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Leibniz Institute for Agricultural Engineering and Bioeconomy e.V. (ATB)
Max-Eyth-Allee 100
D-14469 Potsdam
Germany
Tel: (0331)-5699-0
Fax: (0331)-5699-849
E-mail: atb@atb-potsdam.de
Internet: www.atb-potsdam.de

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Editors:

Giacomo Rossi
Dr. Oliver Schlüter
Dr. Marios Psarianos
Dr. Shikha Ojha
Dr. Sara Hadjiali
Dr. Thomas Piofczyk

Bibliography of cover photos
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(1) Manuel Gutjahr, ATB, Potsdam
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(3) Jessica Lietze, ATB, Potsdam
(4) Helene Foltan, ATB, Potsdam
(5) Manuel Gutjahr, ATB, Potsdam
(6) Susanne Klocke, ATB, Potsdam

Layout:

Anke Kemnitz

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Preface

The 9th INSECTA International Conference is organized by the Leibniz-Institut für Agrartechnik und Bioökonomie e.V. (ATB) and the Pilot Pflanzenöltechnologie Magdeburg e.V. (PPM) on May 14, 15, and 16, 2024. The conference, hosted for the first time at the main ATB campus and the business promotion bank of the federal state of Brandenburg (ILB), Potsdam, Germany, aims to provide an overview of the state-of-the-art in insect utilization along with the prospects and constraints of using insects for food, feed and non-food purposes in Europe and worldwide. This publication contains the abstracts of all oral and poster presentations at this conference.

ATB and PPM alternate responsibility for conference leadership on an annual basis. PPM initiated INSECTA 2015 in Magdeburg and took the leadership in 2016 (Magdeburg), 2018 (Giessen), 2021 (Magdeburg), and 2023 (Magdeburg). ATB was responsible for the organization in 2017 (Berlin), 2019 (Potsdam), 2022 (Giessen), and 2024 (Potsdam). This year, we are delighted to be guests at the ILB for the opening day and to invite you to the Center for Research and Communication in a Circular BioEconomy (CIRCLE) of ATB for day two and three of the conference.

INSECTA 2024 aims to sustain the success of recent congresses and to ensure its impact in insect science and technology for both industry and academia, as well as to bridge insect farming with insect processing and biotechnology. The theme of the conference is "*Insects in circular bioeconomy*" with emphasis on insects as food, feed and non-food applications for resilient and sustainable agri-food systems. This conference aims to bring together industry and research innovation, helping to discover innovative perspectives of insect technology. We have compiled a broad scientific program consisting of five central conference themes: i) Insect rearing and production systems, ii) Insect processing for food and feed, iii) Safety and environmental aspects, iv) Non-food applications of insects, and v) Animal welfare, ethical and legal aspects.

Within the conference, we offer a special platform for intensive and trustful professional exchange between newcomers and experts as well as academia and industry. In total, the conference has attracted 130 presentations from 36 countries. In the conference period of three days, four keynote lectures and 52 oral presentations are arranged in four plenary and 12 parallel sessions. Additionally, 65 posters and 11 company stands will be displayed for further discussion and exchange. A hybrid meeting of the COST Action (CA22140) on Improved Knowledge Transfer for Sustainable Insect Breeding (Insect-IMP) and a joint workshop organised by two EU projects (CiproMed and Advagromed) will also be hosted on the last day of the conference.

Finally, as the chairpersons of the conference, we would like to express our sincere gratitude to the authors, members of the scientific committee, sponsors and supporters for their valuable contribution.

Oliver Schlüter, Thomas Piofczyk, Giacomo Rossi Potsdam, May 2024

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About the venue

The Leibniz Institute of Agricultural Engineering and Bioeconomy e.V. (ATB) is a nationally and internationally networked research centre, working in the agricultural engineering and bioeconomy research fields.

Founded in 1992 as Institute for Agriculture Engineering Bornim e.V., ATB immediately became part of the Blue List, later named Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (WGL), today Leibniz Association. Following the increasing research outputs in the bio-economy and sustainable production fields, the institute was officially renamed on September 1, 2016, becoming “Leibniz Institute for Agriculture Engineering and Bioeconomy”.

Today, ATB is an international recognized institution, which research is guided by the idea that a circular, diversified, innovative and sustainable bioeconomy produces healthy food for all, operates on the basis of renewable raw materials and facilitates the realization of the One Health concept for humans, animals and the environment.

ATB has state-of-the-art infrastructures, including special laboratories, large-scale equipments (atmospheric boundary layer wind tunnel), pilot plants (pilot plant for lactic acid , pilot plant for natural fibre processing) and experimental facilities (e.g. the Field Lab for Digital Agriculture in Marquardt) as well as the Leibniz Innovation Farm for Sustainable Bioeconomy, a real-lab for sustainable circular bioeconomy, which is currently being established.

The peculiar interdisciplinary approach of the institute, covering a broad spectrum of methods from the natural, engineering and economic sciences, and the constant dialogue with society, enables ATB to effectively contribute on solving socially relevant issues and to continuously transfer knowledge into the modern economy.
Through a 360-degree approach, spacing from basic research to final application, ATB aims to create a solid knowledge-based scientific foundation, with the goal of transforming the agricultural, food, industrial and energy systems into a comprehensive bio-based circular economy.

The research carried out at ATB is structured in five well-integrated program areas:

- Diversified crop production
- Individualized livestock production
- Healthy foods
- Multifunctional biomaterials
- Integrated residue management

Aligning to the ATB main goal and focusing on the three main drivers of diversification, digitalisation and microbiota management, each program area works in strict connection aiming to create and promote a sustainable intensification of traditional and innovative production systems and improving the quality of life.

