kenyatta University of Agriculture and Technology, Kenya
[2]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Kenya
[3]Department of Public Heath, University of Kabianga, Kenya
[4]German Federal Institute of Risk Assessment (BfR), Berlin- Germany
[5]African Institute for Capacity Development, Kenya
*alexask.n@gmail.com

Globally chitin has gained significant attention from scientists due to its antimicrobial, antioxidant, and anti-inflammatory potential. Chitin has wide application in food, medical, pharmaceutical cosmetic and textile industries. Malnutrition is still a significant public health problem which requires to be addressed. Apart from lack of adequate food, one of the other major cause of malnutrition among children is environmental enteropathy (EE). An effective way of eliminating EE is to promote the growth of gut microflora. And in this regard the study aims at demonstrating invitro the prebiotic potential of edible insect chitin. In the course of this study, chitin was extracted from house cricket, filed cricket and BSF cocoons. The chitin was then subjected to invitro digestion followed by fermentation using probiotic microorganisms for 24 and 48 hours. The results shows that fermentation time and sample concentration had a significant effect on the antioxidant activity of metabolites obtained after invitro digestion and fermentation of the chitin samples ($p<0.05$). In samples fermented using ABY10 the highest antioxidant activity was reported in *Hermetia illucens* samples fermented for 48 hrs and at a concentration of 5 mg/ml while the least antioxidant activity was reported in the control. It is worth noting that antioxidant activity increased with increase in sample concentration. Samples obtained from invitro digestion and fermentation of the chitin samples showed a low MIC against Escherichia coli, *Staphylococcus aureus* ATCC43300, *Staphylococcus aureus* ATCC25923, *Vibrio cholera*, *Bacillus cereus*, *Bacteroides fragilis*, *Enterobacter agglomerans* and Shigella *dysenteriae* as compared to the control. The samples obtained after invitro digestion and fermentation of the chitin exhibited significantly different antimicrobial activity against the tested pathogenic microorganisms ($p<0.05$). It is worth noting that antimicrobial activity increased with increase in sample concentration. In conclusion invitro digestion and fermentation of chitin yielded compounds with significant antioxidant and antibacterial activity. Thus, consumption of whole insects as well as chitin based products may help enhance gut health and consequently enhance nutrition and health status.

Keywords: antioxidant, antibacterial, chitin, fermentation, invitro digestion

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Potential of Insects to contribute to Food and Nutrition Security in Uganda

Dorothy Nakimbugwe
Department of Food Technology and Nutrition, Makerere University, Kampala - Uganda
dnakimbugwe@gmail.com

This keynote address will highlight the potential of insects to contribute to food and nutrition security in Uganda (with implications for Sub-Saharan Africa - SSA), through both food and feed. Past, present, and future research on the availability and acceptability, rearing, post-harvest handling and processing, nutritional value and nutritional quality, safety and stability, economic and consumer insights, extraction and utilization of high-value products, some intervention studies conducted and key findings from the research will be presented. Challenges encountered and research gaps needing further research, as well as achievements towards creating an enabling regulatory environment, will also be acknowledged. Research conducted and its findings will be presented and discussed for its potential to contribute to improved nutrition and health of vulnerable individuals such as women of reproductive age and children aged less than 5 years. Specifically, research progress and key findings on the topics listed in the methods section above will be presented and discussed. Substantial research progress has been made towards realizing the potential of insects as a highly nutritious and sustainable source of food and feed. Insects are readily accepted and widely consumed as delicacies and animals fed on insect-enriched diets and acceptable to both producers and consumers. Rearing and incorporation of insects in food and feed has increased. However, insect value chains, especially for harvested insects, are still generally under-developed. Harvesting and post-harvesting methods remain largely traditional and uncontrolled, processing and packaging approaches do not ensure safety and stability thus availability is still seasonal. Nevertheless, substantial progress is being made towards closing these gaps e.g. processing protocols and National standards for ensuring safety and quality of insect foods and feeds are in place.

Key words: insects, food, feed, nutrition, safety

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Nutritional value of edible insect larvae reared and processed in various ways

T. Spranghers[1*], A. Moradei[2], K. Vynckier[1], D. Deruytter[3]

[1]Centre of expertise for agro- and biotechnology, VIVES University of Applied Sciences, Wilgenstraat 32, 8800 Roeselare, Belgium
[2] University of Milan, Department of Veterinary Medicine, and Animal Sciences (DIVAS), Via dell'Università 6, 26900 Lodi, Italy
[3] Insect Research Centre, Inagro, Ieperseweg 87, 8800 Rumbeke-Beitem, Belgium
*thomas.spranghers@vives.be

The use of edible insects is currently limited. The focus of the PetSect project is investigating the value as ingredients for pet food (cats and dogs). Despite the focus on pets, the results can also provide information for other monogastric animals like poultry and pigs. This research focused on the nutritional value and use of yellow mealworms (YMW) and black soldier fly larvae (BSFL) reared, harvested, and dried in different ways. For YMW standard rearing crates were harvested over different sieve meshes dividing them according to width. For BSFL the harvest sizes are more homogenous, and difference was created by different rearing densities (10,000, 15,000, 30,000 and 40,000 per crate of 60 by 40 cm). Concerning the effect of drying methods on the nutritional quality, 3 different techniques: hot air at different temperatures (60, 90 and 120 °C), freeze drying, and microwave drying were evaluated using proximate analyses and *in vitro* digestibility trials. To compare the means One-way ANOVA was used followed by post hoc Tukey or Tamhane tests. For YMW smaller larvae had a higher protein content, however, this was compensated by a lower digestibility due to a higher crude fiber content. In general, protein digestibility was very high (97-98%). For BSFL, the only significant differences were in a higher dry matter (DM) and lower fiber content of the biggest larvae (10.000/ crate). In contrast to YMW, the biggest BSFL had the lowest *in vitro* digestibility (only 48% for DM and 83% for protein compared to 60% for DM and 86% for protein for the smaller sizes). Drying at 60 °C resulted in YMW with lower DM (82%) and comparable protein (96%) digestibility compared to other techniques (86% DM and 97% protein). For BSFL all DM and protein digestibility values were about 60% and 95%, respectively.

Keywords: *Tenebrio molitor*, *Hermetia illucens*, proximate analyses, *in vitro* digestibility, drying

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Effect of crickets enriched complementary porridge and nutrition education on infant and child growth in Siaya County Kenya: Randomized Control Factorial Trial

Nicky Odhiambo Okeyo[1*]; Cecilie E. Wille[2]; Asenath J. Sigot[1] Jeremy Ng'ang'a[3], John Kinyuru[3]; Nanna Roos[2] & Silvenus O. Konyole[1]

1. Department of Nutritional Sciences, Masinde Muliro University of Science and Technology
2. Department of Nutrition and Sports, University of Copenhagen
3. Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Kenya
*nickokeyo2000@gmail.com

Child malnutrition is a complex health state driven by low diet quality, food preparation and feeding practices. Insects are currently of interest in alleviating malnutrition due to their energy density, high protein, vitamins, and micronutrients (iron, zinc). Despite insect-based foods being nutritious and highly digestible possible alternative to red meat, the use of edible insects in infant complementary foods remains novel. Single nutrition interventions are less effective. A combination of nutrition-specific and nutrition-sensitive interventions are considered to yield a better outcome. The study is designed as a main study with two sub-studies; - Human Milk Intake (HMI) and gut health, using a 2x2 factorial design implemented for 8months. To determine the effect of integrating two nutrition treatments - Cricket Enriched Porridge (CEP) with Nutrition Education (NE) on the infant and young child growth and gut health, infants (6 months) between February and April 2023 were screened. Those who were non-malnourished (MUAC>11.5), and willing to participate were recruited and followed up for 8 months. A recruited sample of 284 mother/infant dyads were randomly assigned to the four study arms. Subsets were assessed for breast milk intake [65] and gut health [75] at Rwambwa Sub-County Hospital, Alego Usonga Sub-County in Siaya County, Kenya. KoboCollect App was used to collect data on household characteristics, feeding practices, child health, maternal and child anthropometrics. Baseline analysis indicate equivalence average ranging: age (6.2 - 6.3 months), weight (7.5 - 7.9 Kgs), height (65.6 - 65.7cm) in all arms. Infants' caregivers were all female aged 16-59 years, 47.5% of households practiced farming and 85.5% owned family house. Sub-study on Breastmilk intake finding show no significant difference in HMI between control and CEP+NE arm with positive association between HMI and increased ANC visits. Loss to follow up is currently at 47 (16.5%) with study close-out ongoing till January 19, 2024.