Program

May 14, 2024: ILB-Potsdam (Babelsberger Straße 21, 14473 Potsdam, Germany)

3:00 pm	Registration
4:15 pm	Welcome – Opening remark
4:30 pm	Keynote 1 – Andreas Vilcinskas *(Justus Liebig University of Giessen – Germany)*
5:10 pm	Keynote 2 – Gertje Peterson *(LAVES – Germany)*
5:50 – 6:50 pm	Company presentation session
6:50 – 7:00 pm	Organisational information
7:00 – 9:00 pm	Get-together

May 15, 2024: ATB-Potsdam (Max-Eyth-Allee 100, 14469 Potsdam, Germany)

7:30 am	Bus shuttle from Potsdam main station to ATB
7:30 am	Bus shuttle from Potsdam Luisenplatz to ATB
8:00 am	Registration
8:30 am	Keynote 3 – Sergiy Smetana *(DIL e.V. – Germany)*
9:10 am	Informal greeting – Thomas Schneider *(BMEL)*
9:40 -10:00 am	Coffee break + poster session
10:00 – 11:20 am	Parallel sessions
11:20 – 11:40 am	Coffee break + poster session
11:40 – 01:20 pm	Parallel sessions
1:20 – 2:20 pm	Lunch break + post session + company demonstration
2:20 – 4:00 pm	Parallel sessions
4:00 – 4:20 pm	Coffee break + poster session
4:20 – 5:40 pm	Parallel sessions
6:00 – 6:30 pm	Bus shuttles from ATB to conference dinner
7:00 – 10:00 pm	Boat tour + conference dinner

May 16, 2024: ATB-Potsdam (Max-Eyth-Allee 100, 14469 Potsdam, Germany)

7:30 am	Bus shuttle from Potsdam main station to ATB
7:30 am	Bus shuttle from Potsdam Luisenplatz to ATB
8:00 am	Registration
8:30 am	Keynote 4 – Laura Gasco *(University of Turin, Italy)*
9:10 – 10:10 am	Workshop: “Presentation of Cipromed and Advagromed projects”
10:10 – 10:30 am	Coffee break + poster session
10:30 – 11:50 am	Parallel sessions
11:50 – 12:50 pm	Finger food + poster session
12:50 – 2:10 pm	Parallel sessions
2:10 – 2:45 pm	Closing remarks (Poster award ceremony, announcements)
3:00 pm	Bus shuttle from ATB to Potsdam main station
3:00 pm	Bus shuttle from ATB to Potsdam Luisenplatz
3:00 – 4:00 pm	ATB tour (optional)
3:30 – 6:00 pm	Insect-IMP cost action meeting (optional)
4:30 pm	Bus shuttle from ATB to Potsdam main station
4:30 pm	Bus shuttle from ATB to Potsdam Luisenplatz

ATB

ATB is a pioneer and driver of bioeconomy research. Our vision:

A circular and sustainable bioeconomy produces healthy food for all, operates on the basis of renewable raw materials and facilitates the realization of One Health for humans, animals and the environment.

We focus on renewable & alternative ressources to enable new value chains. Therefore, we integrate smart & innovative technologies.
Our research on insects aims at the sustainable exploitation of insects for food, feed and non-food applications. Special focus is on a systemic evaluation of material, energy and information flows while complying a balance of quality & safety.

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- Protein Dispersibility Index (PDI)
- Thermostability, Foaming, Emulsion Stability, Gel Formation
- Protein Solubility
- Viscosity/Rheological Analysis
- Colour Analysis – Colourimeter
- Texturisation
- Succinylation
- Enzymatic Modification

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- Lab Scale Oil Extraction
- Pilot Scale Oil Extraction
- Oil Refinery – Lab Scale
- Oil Refinery – Pilot Scale
- Oil Modification

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- Gravimetric Fat Content
- Fat Index Iodine value
- Fat Index Peroxide value
- Fat Index Acid Value
- Fat Index Saponification Value
- Fat Index Water Content in Oil (Karl Fischer)
- Melting Point Determination and Melting Behaviour Using Differential Scanning Calorimetry (DSC)
- Colour Analysis Gardner/Lovibond/AOCS/CIELAB
- Protein Content Analysis
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INSECTA 2024

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Partners

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Inhouse farming (DLG):
https://www.inhouse-farming.com

Economic Development Agency Brandenburg:
https://www.wfbb.de/

VDI – Magdeburger Bezirksverein

The VDI is an association for technically and scientifically active people (VDI: Association of German Engineers) and is one of the largest technically oriented clubs and associations in the world. The VDI Magdeburger Bezirksverein supports the INSECTA conference since 2015 and grants the “VDI Best Young Scientists Presentation Award” every year. It is divided into 6 district groups and many thematically different working groups and has offers for all ages. One group related to INSECTA conference is the Arbeitskreis Nachwachsende Rohstoffe (circle of experts for renewable resources) that is managed by Sara Hadjiali. VDI Magdeburger Bezirksverein is organised by voluntary works. The VDI Magdeburger Bezirksverein is supported in its work by numerous companies in the region and forms an important network and the VDI is also international networked. Also, VDI Magdeburger Bezirksverein has a sponsorship award for students at the universities in Magdeburg every year and the Gruson plaque of honor for members who deserved in the technical development and the work of VDI Magdeburger Bezirksverein Magdeburg.

More information can be found at homepage:
https://www.vdi.de/ueber-uns/vor-ort/bezirksvereine/magdeburger-bezirksverein

INSECTA 2024
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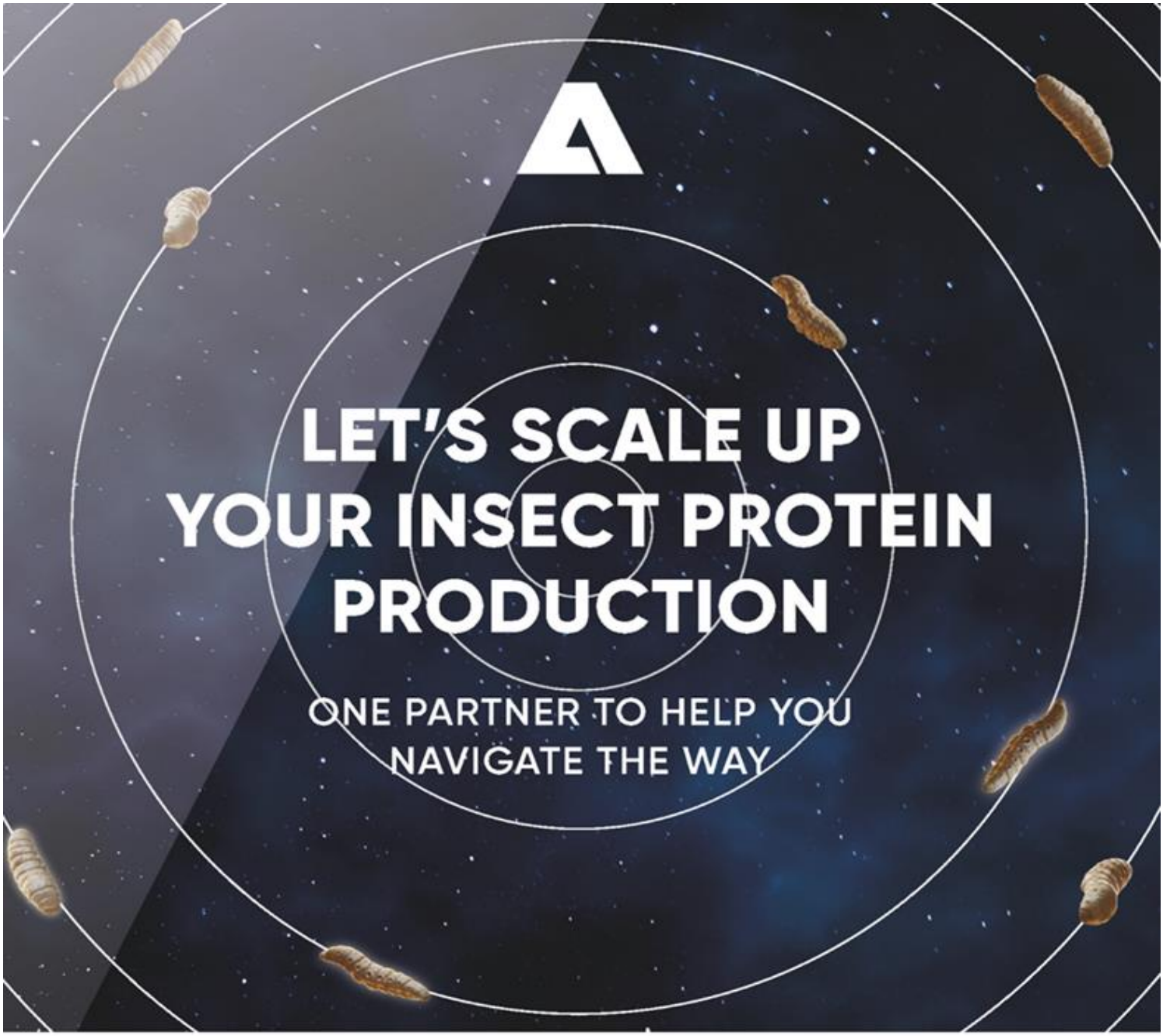

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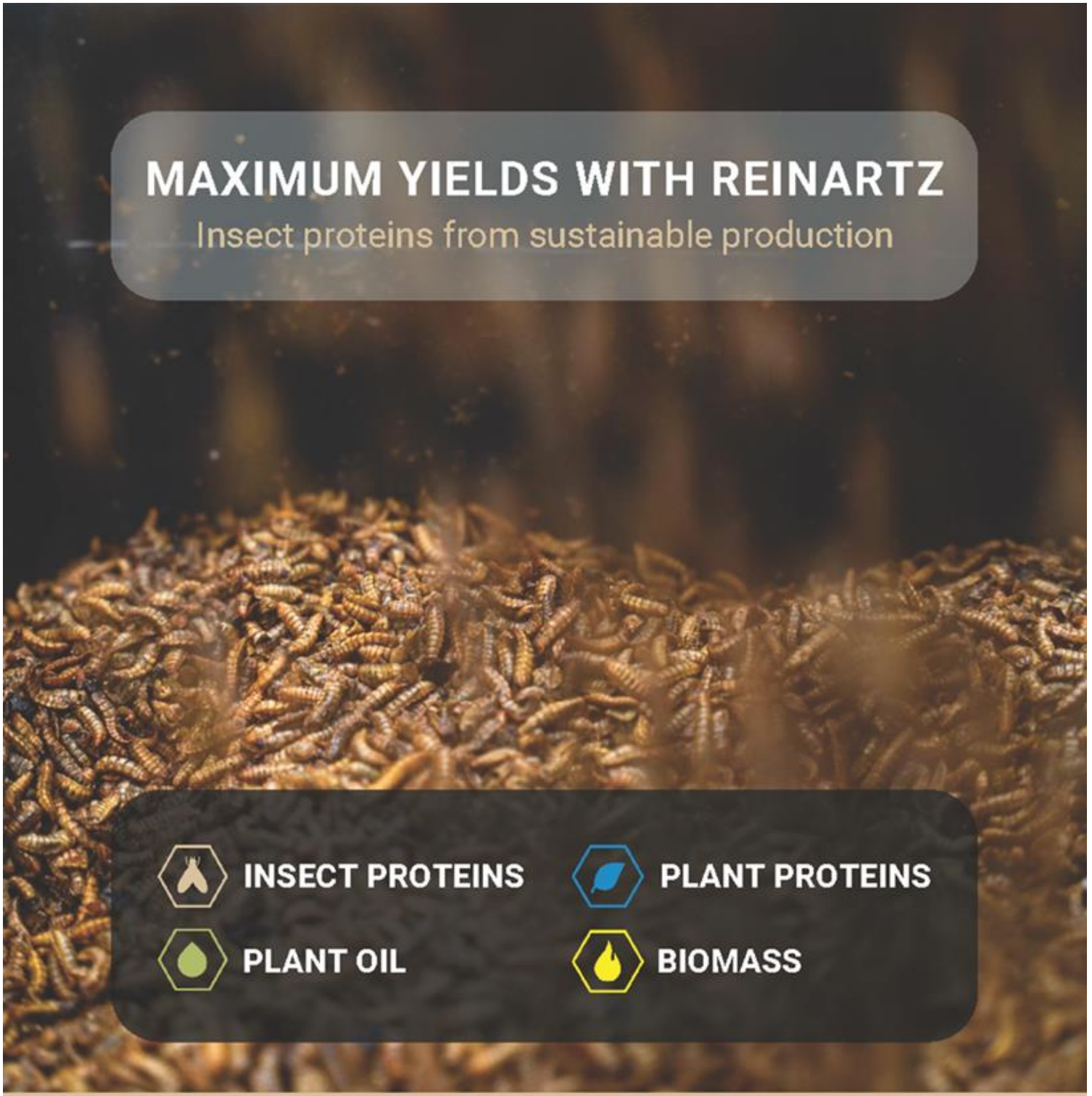