Key words: infants, breastmilk, gut health, stable isotopes, insects

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Microbiological changes during the storage of extruded cricket-enriched porridge flour

Jeremiah Ng'ang'a[a], Samuel Kiiru[a], Nicky Okeyo[b], Silvenus Konyole[b], John Kinyuru[a,c]

[a]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Kenya
[b]Department of Nutritional Sciences, Masinde Muliro University of Science and Technology, Kenya
[c]African Institute for Capacity Development, Nairobi, Kenya
*Kandojeremies@yahoo.com

Food safety is a critical aspect for all ready to-eat-food products. Identified food safety hazards need to be controlled throughout the supply chain to deliver safe food to the consumers. Extrusion processing favors the elimination or reduction of the biological hazards. This study was done to evaluate the effect of extrusion process and the storability of cricket-enriched flour (CEF). CEF consisting of dehulled maize (30%), roasted millet (40%), cricket powder (24%), sunflower seed oil (5.8%) and micronutrient, was formulated to meet nutritional needs of infants and young children based on Nutrisurvey software and compared with corn-soy blend (CSB). The porridge flours were processed by co-extrusion after which the extrudates were ground into flour and packaged into one kilogram plastic containers and stored at room temperatures. The microbiological load, pH and moisture content were monitored monthly for four months. Analysis of both flour revealed average moisture levels below the maximum limit of 12%, with a slightly acidic pH (5.51 – 6.18) in CEF, and no significant variations observed during storage. High counts of total aerobic, total coliforms, *Staphylococcus aureus*, yeasts and moulds were observed in both non-extruded flours. However, a statistically significant reduction in all types of counts was observed after extrusion. No changes were observed during the entire storage period except a signicant increase in fungal counts in CEF at the end of storage period. Both flours were devoid of Salmonellae and *Escherichia coli*. The results of the study reveal that the moisture content and microbial load of both flours were within acceptable limits and pose no threat to consumers. Utmost care for the flours during post extrusion handling to avoid any cross-contamination is important.

Keywords: microbial counts; cricket powder; moisture content; storage; pathogens

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Technological impact of *Gryllus bimaculatus* powder in gluten-free flour formulations

Samuel Kiiru[a*], Jeremiah Ng'ang'a[a], Silvenus Konyole[b], Nanna Roos[c], Hetzer Birgit[d], Anna-Kristina Marel[d], Agnieszka Orkusz[e], Joanna Harasym[e] , John Kinyuru[a,f]

[a]*Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Kenya*
[b]*Department of Nutritional Sciences, Masinde Muliro University of Science and Technology, Kenya*
[c]*Department of Nutrition, Exercise and Sports, University of Copenhagen, Denmark*
[d]*Institute of Food and Bioprocess Engineering, Max Rubner Institute. Germany*
[e]*Department of Biotechnology and Food Analysis, Wroclaw University of Economics and Business, Poland*
[f]African Institute for Capacity Development. Kenya
*(kiirusam@rocketmail.com)

Gryllus bimaculatus (field cricket) powder is a prospect in enriching gluten-free food products' protein and mineral contents. However, the technological effects of replacing common gluten-free cereal flours with *G. bimaculatus* powder are still developing. This study investigated the effect of substituting rice, maize, finger millet and proso millet flours with 5%, 10%, 15% and 20% *G. bimaculatus* powder on hydration, pasting and microstructural properties. Hydration properties differed significantly ($p \leq 0.05$) except in proso millet flour. Blends exhibited significant ($p \leq 0.05$) reductions in swelling power and increased water solubility index. Overall, blends' water absorption capacities were higher than oil absorption capacities. Pasting parameters showed significant differences ($p \leq 0.05$) except for peak time in proso millet blends. Pasting viscosities ranked as follows: rice > finger millet > proso millet and maize flours. *G. bimaculatus* powder addition resulted in significant ($p \leq 0.05$) viscosity reductions. Reductions in final viscosity were higher in rice (1045 cP) > maize > proso millet > finger millet blends (315.75 cP). Maize and proso millet blends had highest positive setback and breakdown viscosities, forming heat-stable pastes. *G. bimaculatus* powder inclusion decreased peak time but increased pasting temperatures. Micrographs revealed a uniform dense network in flour pastes, transitioning to discontinuous and irregular structures upon *G. bimaculatus* powder addition. Findings suggests promising formulations of low-viscosity and heat stable insect-derived gluten-free products particularly with maize and proso millet flours.

***Keywords**:* edible insects, gluten-free, physiochemical, pasting

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Organic waste pre-treatment enhances growth, bioconversion and quality of black soldier fly larvae (*Hermetia illucens*)

Mube K. Hervé[1*], Gagueng F. Lionel[1], Djouaka F. Rousseau[2], Shaphan Y. Chia[3], Sali A. Ndindeng[4]

[1]Faculty of Agronomy and Agricultural Sciences, University of Dschang, Dschang, Cameroon
[2] International Institute of Tropical Agriculture (IITA), Cotonou, Benin
[3]International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
[4]Africa Rice Center (AfricaRice), Agri-food Systems, Crop based system, Farming systems and post-harvest, Côte d'Ivoire.
*mubehervemkh@yahoo.com

Amidst escalating global urbanization and population growth, the necessity to revolutionize food systems and redefine waste management strategies has become paramount. This study aimed to contribute to the evolution of protein resource diversification within animal feed and offer a sustainable solution for organic waste management using black soldier fly larvae (BSFL) in Bafia, Cameroon. A survey characterized waste production in both restaurants and households to assess their quantity and quality. Subsequently, collected organic wastes were subjected to two pre-treatments: heating (60°C) and fermentation (4 days), while another batch was used fresh as feeding substrates for BSFL in comparison to a broiler starter diet in a 17-day larval feeding experimental period. We evaluated the physicochemical properties of substrates, bioconversion, and growth parameters, adult BSF's life cycle traits, and the larvae's nutritional composition. Data collected were subjected to one-way ANOVA, and a post hoc test was performed using Fisher's LSD test to separate statistically different means. The survey highlighted a disparity in the disposal practices of food waste: restaurants tended to discharge waste indiscriminately (98%), while households commonly use waste as fertilizer (95%). In the experimental phase, heat treatment exhibited the highest substrate temperature and pH levels. Larvae reared on heated substrates showed superior daily weight gain (0.05/larva/day) and bioconversion rate (41.76%) compared to other substrates. Additionally, larvae from heat-treated substrates had the highest lipid (35%) and protein (29.89%) contents compared to all other organic waste treatments, although their protein content remained lower than that of the chick's starter diet, which had a higher value (37.53%). Notably, flies from larvae reared on heated substrates emerged two days earlier than those from other treatments. These early-emerging adults lived longer and produced more eggs than their counterparts. This study has revealed a stark contrast in the disposal practices of food waste between restaurants and households in Bafia. The findings underscore the potential of utilizing waste, especially after heat pre-treatment, to produce high-quality BSFL, offering sustainable protein sourcing in animal feed and efficient organic waste management.