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The **Cluster Food Industry** and **Cluster Plastics and Chemistry** provide the platform for all bio-economy players in The German Capital Region. It links the entire value chain with industry-related economic sectors and the scientific potential of the region. Consequently, it ensures sustainable growth through innovation and value creation. All companies, scientific institutions, associations and networks are welcome to be active partners in the Food Industry Cluster and Cluster Plastics and Chemistry. Grow with us! Become a partner in the Brandenburg Cluster.

The managements of the Clusters Food Industry and Plastics and Chemistry see their combined role as **source of inspiration, initiator and moderator in the field of bio-economy**. It is most crucial to encourage and sustainably establish the cooperation of all active Cluster members. This is achieved through promoting transparency, initiating contacts and launching both small and large-scale projects among companies or between scientific institutes and companies; nationally and internationally.

food-industry-brandenburg.com
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CLUSTER FOOD INDUSTRY BRANDENBURG

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The clusters are supported by Economic Development Agency | Brandenburg

Co-funded by the European Union

INSECTA 2024
Keynotes

Insect farming to create a circular bio-economy in Controlled Environment Agriculture

Andreas Vilcinskas[1,2]

[1] *Institute for Insect Biotechnology, Justus Liebig University of Giessen, Giessen, Germany*
[2] *Branch Bioresources, Fraunhofer Institute for Molecular Biology and Applied Ecology, Giessen, Germany*

Corresponding author: andreas.vilcinskas@agrar.uni-giessen.de

Controlled Environment Agriculture (CEA) involves the production of plants - including algae -, fungi, insects, shrimp and fish in almost closed and regulated systems to enable the decoupling of production from seasons, climate and location. CEA aims higher productivity with consistently high product quality, reduction of environmental and health stresses (nutrient leaching, water consumption, land use) as well as application of pesticides, herbicides and antibiotics. In this context, insect farming promotes the coupling of different CEA production systems for a resilient and resource-optimized agriculture aiming zero waste in a circular bioeconomy (Circonomy©). Farmed insects, such as the larvae of the Black Soldier Fly *Hermetia lucens*, are considered as a missing link for the circular bio-economy in CEA because they can mediate the industrial bioconversion of agricultural or industrial side streams into feed for aquaculture and livestock. In turn, the leftovers of farmed insects, the so-called frass (excrements, chitinous exuvia of the molting larvae and feed leftovers), represents a valuable biofertilizer, which can replace chemical fertilizer in agriculture and vertical farming. The ability of *H. illucens* larvae both to utilize almost all organic substrates, even liquid manure, as a diet and to produce a potent a biofertilizer has been attributed to their beneficial microbes in the gut, which can also mediate the detoxification of plant-derived secondary metabolites. The avenues for revenues of industrial insect farming can be expanded beyond the production of food, feed and bio-fertilizer to encompass the development of higher-added value products from the generated protein, lipid and chitin fractions. Taken together, farmed insects can help to create a sustainable circular bio-economy in the food and feed industry.

Sustainable Adaptation – The promise of genetic improvement for farmed insects

Gertje Petersen

Lower Saxony State Office for Consumer Protection and Food Safety (LAVES), Oldenburg, Germany

Corresponding author: gertje.petersen@LAVES.Niedersachsen.de

Selective plant and animal breeding have drastically shaped the species humans depend on for food, clothing and shelter, ranging from microbiota used in the fabrication of antibiotics and other drugs to trees and large livestock species. Over the past handful of decades, these changes have accelerated rapidly, transforming domestic crops and livestock already modified far beyond the confines of their wild counterparts through the use of powerful statistical and molecular tools. With the advent of genomic selection methods combining both of these aspects, modern breeding programs can be designed in a way specifically tailored to the biology of the respective species as well as the economic framework of their production system. As a result, genomic selection and associated technologies seem like a silver bullet that could overcome limitations present in traditional breeding schemes, especially in production systems where data collection on individuals is laborious and expensive. This talk explores the promise of selective breeding in the world of farmed insects, with a specific focus on the use of modern genotyping and phenotyping methodologies.

From waste to sustainability: nutrient, economic and social circularity of insect technologies

Sergiy Smetana[1,2]

[1] *Deutsches Institute für Lebensmitteltechnik e.V. (DIL e.V.), Quakenbrück, Germany*
[2] *Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover (TiHo), Hannover, Germany*

Corresponding author: s.smetana@dil-ev.de

Circularity is a system concept of circular economy, reflecting on the potential of technologies to recover and return lost benefits back to the system. The effects of return and upcycling of materials (metal, glass, paper) are well studied and known, as well as the ecodesing on food products mostly oriented towards initial environmental impact reduction and packaging recycling (e.g., Circular Design for Food by Ellen Macarthur Foundation). The information on the effects of different Waste-to-Food technologies (including insects, heterotrophic microalgae, and single-cell organisms) for the nutrient recovery, cost reduction and social implications is missing. Mass-produced insects (e.g., *Hermetia illucens*) are considered as one of the potential bio-transformation and upcycling agents able to deal with actual food waste and recover some nutrients. Their efficiency, however, should be analyzed through the proposed Waste-to-Food Sustainability Assessment Framework in a holistic perspective, with the consideration of actual elements recovery rates through technological transformations and social interactions. Such a technology-oriented system approach (based on life cycle thinking) allows for defining the best recovery routes while highlighting unfeasible nutrient recovery scenarios. The gained knowledge highlights the potential of insects for nutrient recovery from a holistic sustainability perspective.

Insects as feed: last research and hot topics

Laura Gasco

Department of Agricultural, Forest and Food Sciences, University of Turin, Italy

Corresponding author: laura.gasco@unito.it

The use of insects as feed has garnered significant attention in recent years due to its potential to address sustainability challenges in livestock production. Studies have investigated the nutritional composition of various insect species, highlighting their high protein content, essential amino acids, fatty acids, vitamins, and minerals. Particular attention has been paid to the black soldier fly (*Hermetia illucens*) and the yellow mealworm (*Tenebrio molitor*), which seem to be the most promising species for feed production.

Researchers have investigated the development of efficient rearing techniques to scale up insect production for feed purposes, optimizing factors such as diet composition, environmental conditions, and automation processes. Furthermore, there has been a growing interest in exploring the functional properties of specific components within insect biomass, such as chitin, lauric acid, and antimicrobial peptides. These compounds have shown potential benefits for animal health and performance, including antimicrobial and prebiotic effects, which could improve gut health and immune responses in livestock.

Recent research on insects for feed has been characterized by a multidisciplinary approach, incorporating advancements in biology, engineering, and nutrition science. By addressing these hot topics, researchers aim to overcome existing challenges and unlock the full potential of insects as a sustainable and nutritious feed source for the future of agriculture.

This presentation reviews the latest research and explores hot topics surrounding the use of insects as feed.

INSECTA 2024
Lectures
(topics 1-5)

A growth model: relationship between substrate composition and black soldier fly larval weight gain

Martina Kießling[1], Knut Franke[2], Kemal Aganovic[1,3], Volker Heinz[1]

[1] *German Institute of Food Technologies (DIL e.V.), Quakenbrück, Germany*
[2] *Leibniz University Hannover, Institute of Food and One Health, Hannover, Germany*
[3] *Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany*

Corresponding author: m.kiessling@dil-ev.de; k.aganovic@dil-ev.de

High production performance as well as effective cost and yield management are critical parameters for successful insect farming. Especially, substrate composition significantly influences the production parameters such as daily gain, required rearing days, and losses.
Therefore, performance of side streams from food production, which are legally permitted as substrates in the European Union, was tested in black soldier fly larvae (BSFL) rearing. Six single substrates and fifty-four mixed substrates were used in feeding trials. Substrates differed in their composition with respect to macronutrients, like proteins and lipids, as well as minor nutrients, like minerals. A commercial chicken feed substrate was applied as a control, and it was replaced stepwise by the substrates investigated. The effect of the replacements on larval weight gain, survival rate, and feed conversion ratio was determined by weighing biomass and substrate residues as well as counting larvae every two days. Data were used to develop an empiric model to predict larval weight based on substrate composition.
The results show that lipid content distinctly influenced the larval growth, enabling a maximum weight gain at moderate lipid contents, whereas a very sharp decrease in larval weight gain was found for lower lipid contents in the substrate. On the other hand, the influence of protein content on weight gain was very linear, where higher weights were obtained at higher protein contents. A direct influence of the content of digestible carbohydrates on larvae weight was not found for the substrates considered demonstrating that this component was not a limiting growth factor in our study.
This model provides a useful basis for evaluating the impact of the main nutrition components in feed-grade substrates originating from by-products of food manufacturing on mean larval weight gain. Furthermore, substrates can be evaluated with respect to their influence on growth performance of BSFL saving the time for extensive feeding trials.

Agri-food side streams in insect-feed-animal chains as a sustainable circularity strategy

Sergiy Smetana[1,2], Dusan Ristic[1,3], Betriz Silva[1,4], Janos-Istvan Petrusan[1], Volker Heinz[1]

[1] DIL e.V. – German Institute of Food Technologies, Quakenbrück, Germany,
[2] Institute of Food Quality and Food Safety, University of Vet. Medicine Hannover, Foundation, Hannover, Germany,
[3] Institute of Food Technology, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
[4] CBQF—Centro de Biotecnologia e Química Fina—Laboratório Associado, Escola Superior de Biotecnologia, Universidade Católica Portuguesa, Porto, Portugal

Corresponding author: s.smetana@dil-ev.de

Insect production for food and feed is facing numerous challenges associated with potentially high costs, environmental impact and a lack of optimization in production. Particularly, these limitations are associated with the legal limitation in European Union on the feeds allowed for insects as farmed animals. Considering the challenges, an assessment approach of suitable agri-food side streams is needed. The proposed assessment matrix approach is aimed to account for the multiple criteria (legal, nutritional, safety, availability and seasonality, cost, and environmental impact) as a basis for the preselection of feeds suitable for different insect species. Moreover, the matrix-based assessment approach allows for further integration in multicriteria analysis (e.g., multi objective optimization) and larger scale economic scenario analysis. The study, performed in the scope of PRIMA funded ADVAGROMED and CIPROMED projects, presents examples of the matrix approach application for the streamlined determination of suitable side-stream feeds. Further scenario analysis included the economic and environmental effect consideration on economy level. It included the potential of use of some organic side streams in insect feeding to be associated with the mitigation of the impact and even resulted in environmentally positive scenarios. As a case study, it was determined that utilization of agri-food side streams from a hypothetical Mediterranean region (city) with 50,000 people can support the daily production of 3.6-7.1 ton dried *Hermetia illucens* biomass with the daily operational costs of 4,500-5,280 €. The two potential effects accounted for were waste reduction and return of nutrients to food systems in the form of fertilizers, feed and food. This study account for waste reduction by insects and the potential of insects for nutrient circularity.

StayPrime: arresting black soldier fly larval growth at different stages for efficient insect farming integration

Anton Gligorescu

EntoPrime, Aarhus, Denmark

Corresponding author: angl@entoprime.com

The rapid expansion of insect production is impeded by challenges in storage and transportation for live larvae, natural variations in egg output and the burden of high production
costs. These constraints amplify costs and operational inefficiencies, constraining market
utilization, while affecting a broad spectrum of customers, from full-life cycle insect producers to specialized breeders, growers, animal farmers, and feed formulators. Ento-Prime's patent pending technology, StayPrime, extends the shelf life of live larvae for weeks, offering potential improvements in the efficiency of Black Soldier Fly Larvae (BSFL) production.