Keywords: household waste, protein resource diversification, insect larvae, organic waste recycling, sustainable animal feed.

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Analysis of the edible insect supply chain in Mfoundi Division, Cameroon

Mube K. Hervé[1*], Ntouba M.W. Paulin[2], Dzepe Daniel[3], Kana J. Raphael[1], Shaphan Y. Chia[4]

[1]Faculty of Agronomy and Agricultural Sciences, University of Dschang, Dschang, Cameroon
[2]Institut Agricole d'Obala, Cameroon
[3]International Institute of Tropical Agriculture (IITA), Cotonou, Benin
[4]International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
*mubehervemkh@yahoo.com

Investigating the intricate dynamics of the edible insect supply chain holds paramount significance in understanding local food systems and socio-economic practices. This study aimed to analyze and delineate various facets of the edible insect supply chain in the Mfoundi Division, Centre Region of Cameroon, aiming to elucidate its stakeholders, practices, market dynamics, and socio-economic implications. A semi-structured survey was conducted involving 95 participants, encompassing inquiries into socio-demographic attributes, insect species consumed, harvesting seasons, marketing approaches, local culinary traditions, and respondents' attitudes towards edible insect consumption. The survey also delved into economic aspects such as selling prices, profit margins, and challenges encountered by stakeholders. Observations made during fieldwork supplemented the survey findings. Descriptive statistical analysis utilizing SPSS software was employed to analyze the collected data. Our findings reveal three distinct insect species sourced for food within the Mfoundi Division: *Rhynchophorus phoenicis* larvae, *Erythrophleum ivorensis* (caterpillars) and *Macroterme* sp. (Termites). Notably, *R. phoenicis* larvae are available throughout the year and sold alive, while the caterpillars and termites, traded dead, are exclusively harvested over a three-month period. Among the 95 sampled individuals, 42.21% were male, while 57.79% were female, predominantly under 40 years (83.16%), single (60%), Christian (88.42%), with 56.94% having attained higher education. Roasting is the preferred cooking method among consumers, accounting for 50%. The costs of insects escalate during periods of shortage, while insect consumption appears to have negligible effects on consumers' income. Several constraints were identified among stakeholders, notably the inaccessibility of specific inputs (28.6%) and the lack of food safety control (28.6%). We show that insects represent a valuable source of food in this region. Yet, limited knowledge and suboptimal practices among producers hinder profitability. Implementing awareness campaigns to educate farmers about insect farming and promote insect consumption is crucial for enhancing both knowledge and profitability in this sector.

Key words: edible insects, supply chain analysis, farmer knowledge, awareness campaigns, Mfoundi

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Insect Frass as a Sustainable Soil Amendment: Effects on *Brassica rapa* Growth and Root-feeding Herbivore Performance

Shaphan Y. Chia[1, 2*], Joop J.A. van Loon[2], Marcel Dicke[2]

[1]International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
[2]Laboratory of Entomology, Wageningen University & Research, Wageningen, the Netherlands.
* schia@icipe.org

Frass, a byproduct of insect rearing, has become popular for its potential use in sustainable agriculture. The rapid growth of insect production results in an increased frass output. The present study investigated the effects of frass as soil amendment on plant growth and resistance to insect herbivory. In greenhouse experiments, *Brassica rapa* L. (Brassicales: Brassicaceae) was grown in unamended soil (NoFrass; control) or soil amended with frass (2g/kg) from larvae of black soldier fly, *Hermetia illucens* L. (Diptera: Stratiomyidae) (BSFF) or yellow mealworm, *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) (MWF). Frass was applied raw ~~or~~ incubated before seed germination. Plant growth and performance of root-feeding *Delia radicum* L. (Diptera: Anthomyiidae) larvae were measured over a 42-day growth period. Initially, raw BSFF and MWF reduced the growth of *B. rapa* and resulted in a smaller leaf area than the control. However, over time, a notable trend emerged. While the difference in leaf area between MWF and control disappeared, BSFF consistently resulted in a smaller leaf area than MWF and control. Raw BSFF reduced *D. radicum* larval survival and pupal biomass. In contrast, raw MWF increased larval survival and biomass of *D. radicum*. Interestingly, incubation of frass in the soil for 16 days before seed germination removed plant growth inhibition and increased plant leaf area, especially for MWF compared to the control. Therefore, frass may be used as a sustainable and natural alternative to conventional organic fertilisers, promoting plant growth and enhancing resistance to herbivory. Our results indicate that soil amendment with raw BSFF may negatively impact herbivore performance, whereas raw MWF may enhance herbivore performance.

Key words: insect residual streams, organic fertiliser, pest management, *Delia radicum,* insect herbivory, insect-plant interactions

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Unraveling the physicochemical attributes of cricket (*Gryllus bimaculatus*) enriched biscuits and implications on preference and willingness to pay in Kenya

Divina Arama[1*], John Kinyuru[1], Jeremiah Ng'ang'a[1], Beatrice Kiage-Mokua[1], Brian O. Ochieng[2] and Chrysantus M. Tanga[2]

[1] Department of Human Nutrition Sciences, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2] International Centre of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya.
* kerubodivina@gmail.com

Disgust and neophobia elicited by whole insect products has necessitated the need to mask insect-based food products. The physico-chemical parameters, sensory acceptance, and willingness to pay (WTP) for wheat biscuits supplemented with cricket powder were evaluated. The biscuits' colour intensity correlated with the cricket inclusion levels. Spread ration of cricket-enriched-biscuits increased (1.0-1.2-folds), while the hardness and fracturability decreased (1.0-1.3-folds and 1.0-1.2 folds, respectively) compared to the control biscuit. Cricket-biscuits exhibited 1.2-1.7, 1.1-3.7, 1.2-3.0 and 1.1-1.2-folds higher ($p<0.05$) protein, ash, fiber, and fat, respectively. Ca, Fe, and Zn were 1.1-3.7, 1.1-1.2 and 1.4-4.0-folds higher, respectively, for cricket-based biscuits. Monounsaturated and polyunsaturated fatty acids proportionally increased with increasing cricket flour. On a Likert scale, 71.4 %, 71.9%, 38.4% and 57.5% of the caregivers and 38.6%, 58.3%, 40.0% and 34.0% for children (5-10 years) strongly preferred the colour, texture, taste, and aroma, respectively, of the cricket-based biscuits. Forty-seven (47%) of the caretakers were WTP a premium of 37 Kenyan shillings (0.34 USD) for cricket-based biscuits each. Our findings demonstrated that integration of cricket flour into existing market-driven consumer familiar food products significantly increased acceptability and WTP, thus promising potential to contribute to improved food and nutritional security.