We conducted three experiments to suspend the growth of BSFL at different stages: neonate (<1-day-old larvae), juvenile (6 days-old larvae), and harvest (6th instar) stage, for 18, 15, and 7 days respectively. Neonate and juvenile experiments included StayPrime suspension treatment and a control group with 5 replicates each, while fully grown larvae had only the StayPrime treatment with 3 replicates. We measured the average and total weights of 20,000 neonates and juveniles, and 16,000 fully-grown larvae before and after suspension, and estimated survival rates based on these weight measurements. Subsequently, we randomly selected 30 larvae from each replicate in the neonate and juvenile
experiments and fed them ad libitum with a chicken feed diet until harvest. At harvest, we
determined development time, average weight, growth rate, and survival rate.

Our results revealed that the average weight of BSFL was similar before and after suspension at all stages, suggesting arrested larval growth. The high survival rate after suspension (>80%) indicates the viability of suspended BSFL. BSFL suspended during neonate and juvenile stages exhibited significantly higher growth rates (>30%) than control groups, primarily due to faster development. High survival rates at harvest (>90%) across all experiments indicate no adverse effect of the technology on this trait.

In conclusion, StayPrime can address natural variations in egg production by creating neonates buffer capacity and ensure cost-effective storage and transportation of juveniles and fully-grown BSFL, Lastly, its application can enhance efficiency when integrated into daily production processes.

Farm maggot for chicken

Henna Pitkänen[1], Maija Karhapää[2], Tiina Siimekselä[1], Miika Tapio[2], Susanne Heiska[2], Vesa Harjunmaa[3], Jouni Virta[2], Jukka Markkanen[2], Pertti Marnila[2]

[1] Jamk University of Applied Sciences, Jyväskylä, Finland
[2] Luke, Natural Resources Institute Finland, Helsinki, Finland
[3] Kaistin Tila Ltd., Huittinen, Finland

Corresponding author: pertti.marnila@luke.fi

The goal of this project is to improve the protein self-sufficiency of poultry farms by replacing imported protein with locally produced insect protein, thereby enhancing circularity and resilience. The need for domestic supplementary protein is acute in organic production, due to the elevated fishmeal prices, usage restrictions, and difficulties in obtaining organic soy. Black soldier fly (*Hermetia illucens,* BSF) maggots are very valuable protein source for poultry. Maggots can be fed with a variety of by-products produced on the farm. A side stream of insect rearing, frass, is an excellent fertilizer and it's use in plant production could add to fertilizer self-sufficiency. At this project we produce farm-scale operating model for producing insect larvae and protein. The model includes information on devices and methods for insect and insect protein production, as well as tools for profitability calculations at farm level. In Finnish organic agricultural practices harvested crops are dried due to cold and moist climate. Ca. 15% of harvested crops are separated as sorting residuals in the drying process. The sorting residuals is a side stream that is not currently used for food or feed. side stream is not Preliminary tests were conducted using a feed mixture composed of 4.5 kg of sorting residual fractions from barley (2 kg), wheat (1 kg), pea (0.5 kg), and rapeseed (1k g) combined with 5.5 kg of water. This mixture was found to yield c.a. 3.4 ± 0.04 kg of live larvae and 2.4 ± 0.37 kg of frass, under ambient conditions of 13-15°C and a relative humidity of 40%. The results of these pilot tests suggest that the use of sorting by-product as a feed is a feasible option for the mass production of BSF. It was observed that the method of grain crushing, the resulting particle size, and the overall structure of the feed mixture are critical factors for optimal growth. The findings from these studies will be published in detail in future research articles. This work contributes to the development of sustainable and efficient practices in insect farming.

"The remains of the day" – Rearing *Tenebrio molitor* larvae on bakery leftovers (Project: TeMoTech)

Nina Kröncke[1], Patrick Sudwischer[2], Angelika Grümpel-Schlüter[1], Mareike Kölln[1], Dirk Sindermann[3], Jörg Heidhues[3], Stefan Kirchner[3], Sven Wildförster[4], Felix Tometten[5], Werner Sitzmann[5], Verena Böschen[2], Sven Dänicke[1], Jeannette Kluess[1]

[1] Friedrich-Loeffler-Institute, Institute of Animal Nutrition, Braunschweig, Germany
[2] International Research Association of Feed Technology e.V., Research Institute of Feed Technology, Braunschweig, Germany
[3] GEA Westfalia Separator Group GmbH, Oelde, Germany
[4] DEVEX Verfahrenstechnik GmbH, Warendorf, Germany
[5] Amandus Kahl GmbH & Co. KG, Reinbek, Germany

Corresponding author: jeannette.kluess@fli.de

The use of bakery leftovers for rearing insects on industrial scale is conceivable in the future if it can be ensured that the insects eat the leftovers and the larvae grow well on it.

The aim of the experiment was to determine the effect of feeding different bread leftovers (wheat, rye, lye roll, spelt and a mixture of different cereals, respectively) on performance parameters as well as the chemical composition of *Tenebrio molitor* larvae (TML). The study was designed as a dose-response feeding trial with a TML-rearing period of five weeks: feeding groups were created by mixing bread leftovers with wheat bran in different ratios (0, 12.5, 25, 50, 100% for each bakery leftover type), whereas 0% corresponds only to wheat bran as control group. For each feeding group, nine replicated rearing containers with 250 g diet were provided, along with 50 g of carrot per week as a water source. TML were reared with an average starting weight of 83.0 ± 1.0 g biomass per rearing container under controlled conditions (26.5 ± 1.0°C). Larval weight gain, feed consumption and frass production were recorded to calculate biomass increase, efficiency of conversion of ingested feed (ECI) and food assimilation (ECD).

Our results indicated that feeding dose is critical for larval growth. Biomass weight and specific growth rates were negatively influenced by the increasing proportion of bread leftovers in diet. Compared to the control group with pure wheat bran, the groups fed with 12.5 and 25% bread leftovers showed comparable biomass increase and growth rates, as well as ECI and ECD. The decreasing content of bread leftovers led to an increase in the number of pupae in the group fed with lye roll, spelt and the mixed group. The development time could be shortened, especially when feeding a mixture of wheat bread leftovers and wheat bran.

The results of this study indicate that bread leftovers might be suitable for feeding TML, but not as a sole substrate.

Evaluation of the growth performance, digestive capabilities and midgut integrity of BSF larvae reared on a polyethylene terephthalate (PET)-contaminated substrate

Martina Marzari[1], Daniele Bruno[1], Davis Roma[2], Jeroen De Smet[3], Mik Van Der Borght[3], Eleonora Mengotti[1], Silvia Caccia[2], Morena Casartelli[2], Gianluca Tettamanti[1]

[1] University of Insubria, Varese, Italy,
[2] University of Milano, Milano, Italy,
[3] KU Leuven, Geel, Belgium

Corresponding author: gianluca.tettamanti@uninsubria.it

Black soldier fly larvae (BSFL), *Hermetia illucens*, have demonstrated to be an efficient system for the bioconversion of organic waste into valuable insect biomass. The presence of contaminants such as microplastics (MPs) in organic substrates derived from food pro-cessing, agrifood chain, or municipal solid waste could potentially hamper the insect-me-diated bioconversion of these substrates. However, the effects of MP exposure on BSFL performance are scarcely known. To address this issue, BSFL were reared on the organic fraction of municipal solid waste (OFMSW) spiked with different quantities (4 and 20% w/w) of polyethylene terephthalate (PET) microparticles, and their impact on larval growth performance, as well as gut physiology and morphology, were investigated.

Our findings demonstrate that larval growth rate was not influenced by PET exposure, although the analysis of bioconversion indexes indicated a lower substrate bioconversion efficiency in both PET treatments compared to control. Measurements of endo- and exo-peptidases activity in the posterior midgut demonstrated the absence of significant differ-ences between PET treatments and control, underling that PET ingestion did not affect protein digestion in the larvae. Furthermore, to investigate possible mechanical damages of the midgut due to MP transit, a morphological analysis was performed. No alterations in the epithelium or the peritrophic matrix were observed, demonstrating that MPs intake does not affect midgut integrity.

The results herein presented provide insights on the bioconversion of PET-contaminated organic waste using BSFL, expanding our knowledge on the potential of insect-mediated valorization of a challenging substrate as the OFMSW.

Transformative insect-based feed initiative: from Nigerian success to Colombian agricultural revolution

Natalia Naranjo-Guevara[1], Marian Peters[1], John Amole[2], Raffaela Schreurs[1], Victoria Ayeni[3], Adebayo Omoloye[4], Clara Yalexy Delgado[5], Karol Barragán-Fonseca[6]

[1] NGN – New Generation nutrition, 's-Hertogenbosch, The Netherlands
[2] NGN – New Generation nutrition, Ibadan, Nigeria
[3] International Institute of Tropical Agriculture (IITA) and CGIAR, Ibadan Nigeria
[4] University of Ibadan/ Botswana University, Ibadan, Nigeria
[5] AGROSAVIA - Corporación colombiana de investigación agropecuaria, Cesar, Colombia
[6] Universidad Nacional de Colombia, Bogotá, Colombia

Corresponding author: nnaranjoguevara@gmail.com

The *Insect 4 Feed* Project in Nigeria tackled the critical need for sustainable animal feed solutions in an industry that notably contributes to the high costs of aquaculture, poultry, and livestock production. By leveraging the local tradition and untapped potential of insect-based feed, this initiative aimed to disrupt the 2 billion USD sector with affordable, high-quality protein alternatives. Collaborating with Dutch expertise, the project focused on overcoming production scale-up challenges, aligning with government sustainability goals. It established the Insect & Input Screening Centre to adapt insect rearing to local conditions, incubated insect-based feed entrepreneurs, and developed a quality-focused input industry. The engagement with feed producers facilitated insect-based feed's market entry, setting a transformative course for Nigeria's feed industry towards sustainability and reduced dependency on imported feed ingredients. Leveraging the achievements of the *Insect 4 Feed* initiative in Nigeria, we are set to launch a groundbreaking project in Colombia aimed at reshaping the agricultural framework of the Colombian Caribbean region. By establishing Demo farms as centres of innovation and learning, the project aims to improve local sustainable agriculture practices, focusing on BSF rearing and efficient waste management. It intends to convert waste from coffee and cacao industries into high-quality protein feed and organic fertilizers, promoting circular economy practices. This initiative will generate sustainable employment, enhance agricultural productivity through sustainable feed and fertilizers, and reduce feed costs, thus benefiting local businesses. It will also create new opportunities within the BSF value chain. In collaboration with local and international partners, this project aspires to adapt the Nigerian model to Colombia's unique conditions, promoting sustainable agriculture, improving food security, and fostering economic growth within circular economy principles.

Results from testing software guided BSF production process

Ykä Marjanen, Saverio Danubio

Manna Insect Oy, Oulu, Finland

Corresponding author: yka.marjanen@mannainsect.com

For BSFL to meet global demand price-competitively is crucial, especially in developing countries. Despite efforts by some insect companies to scale BSFL production through semi-automated factories, challenges remain in competing with traditional feeds like soy and fish meal, due to high operational costs. In many cases a smaller scale farm that doesn't need of sophisticated infrastructure is the only option to utilize BSFL.

Many aspiring insect farmers and companies face challenges across all production stages. Access to support, training, and resources is critical for their success as most have little or no experience with BSFL or background in biology. These farmers and teams require a structured, cost-effective support system that enables them to scale their operations profitably, with realistic and risk-minimizing milestones for business model validation and fundraising.

This study reports results of a training program supported by a software solution developed by Manna Insect. The solution was tested in several countries with different scale operations. In each case employees with little BSFL production experience were trained with a systematic program and the production results were noted during each training week. The program included a full production cycle from breeding to harvest larvae and rearing them to pupa and back to flies. After the initial training they continued operations using the developed software.

The evaluation of the program success was done based on three key metrics: number of eggs collected per cage surface area, egg to 5dol larvae survivability in nursing and how systematic FCR was from 5dol to 12dol. The guidance on how to measure and log each metric was part of the training program with guidance of each task and tools needed.