Keywords: food supplementation, nutritional quality, sensory evaluation, caregivers, children

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Perception of consumers, nutritional composition of selected edible insects in Akwa Ibom State, Nigeria

Simon Idoko Okweche[1*], Martin Etimbuk Leo [1], Pius Agaji Oko[1], Chukwudi. Nwaogu[2,3]

[1]*Department of Forestry and Wildlife Resources Management, University of Calabar, Calabar, Nigeria*
[3]Department of Environmental Management, School of Environmental Sciences, Federal University of Technology, Owerri, Imo State, Nigeria.
[4]Department of Soil Science "Luiz de Queiroz", College of Agriculture, University of São Paulo, Piracicaba, Brazil.
* idokosi@unical.edu.ng

Malnutrition is widespread in developing countries including Nigeria. An alternative animal protein source like edible insects (EIs) can be used as substitute for conventional animal proteins because of its high nutrient content. This work is aimed at investigating the nutritional composition of EIs and consumers perception on the human and environmental health associated with the consumption of EIs in Akwa Ibom State, Nigeria. Survey and laboratory experiments were conducted to determine consumers perception and nutrient compositions of selected EIs in Akwa Ibom State. Structured questionnaires were administered to 450 respondents from nine Local Government Areas of the state to determine their perception towards consumption of termite (*Macrotermes bellicosus*), crickets (*Brachytrupes membranaceus*), palmweevil (*Oryctes rhinoceros*), and raffia palmweevil (*Rynchophorus phoenicis*). Fresh samples of *M. bellicosus* (adult)*, B. membranaceus* (adult)*, O. rhinoceros* (larva) and *R. phoenicis* (larva) were collected from the three zones of the State. The samples were collected and kept in well-ventilated plastic containers and were conveyed to the laboratory, Department of Physical and Applied Chemistry, University of Calabar, where they were utilized within 24 h. The samples were dried except the ones for moisture content and were crushed using pestle and mortar previously washed with acid. The homogenized samples were later dried for 3 h in the oven at 105°C. Proximate analysis was then conducted to ascertain the nutritional and mineral compositions of the EIs compared with chevon. Moisture content (MC) in EIs is between 4 and 17% compared with 69% MC in chevon. The EIs contained higher amount of protein (66% in *R. phoenesis* and 18% in chevon), carbohydrates (15-20 %) and metabolizable energy (ME) (1398kj/100g for crickets) when compared with chevon with 3% carbohydrate and 109 kj/100g ME. Similarly, EIs contained higher amount of macro elements, an essential component for human growth and development. Sodium (1120mg/100g in *M. bellicosus* and 82mg/100g in chevon), potassium (3380mg/100g in *M. bellicosus* and 385mg/100g in chevon), magnesium (145mg/100g and 3.33mg/100g in chevon). The amount of trace elements was significantly lower in EIs (Zinc 0.65-23mg/100g) compared with chevon (99mg/100g), iron (1.2mg/100g and chevon (905mg/100g). The consumption of EIs was found to have contributed significantly to the achievement of UN-SDGs especially the SDG 1, 2, and 3. Hence, more awareness should be created on the importance of EIs consumption and the training of farmers and household on the rearing of EIs by government and stakeholders.

Key words: edible insects, nutrient composition, mineral elements, SDGs, sustainability, chevon

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Microbial and sensory quality of crickets (*Gryllus bimaculatus*) flour preserved with ginger and garlic extracts

Jolly Oder Akullo[1, 2*], Beatrice N Kiage-Mokua[2], Dorothy Nakimbugwe[3], Jeremiah Ng'ang'a[4], John Kinyuru[4,5]

[1]Department of Animal Production and Management; Faculty of Agriculture and Animal Sciences, Busitema University, Soroti, Uganda
[2]Department of Human Nutrition Sciences; School of Food and Nutrition Sciences, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Department of Food Technology and Nutrition; School of Food Technology, Nutrition and Bio-engineering, Makerere University, Kampala, Uganda
[4]Department of Food Science and Technology; School of Food and Nutrition Sciences, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[5]African Institute for Capacity Development, Nairobi, Kenya
* jollyakullo@gmail.com

Insects are a vital food resource in many cultures in different parts of the world. Although spices have been used in food for centuries, little is known about their use to preserve insect-based foods. This study assessed the flour produced from blanched crickets treated with extracts of either ginger, garlic or both at a ratio of 1:4 (v/w) for microbial profile, sensory quality, and acceptability. Sodium benzoate treated and untreated cricket flour was used as positive and negative controls, respectively. The flour was stored at ambient conditions and analyzed on 0, 30, and 60 days of storage. Total microbial count, yeast and molds significantly decreased with storage duration ($p<0.05$), while fecal coliforms and Escherichia coli were not detected in any of the samples. At the end of the 60-day storage period, cricket flour treated with sodium benzoate and garlic extracts both had a significantly lowest population of yeast and molds (1.91 log cfu/g). On five point hedonic scale (1. Dislike extremely and 5. Like extremely), color (3.84±0.86 to 2.55±0.99), aroma (3.59±1.09 to 2.40±1.01), texture (4.11±0.97 to 3.11±0.97) and overall acceptability (3.77±0.64 to 2.83±1.01) sensory scores were all significantly high on day 0 and low on day 60 of storage, respectively. The study concluded that the cricket flours were microbiologically safe and acceptable to consumers. Further studies are required on longer storage longer as utilization of the flour in different food applications to determine its suitability.

Key words: Spice extracts, insect-based foods, cricket flour, storage, acceptability

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Insects as food: How good is insect protein to meet human requirement?

Nanna Roos[1*], Jan V Nørgaard[2], Navodita Malla[1]
[1]Department of Nutrition, Exercise and Sports, University of Copenhagen, Denmark.
[2]Department of Animal and Veterinary Sciences, Aarhus University, Denmark
*nro@nexs.ku.dk

The nutritional composition of edible insect differs widely between species and developmental stages (pupae, larva, and adult). Insects are equally to other animal-sourced foods considered a valuable source of protein, for food as well as for animal feed. To fully understand and release the potentials of mass-production of insects, insect protein from relevant species needs to be characterized for quality to ensure the best future applications. Protein quality is evaluated for the amino acid (AA) composition as well as for the digestibility of Indispensable AA. We assessed the protein quality using the 'Digestible Indispensable AA score' (DIAAS) method, conducted in ileum cannulated growing pigs. The DIAAS was determined for five commonly farmed species: Two mealworms (*Alphitobious diaperinus*, *Tenebrio molitor*), two crickets (*Acheta domesticus*, *Gryllodes sigillatus*) relevant for human food, and black soldier fly (BSF *Hermetia illucens*) mainly considered for feed. Digestible sulfur-containing AA (methionine/cysteine) was found to be the limiting AA to meet humans requirements above 3 years of age for the four species relevant for food, while BSF limited in lysine. Crickets were slightly superior in DIAAS than mealworm. For the comparison with other protein rich foods, the quantification of true protein should take into account that insects contain relatively high concentrations of non-protein nitrogen. The true protein content is therefore overestimated, while the protein quality (DIAAS) is proportionally underestimated. Recently reviewed studies conducted in humans have reported the bioavailability of insect AA and stimulation of muscle synthesis to be similar to whey protein.

Key words: protein quality, amino acids, human requirements

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Technological prediction of protein and fat in black soldier fly larvae

Frank Ssemakula[1,6*], Andrew Kabuye[2], Geoffrey Ssepuuya[3], Roseline Akol[1], Cosmas Mwikirize[1], Catherine Kunyanga[4], Rawlynce Bett[5], Dorothy Nakimbugwe[2], Andrew Katumba[1], Grum Gebreyesus[6]

[1]Department of Electrical and Computer Engineering, Makerere University, Uganda
[2]Department of Food Technology & Nutrition, Makerere University, Uganda
[3]Department of Food Science & Technology, Kyambogo University, Uganda
[4]Department of Food Science, Nutrition and Technology, University of Nairobi, Kenya
[5]Department of Animal Production, University of Nairobi, Kenya
[6]Center for Quantitative Genetics and Genomics, Aarhus University, Denmark
* Semakulafrank@gmail.com

The black soldier fly larvae (BSF: *Hermetia illucens*) has gained considerable attention as a sustainable alternative protein and fat source for animal feeds, attributed to their high levels of protein and fat. In this work we propose the use of FTIR spectroscopy and chemometric methods to predict the protein and fat content in BSF. Chemometric method is for providing the ground truth which can be extended to other technologies such as computer vision. FTIR provides quick, simple and non-destructive chemical nutritional composition analysis. Chemometric analysis is commonly used as a benchmark to compare results with other methods and has become the primary method for estimating protein and fat content due to its high precision, outstanding consistency, and universality. The experiment involves rearing BSF half-sibling families on different substrates, analyzing larvae protein and fat using FTIR, and chemometric methods. This research will examine the effect of substrate type and genetic distribution on the nutritional quality of BSF larvae, providing important information for improving rearing techniques using new emerging technology.