The results showed that it is possible to train anyone for professional level BSFL production, if they can be supported after the initial training and they learn to log the critical metrics correctly. Additionally it was concluded that controlled climate conditions help significantly on production stability and efficiency compared to outdoor production. The test farms were estimated profitable even at the level of one ton of live larvae per month.

Making better bugs: improving how we raise black soldier flies for a sustainable tomorrow

Aditya Francis[1], Sergiy Smetana[2], Eric Schmitt[3]

[1] *German Institute of Food Technologies – DIL e.V., Quakenbrück, Germany*
[2] *Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany*
[3] *Protix, Bergen op Zoom, Netherlands*

Corresponding author: a.francis@dil-tec.de

The Black Soldier Fly, recognized for its sustainability, undergoes testing in production settings as the industry evolves. Our research prioritizes eco-friendly alternatives to minimize environmental impact. Through renewable resource integration, optimal larval nutrition, and insect genetic advancements, we drive a transformative shift in cultivation. This study offers valuable insights, highlighting the Black Soldier Fly´s pivotal role in sustainable agriculture. Our analysis of large-scale Hermetia larvae production involves two main steps: examining production data and modeling it in SimaPro v9.5.0.2 software for impact analyses. Using Life Cycle Assessment (LCA), we evaluate environmental impacts, focusing on climate change, water scarcity, and land occupation. The methodology used for impact assessment was IMPACT 2002+. The system boundary covers raw material extraction, processing, transportation, and disposal, with the primary functional unit as 1 kg of fresh matter insect. Findings show significant reductions in environmental impacts compared to previous production systems. For instance, carbon emissions (kg CO_2 eq) reduced from 0.020-0.01123 for insect frass-based fertilizers, 0.402-0.198 for fresh insect production, 0.439-0.217 for fresh Hermetia puree, 0.907-0.477 for Hermetia fat production, and 1.149-0.832 for Hermetia meal production. Land use (m^2 org.arable) reductions range from 0.020-0.00004 for insect frass-based fertilizers, 0.461-0.0007 for fresh insect production, 0.445-0.001 for fresh Hermetia pure, 0.898-0.0102 for Hermetia fat production and 1.137-0.0178 for Hermetia meal production. Utilizing feed savings (diet optimization) results in a 64.54% reduction in total carbon emissions. With a total reduction of 70.74% in non-renewable energy use, carbon emissions of different products reduced to 63.59% on average. Results are from Protix, a company in Bergen op Zoom, the Netherlands.

Assessing amino acid requirements of neonate larvae of the black soldier fly, *Hermetia illucens*

Christoph Sandrock[1], Jens Wohlfahrt[1], Timo Stadtlander[1], Franziska Schindler[2], Maike Hardick[3], Melissa Terranova[4], Christian Lambertz[5], Andreas Lemme[6]

[1] Research Institute of Organic Agriculture (FiBL), Livestock Sciences, Switzerland
[2] Hermetia Baruth GmbH, Baruth/Mark, Germany
[3] Agravis Raiffeisen AG, Münster, Germany
[4] AgroVet-Strickhof, ETH Zurich, Lindau, Switzerland
[5] Research Institute of Organic Agriculture (FiBL), Frankfurt, Germany
[6] Evonik Operations GmbH, Hanau-Wolfgang, Germany

Corresponding author: christoph.sandrock@fibl.org

Dietary requirements of amino acids (AA) in black soldier fly larvae (BSFL), particularly during the neonatal phase, remain poorly investigated. Our targeted feeding trial consisted of a semi-artificial low-protein nursery diet (NC) to which 20 free AA were added to obtain a diet with 18% protein content (PC) that simulated the AA profile of a commercial feed for laying hens (RC). In addition to these three control diets, contents of six AA, i.e. Lys, Met, Thr, Arg, Ile, or Trp, were individually varied by either omitting or doubling respective supplementations of free AA, resulting in a reduction or excess of 31 to 46% relative to their levels in PC and RC (-AA and +AA treatments, respectively). Per triplicate tray of each treatment 10,000 freshly hatched sober neonates were provisioned with 10 mg dietary dry matter per BSFL.

Growth rate was most compromised in NC and -Lys treatments. While -Met and -Trp growth curves were similar to that of PC, responses for -Arg, -Ile and -Thr were intermediate between PC and NC. Surplus levels of Met, Thr, Trp, and Ile did not improve performance over PC, but +Lys and +Arg both speeded up growth translating into premature achievement of the fattening status that is reached around 10 mg larval live weight. Notably, BSFL of each -AA treatment took 1-5 days longer to achieve the fattening status than their +AA counterparts. Referring to the effectively used dietary baseline our inferences are i) Lys is first limiting in NC, ii) Arg, Ile and Thr co-limit growth, and iii) Met and Trp do not seem to limit growth in neonate BSFL. Interestingly, despite strong treatment effects on temporal growth dynamics, all treatments finally reached the fattening status with largely invariable total BSFL biomass. Survival was not affected and showed similarly high rates across treatments (>90% on average), thus allowing overall comparisons of rations, except for RC which induced substantially higher mortality.

Identify and improve – optimizing key parameters in black soldier fly breeding to sustainably supply a growing network of larval fattening facilities

Angelos Katsanis

FarmInsect GmbH, Bergkirchen, Germany

Corresponding author: ak@farminsect.eu

To bring qualified Black Soldier Fly (BSF) breeding to the next level, continuous adjustments of natural biological parameters are required. This is particularly the case when it must be ensured that numerous individual fattening systems are to be permanently supplied with BSF seed larvae of consistent quality and homogeneity within a short period of time. Scaling up from a unique BSF farming set up to a greater number of fattening systems poses enormous challenges to the biology- and reproduction department.

In the light of permanent progress and the continuous expansion of a network of decentralized BSF Larvae (BSFL) rearing systems, various breeding programs have been initiated at FarmInsect. Within these, emphasis was put on the selection of individuals with superior performance characteristics, such as improved larval development and quality, and enhanced biomass gain.

By means of feeding bioconversion experiments and selective breeding, it was possible to obtain individuals with the desired phenotypic traits and to increase the overall genetic performance of the breeding population over several generations.

In line with the global approach of sustainable insect breeding, particular attention was