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Suitability of mealworm-enriched snacks and porridge for children in refugee and host communities

Dorothy Nakimbugwe[1*], Catherine Ndagire[2], Geoffrey Ssepuuya[3], Ribon Musoga Okot[1], Racheal Bugosera[1]

[1] Department of Food Technology and Nutrition, Makerere University, Uganda
[2] Department of Food Innovation and Nutrition, Mountains of the Moon University, Uganda
[3] Department of Food Science and Technology, Kyambogo University, Uganda
* dnakimbugwe@gmail.com

Adequate infant feeding is critical for the growth, development, survival and overall health of a child. This study aimed at developing mealworms enriched nutritious products suitable for complementary feeding to improve the nutrition status of children in refugee and host communities in Western Uganda. Composite flours and mealworm enriched snacks were made by extruding a mixture of mealworms, maize flour, sunflower seed oil and sugar at specific temperatures and frequencies. The extruded samples were used as ingredients in snacks and porridge and stored in airtight polyethylene bags at room temperature (22-25 ^{0}C). Sensory acceptability and descriptive profiling of the products were achieved using a 9 point hedonic scale and an 8-member trained panel respectively. Viscosity was assessed using a DVII viscometer (spindle 03, rpm of 5, 10 and 20). Data was analyzed using SPSS version 25. Overall, the snack and enriched porridge were acceptable by children in both the refugee and host primary schools (scores of 4.31 and 4.38 which correspond to 'like moderately' respectively). Generally, teachers from the refugee and host communities expressed willingness to consume the mealworm enriched snack and porridge frequently, i.e., three times a week. Ideal viscosity was 2640 cp (drinkable viscosity range is 2500-3000 cp) at 5 rpm. Mealworms are functionally a viable and acceptable ingredient of nutritious composite flour and snacks suitable for feeding children in refugee and host communities.

Keywords: Mealworms, Acceptability, Porridge, Snacks, Consumption frequency

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Black soldier fly (*Hermetia illucens*) larvae as a potential innovative and environmentally friendly tool for reducing parasitic gastrointestinal nematodes in livestock manure

Rawlynce Bett* and Felix Kibegwa

Department of Animal Production, Faculty of Veterinary Medicine, University of Nairobi
* rawlynce@uonbi.ac.ke

Helminth infestation in domestic animals have traditionally been controlled using anthelmintics (AHs). However, many years of intensive and incorrect use of AHs, together with poor-quality products, have culminated in the rapid development of anthelmintic resistance (AR) in domestic animals, threatening continued use of these vital drugs. Since some of these parasites are zoonotic and capable of producing patent infections in people, the prospect of AR developing in humans cannot be disregarded any longer. Development of alternative strategies to AHs has therefore becomes imperative. This study was undertaken to evaluate the effectiveness of using black soldier fly larvae (BSFL) as a potential alternative to anthelminthic treatment in reducing parasitic gastrointestinal nematodes in livestock manure. Faecal samples were collected from 12 sheep reared at the Kenya Agricultural and Livestock Research Organization, Veterinary Research Institute, Muguga. The samples were divided into two portions. From a subsample of the first portion, faecal egg counts (FEC) were determined, using the Modified McMaster Techniques, before and after incubating the samples for 10 days with BSFL larvae. The second portions were cultured for 10 days after which the determination of nematode larvae species and numbers present was done on a subsample. Thereafter, BSFL were introduced to the remaining frass with nematode larvae, and incubated for 10 more days, after which the nematode larvae present were again determined. A comparison was then made between the before and after BSFL introduction for the FEC and nematode larvae. The results indicated that there were statistically significant differences between the pre and post BSFL inoculation for the FEC and nematode larvae. The mean FEC reduced from 1,659 epg to 50 epg ($P<0.001$). Similarly, the mean number of larvae reduced from 44 to 28 ($P= 0.006$). The findings indicate that BSFLs are a viable biological helminth control strategy that farmers can easily adopt and implement.

Key words: nematodes, dorper sheep, black soldier fly larvae, biological control, manure

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Amendment of soil with black soldier fly frass fertilizer improves plant direct defences

Daniel M. Mutyambai[1,2*], Johnstone Mutiso Mutua[1,3], Abdul A. Jalloh[1,4], Dennis Beesigamukama[1], Fathiya Khamis[1], Sevgan Subramanian[1], Thomas Dubois[1], Sunday Ekesi[1], **Chrysantus M Tanga**[1]

[1]International Centre of Insect Physiology and Ecology, Nairobi, Kenya
[2]Department of Life sciences, South Eastern Kenya University, Kitui, Kenya.
[3]Department of Biochemistry, Microbiology and Biotechnology, Kenyatta University, Nairobi, Kenya.
[4]Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa.
* dmutyambai@icipe.org

Soil amendment with insect frass and exuviae influences soil health with positive consequences for plant growth and development. Black soldier fly (*Hermita illucens*) frass fertilizer (BSFFF) is a residual stream from the insect's production for feed and can be used as a soil amendment. However, there are limited studies that have examined the effect of soil amendment on insect pest resistance and the underlying mechanisms. In this study, we investigated the impact of amending soil with BSFFF on maize defense genes and larval feeding of invasive *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Maize plants were grown on soil amended with BSFFF, synthetic fertilizers and unamended control soils. We evaluated plant growth by measuring maize plant height, chlorophyl concentration and biomass accumulation at different levels of growth and development. Maize defense genes; pathogenesis related protein 5 (*pr-5*), maize proteinase inhibitors (*mpi*) and lipoxygenase 3 (*lox-3*) were highly expressed both constitutively and inductively in maize planted on BSFFF-amended soil than on synthetically fertilized and non-amended soils. *Spodoptera frugiperda* larvae consumed significantly less leaf tissue on plants grown on BSFFF-amended soils than synthetically fertilized and unamended soils. Maize plants grown on BSFFF-amended soils had higher height, chlorophyl concentration and biomass accumulation than those grown on synthetic fertilizers and non-fertilized soils. There was significant negative correlation between expression levels of *mpi* defence gene and larval feeding. Our results show that soil amendment with BSFFF strengthens plant defense mechanisms and do so without negatively affecting plant growth and productivity. Thus, soil amendments with BSFFF can be used as a potential strategy for crop protection against herbivore pests for food security.

Key words: black soldier fly frass fertilizer, insect resistance, *Spodoptera frugiperda*, plant performance, soil health

Insects in Social and Economic Contexts

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Futuristic nomenclature for edible insect: 'Entoculture' as a practice of farming insects and 'entomeat' as flesh of harvested insect

John Kinyuru[1,2*], Jeremy Ng'ang'a[2], Shaphan Y. Chia[3], Dennis Beesigamukama[3], Chrysantus M. Tanga[3], Johnson Kinyua[2]

[1]African Institute for Capacity Development, Nairobi, Kenya
[2]Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]International Centre of Insect Physiology and Ecology, Nairobi, Kenya
*jkinyuru@agr.jkuat.ac.ke

Insects as food and feed is gaining momentum as a sustainable solution to global food security. This paper explores the conceptualization of a futuristic nomenclature for edible insect farming, introducing the term 'Entoculture.' Rooted in 'entomo' for insects and 'culture' for cultivation, 'Entoculture' encapsulates the cultivation of insects for both food and feed. 'Entoculture' represents a paradigm shift towards embracing insects as a mainstream food and feed source. It acknowledges the need for a systematic and sustainable approach to insect farming, aligning with the principles of conventional agriculture. This involves controlled environments, optimized diets, and efficient resource utilization to maximize insect growth and harnessing their nutritional value. The term positions insect farming as a deliberate and progressive cultural practice, fostering recognition, acceptance and understanding among diverse global community of consumers. As a product of the 'Entoculture' practice, the paper introduces 'Entomeat'. This term embodies the harvested essence of insects, drawing inspiration from the characteristic edible parts from harvested insects that can be utilized as food and feed). Entomeat serves as a versatile and inclusive representation of various edible insects, aiming to transcend cultural and culinary boundaries. It emphasizes the lightness and positivity associated with a dressed body of a meat animal, fostering a positive association with insect-based food and feed products. The paper proposes 'Entoculture' and 'Entomeat' as interconnected concepts, envisioning a future where insect farming is seamlessly integrated into mainstream agriculture and dietary habits. By framing insect cultivation as a cultural practice and offering a product with an appealing and neutral name, this approach aims to mitigate potential resistance and elevate the status of edible insects in the global food landscape. As 'Entoculture' and 'Entomeat' become ingrained into edible insects' discourse, thereby contributing to the broader conversation about sustainable and resilient food systems, aligning with the imperative to nourish a growing world population.

Key words: insects and insect products, insect production and consumption

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Improving the health, incomes, and nutrition of refugee communities through the rearing of insects: The approach of the RefIPro project in Kyaka II Refugee settlement, Uganda

Violet Gwokyalya[1*], RefIPro consortium[2]

[1] Mothers Against Malnutrition and Hunger, Uganda
[2] Research and Action for Income Security, Denmark
[2] University of Copenhagen, Denmark
[2] International Centre of Insect Physiology and Ecology (*icipe*), Kenya
[2] Makerere University, Uganda
[2] Bobo Eco Farm, Uganda
*gwokyalyav@gmail.com

Introduction: Uganda has one of the largest refugee populations in the world, and levels of poverty are high among the refugee populations. Refugees have very limited access to land and resources, suffer inadequate access to nutritious food and very limited income-generating opportunities; yet the WFP has since 2020 reduced the food rations by 60%. Edible insects hold potential for refugees to access nutritious food, and refugees can generate income from insects. Since August 2022 the Refugee Insect Production for Food and Feed (RefIPro) project is supporting the refugee communities in Western Uganda to produce the Black Soldier Fly Larvae (BSFL) and the yellow mealworm. **Objectives:** 1) Improved nutrition and health of refugee and host community children through the production of mealworm, and 2) Improved incomes of refugees and host community members through production of Black Soldier Fly Larvae for sale as animal feeds. **Methods:** Refugee farmers organized into associations, are trained in insect rearing and registered into an insect farmers' union for support in sustained insect production. BSFL breeding centres are established in the community for easy access to eggs or young larvae. Schools receive a rearing unit and student clubs are trained in mealworm rearing then supported by a teacher patron, the parent teacher association (PTA) and the district mealworm club composed of head teachers. **Results:** Nine hundred and sixty-five (965) farmers have been trained in BSFL rearing and 4 breeding centres established, up to 262 farmers have started earning an income of up to 21,000 Ugx per month from the sale of BSFL. Ten (10) schools with 21,650 pupils were trained and equipped with yellow mealworm rearing units and are growing their stock to start the feeding. An RCT is scheduled in two schools (N=250) to document the effect of adding mealworm to school meals on health and nutrition indicators of school children.

Key words: refugees, insect production, incomes, nutrition

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Do cognitive and experiential factors drive the adoption of insect farming among farmers in Africa? Evidence from three countries

Mohammed Hussen Alemu[1*], Søren Bøye Olsen[1], Jacob Paarechuga Anankware[2], Philip Nyeko[3], Monica Ayieko[4], John Kinyuru[5], Silvenus Konyole[6], Nanna Roos[7]

[1]Department of Food and Resource Economics, University of Copenhagen, Denmark
[2]Department of Horticulture and Crop Production, University of Energy and Natural Resources, Ghana
[3]Department of Forestry, Biodiversity and Tourism, Makerere University, Uganda
[4]Department of Plants, Animals and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, Kenya
[5]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Kenya
[6]Department of Nutritional Sciences, Masinde Muliro University of Science and Technology, Kenya
[7]Department of Nutrition, Exercise and Sports, University of Copenhagen, Denmark
*mha@ifro.ku.dk

In the last decade, edible insects have emerged as a high-quality protein source for both humans and animals. This represents a shift from perceiving insects solely as traditional foods to acknowledging them as an alternative animal protein. This shift positions insects as mini livestock, offering a solution to sustainability challenges faced by smallholder farmers. While efforts focus on entrepreneurial ventures, there is lack of knowledge on why (why not) farmers adopt insect farming for household consumption—an essential element for achieving food security. In this study, we present evidence regarding the drivers of adoption of insect farming for consumption based on large cross-sectional surveys conducted in three African countries – Ghana, Kenya, and Uganda. Our regression analyses reveal that cognitive factors, including risk attitude, perceived benefit and control, and knowledge are important determinants of adoption. Farmers with risk-taking attitudes are more willing to adopt insect farming, as are those who find it beneficial and simple. Experiential factors, such as prior insect-serving experience and information from sources like religious and community organizations, positively influence willingness to adopt. Young men and risk-taking women are more willing to adopt. Conversely, factors like cultivated land size, distance to markets, and household dietary diversity are associated negatively with adoption, except for households where insects contribute to dietary diversity. Our results have important policy implications. First, the findings suggest that promoting insect farming among households with lower dietary diversity can be a relevant strategy. Second, enhancing farmers' knowledge and skills may increase their perceived level of control to engage in insect farming. Third, interventions should target farmers with a risk-averse attitude by emphasizing the benefits of insects as food and addressing marketing constraints. Fourth, religious and community organizations can serve as crucial information channels to promote insect farming.

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Scaling insect farming in sub-saharan Africa: Implication for circular economy and green growth

Zewdu Abro[1]*, Ermias Engida Legesse[2], Chrysantus M. Tanga[1], Dennis Beesigamukama[1], Sevgan Subramanian[1], Julius Ecuru[1], Tadele Tefera[3], and Menale Kassie[1]

[1] International Center of Insect Physiology and Ecology (*icipe*), Nairobi, Kenya
[2] University of Bonn
[3] International Center of Insect Physiology and Ecology (*icipe*), Addis Ababa, Ethiopia
*zabro@icipe.org

With the global population projected to reach 9 billion by 2050, the gap between food supply and demand is expanding due to limited resources, climate change, geopolitical unrest, and inefficient waste management. Insect farming emerges as a sustainable and efficient solution, transforming organic waste into nutrient-rich feed and biofertilizers with reduced environmental impact. As a nascent sector, however, there is lack of evidence on the potential economic and environmental impact of insect farming. Using a computable general equilibrium modeling approach, we studied the potential economic and environmental impact of scaling Black soldier fly (BSF) farming in sub-Saharan Africa. Preliminary results from Kenya indicated that exploiting 25% of the biowaste in the country for BSF farming could create employment for more than 236,000 people, lift 170,000 people above the poverty line, and reduce greenhouse gas emissions by 1 million tonnes per annum. Our results further suggest that the substitution effect of BSF farming is huge, substituting fishmeal and soybeans by 33-38%, and chemical fertilizers by 19% if the country exploits just 25% of the biowaste. These findings call for designing policies that can integrate an efficient waste management system with insect farming. Such policies can support the existing small but growing number of insect farming agribusinesses.

Keywords: frass fertilizer, circular economy, edible insects, feed protein, food security, green growth, job creation

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Eco-innovative technologies for improved nutrition, sustainable production, and marketing of agroecological food products in Africa: The INNO ECOFOOD project

John Kinyuru[1,2*], Florence Kyalo[1], Gareth Kituu[1] on behalf of the INNOECOFOOD consortium

[1]Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]African Institute for Capacity Development, Nairobi, Kenya
*jkinyuru@agr.jkuat.ac.ke

The project aims to establish innovative production/ business ECOHUBS and improve local aquaculture cage farms in lakes and rivers using AI and IoT in six diverse African countries. INNOECOFOOD Project will train rural farmers, youth, and women to innovatively produce and process nutritious selected insect value chains at pilot/large scale level into certified marketable human food products and feed. This farm to fork approach will be achieved by using climate smart sustainable local resources, innovatively designed ECOHUBs. The project will establish four sustainable and innovative agribusiness rural ECOHUBS using renewable solar/ wind energy for the production, processing, and marketing of insect species in diverse African countrie. Sustainable production of selected insect species and post-harvest processing will be optimized using AI sensors and IoT technology in the ECOHUBS. New food and feed products will be development from insects and the nutritional and sensory quality, microbiological and chemical safety, consumer acceptance, life cycle analysis (LCA) impact evaluated. A total of 120 youth and 120 women in person in four ECOHUBs will be trained on production, food quality and safety and business and marketing of insect products to improve income. The training will also be digitized and made widely available hence training over five thousand community members and farmers through digital technology. The project will closely partner with certification stakeholders including trade ministries and border management. Project data and information gathered on the ECOHUBs, via research and commercial publications, media channels and workshops, internet, mobile apps and conferences will be disseminated. The project is supported by Horizon Europe CALL CL6-2023 FARM2FORK-01-19: Support to the markets and trade of agroecological food products under the Food and Nutrition Security and Sustainable Agriculture (FNSSA) partnership (Innovation Action).

Key words: edible insects, value chains, living labs, ECOHUBS

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Effect of training on farmers knowledge, and willingness to use and pay for fertigro (organic fertilizer made from BSF) in Meru and Bomet Counties, Kenya

Maurice Kimani[1]*, Mary M. Mutisya[1], Martha Arinaitwe[1], Steve Baleba Soh[2], Doreen Njeri Oguttu[1] and Talash Huijbers[1]

[1]Insectipro Company Limited, P.O BOX -00100, Julian Road, Limuru, Kenya
[2]Max Planck Institute for Chemical Ecology, Department of Evolutionary Neuroethology, Hans-Knöll-Straβe 8, 07745 Jena, Germany
* maurice@insectipro.com

Insect mass rearing systems produce huge quantities of frass (a combination uneaten substrate, the insects' faeces, and exuviae-chitin and chitosan) with a great potential for improving soil and crop productivity. From our previous studies, fertigro (an organic fertilizer produced by insectipro using black soldier fly larvae frass (BSFF) has been shown to accelerate crop growth, improve yields by 30-50% and reduce the prevalence of pests and diseases drastically. Despite the great potential of the fertilizer to sustainably salvage the deteriorating situation of Kenyan soils, farmers in many counties have little to no knowledge on fertigro, and how to use it for optimum benefits. To evaluate the impact of training on increasing farmer knowledge and willingness to use and pay for fertigro, we established distribution hubs and demo plots in Bomet and Meru counties, Kenya, and engaged field agents to train farmers on proper use of fertigro as well as other good agronomic practices for optimum yields for 5 months. A well formulated questionnaire was developed and data collected in both counties to establish the impact of our trainings on farmer knowledge, willingness to use and pay for fertigro, as a strategy for improving household food and nutritional security, and revenue collection for our company, all geared to achieving SDGs 1,2,5,8,9,10,12 and 13. The results of the study were that a total of 2762 farmers were trained in both counties, 1694 in Meru and 1068 in Bomet. Generally, more males than females were trained. More than 80% of farmers in the targeted regions confessed to have gained knowledge on fertigro through the trainings and were willing to purchase and use the product. This was mostly influenced by the results seen on the demo plots, and the explained long term benefits by our field agents. Most farmers were comfortable paying the fertilizer price of Ksh 1500/50kg bag, compared to the government's subsidy of Ksh 3500. Also, over 90% of the interviewed farmers testified to have improved their knowledge on good agronomical practices. Through our approach, we were able to have increased fertilizer sales. Our conclusion from the study was that farmer education through trainings increases farmer knowledge, willingness to use and pay for farm inputs such as fertigro, contributing to increased food security and commercial agriculture for smallholders and those in agribusiness.

Keywords: fertigro, demo plots, training, farmer knowledge, willingness to pay, use

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Improving the nutrition of school children in refugee settlements through the production of the yellow mealworm: a pilot intervention in Kyaka II Refugee settlement

Violet Gwokyalya[1*], Edward Ssebbombo[2], Michael Skaarup[3], Rasmus Schjødt[3]

[1]Mothers Against Malnutrition and Hunger,
[2]Bobo Eco Farm,
[3]Research and Action for Income Security
* gwokyalyav@gmail.com

Uganda has one of the largest refugee populations in the world, with high levels of malnutrition among both refugee and host community populations. Nearly half of the children in refugee settlements suffer chronic undernourishment and 20-25% are acutely malnourished. Insects are rich sources of nutrients and can fight malnutrition. We introduced the first ever yellow mealworm production in Uganda in 10 schools in Kyaka II Refugee settlement to combat child malnutrition. To demonstrate feasibility of producing and the acceptability of yellow mealworms in schools for improved nutrition. Pupils are organized into mealworm clubs and trained in mealworm rearing with the guidance of a patron, and schools receive rearing kits. School entry includes engagement with school administration, parents and teachers plus feeding demonstrations with mealworm fortified meals. We interviewed 391 parents, 158 teachers and 2000 students on knowledge, attitudes, and perceptions on the use of the yellow mealworm in school meals and (children's) willingness to consume mealworm fortified meals. All 10 schools with 21650 students established mealworm rearing, 94% of parents tasted the mealworm and 90% recommended mealworm fortified meals for their children. All teachers tasted and recommended the mealworm to children. Ninety six percent (96%) of children liked the mealworm fortified porridge and all requested to engage in mealworm rearing. The production and use of yellow mealworms in schools is acceptable and feasible. A follow-on study is under way by a consortium of 6 organizations from Denmark, Kenya, and Uganda to document the effect of mealworm fortified meals on health and nutrition indicators of school children and contribute knowledge on the potential for edible insects to improve children's gut health.

Key words: mealworm, fortified meals, nutrition, school children, acceptability

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Effect of Perceived Usefulness and Ease of Use of Cricket Farming Technology on Adoption Intention of Smallholder Farmers in western Kenya

Charles Adino Ngónga[1*], Monica. A. Ayieko[1], Kelvin Mashisia Shikuku[2]

[1]Department of Agricultural Eonomics and Agribusiness Management, Jaramogi Oginga Odinga University of Science and Technology
[2]International Livestock Research Institute, Kenya
* ngonga.charles30@gmail.com

Cricket farming is being championed due to its propitious disposition in addressing malnutrition, environmental, and economic challenges. However, the farming uptake among rural households is still low in Kenya. We investigated farmers' intention to adopt cricket farming which is critical for achieving the intended social, economic, and environmental benefits of insect farming in western Kenya. Technology Acceptance Model (TAM) has widely been used to predict technology acceptance given its robustness, persuasive and parsimonious features. This study used extended TAM constructs that incorporates determinants of Perceived ease of use (self-efficacy, facilitating conditions, anxiety, playfulness, perceived enjoyment, objective usability) and Perceived Usefulness (voluntariness, subjective norm, image, relevance, result demonstrability, output quality) to determine adoption intention. A structured questionnaire with a five-point Liker-scale of strongly disagree to strongly agree was designed and face to face interviews were conducted by trained enumerators. Partial Least Square Structural Equation Model (PLS-SEM) approach was used to explore the paths among the constructs and to predict the inter-relationship among observable and latent variables in the conceptual model. Smart PLS 3.0 was be used to examine the structural model and hypothesis. To estimate t-statistics to check for statistical significance of the standardized path coefficients (β), a bootstrapping procedure with 5,000 sub-samples was applied. Perceived benefit of cricket farming may positively affect the intention to adopt the technology hence its actual use.

Key Words: cricket farming, adoption, technology acceptance model

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The Edible Insects of Tanzania; Current Potential and Future Opportunities

Mmari M. M[1,2*], Suleiman Rashid[1], J.N. Kinyuru[3]

[1]Sokoine University of Agriculture, Department of Food Science and Agro-processing, Morogoro, Tanzania
[2]The Open University of Tanzania, Department of Biology and Food Sciences, Dar es Salaam, Tanzania
[3]Jomo Kenyatta University of Agriculture and Technology, Department of Food Science and Technology, Nairobi, Kenya
* mercy.mmari@out.ac.tz/mmarimercy@gmail.com

Edible insects are considered the fastest-growing alternative protein market in the world. The practice of eating insects by humans is known as human entomophagy, and people throughout the world have been eating edible insects as a regular part of their diets for millennia. It is considered safe as there are no reported cases of disease transmission, parasitoids, or heavy metals contamination to humans from the consumption of insects. The field of Entomophagy is under- researched in Tanzania, and there are no specific policy issues for it. Despite the fact that edible insects are reported to contain more nutrients like protein, fats, vitamins, and minerals of high value compared to other conventional sources, bioactive compounds, and medicinal traits, there is limited data. There is no information on the occurrence, habitats, indigenous processing methods, cultures, beliefs, nutritional composition and value addition of the edible insects of Tanzania. This writing is looking at the literature, the internet, online survey and chronological reports on the edible insects of Tanzania. Several tribes in Tanzania are known to have edible insects as part of their traditional diets with cultural significance, and some treat them as respectable delicacies. Commercialization and consumption of processed edible insects such as longhorn grasshopper (*senene*) is increasing countrywide. There are several farms identified in Tanzania that are practicing insect rearing primarily for animal feed. There are different value-addition possibilities with scaling up potential focusing on nutrition improvement in traditional diets and livelihood improvement to low-income societies. Innovations in the value addition of edible insects have potential to fight malnutrition and poverty following increased commercialization.

Keywords: edible insects, Tanzania, senene, innovation, technology

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An exploratory study of edible insects along an altitude transect in Western Kenya

Nyakeri E[1], Mweresa C[1], Ayieko A[1],Awuor C[1]; Oyieke H[2], Kioko E[2], Mutua M[2], Achieng J[2]

[1]Jaramogi Oginga Odinga University of Science & Technology; [2]National Museums of Kenya;
* evans.nyakeri@gmail.com

Food insecurity is a topical global challenge. Kenya's, Western region is more protein insecure compared to Central and Rift valley areas though its major economic activity is fishing. In Nyanza, 22.7, 2.0 and 7.4% of children under five years of age are moderately, severely stunted and underweight respectively (KNBS, 2014; Milner et al., 2014). The quest to promote use of traditional but underutilized food resources may be a remedy. Edible insects, a food of choice of yore, are a novel source of nourishment with several advantages over conventional types. An exploratory field study was conducted by Jaramogi Oginga Odinga University of Science and Technology and the National Museum of Kenya to (i) document indigenous knowledge on the insect consumption (ii) Establish the current status on the consumption of edible insects within the region and (iii) collect representative specimens of edible and other important insect species from diverse ecosystems for establishment and stocking of a robust repository for future reference, research, training and capacity building. The study used questionnaires, Focused Group Discussions (FGDs) and insect collection techniques in three selected sites along a transect based on altitude namely highland, midland and low land areas. Insect collection was done by use of time limited search techniques such as aerial nets, sweep nets and aspirators; use of pan traps and pitfall traps. Entomophagy was reported in all three study counties by different communities and the old are more conversant compared to the young generation. A total of 14 insects were identified as edible in the area albeit with different consumption patterns. Different species of alate termites are a universal delicacy across the transect study areas while black ants, crickets, cow dung beetle, caterpillars, grasshoppers and locusts, honey bee brood, carpenter bees, cow ticks, armyworms, locusts, lake flies and Galianthus beetle have specific geographical niche areas where they are consumed greatly influenced by culture. Again, consumption is noted to decline with age of participants (majority of those below 40 do not consume while 60% of those above 60 years consume). The harvesting, processing and consumption of edible insects is influenced by season, gender, age. Harvesting and processing is confined to children and women. Over 29041 insect specimens were collected during the study belonging to 14 orders with the most dominant belonging to orders Collembola, Hymenoptera and Diptera while Blattodea, Odonata, Mantodea, Opiliones, Isopoda and Acari had the least members. 78.2% of insect collected were from Bungoma (though with the least diversity), 5.5% from Kakamega and 16.3% from Siaya county (but with highest diversity). The pattern corresponds to conservation efforts in the three sites. There is therefore need to create awareness on the importance of conservation and entomophagy as an alternative source of nutrition and livelihood.

Key words: edible insects, transect, Western Kenya

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Challenges and opportunism for edible insects in Uganda

James P. Egonyu

Faculty of Agriculture and Animal Sciences, Busitema University, Soroti, Uganda
jpegonyu@gmail.com

Insect consumption is rapidly evolving as a viable environmentally friendly solution to malnutrition and food insecurity in many parts of the world. This is because, insects are rich in nutrients and their production generates low ecological footprints. Uganda has a rich culture of consuming insects such as grasshoppers, termites and palm weevil larvae, depending on the cultural norms of the diverse ethnicities. It is also endowed with many species of insects like rhinoceros beetle larvae and saturniid caterpillars, which are locally shunned, but are delicacies in other countries. A key set back to edible insects industry is reliance on wild harvests which are threatened by aggressive harvesting techniques, encroachment on their breeding habitats, and climate change among other factors. Other key limitations are inefficient technologies for their production and processing, and phobia from some communities based on ethnicity, age and gender. This presentation highlights some key research findings towards addressing bottlenecks in the value chains of edible insects in Uganda and beyond. These entail improvements in harvesting, rearing and processing technologies, analyzing cultural practices on entomophagy, assessing nutritional value and safety of edible insects for human consumption, their preservation and development of insect enriched food products which could be more appealing to consumers. More intensive research is needed on developing insect production value chains [e.g., rearing protocols, processing, value addition and marketing]. Attitude change and value addition to make insects more palatable is critical.

Keywords: farming, harvesting, processing, safety, value addition

Insects for the Green Economy Conference

Theme: **Sustainable Food Systems and Livelihoods in Africa**

Date	**28th – 29th February 2024**
Venue	The African Institute for Capacity Development (AICAD) at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya.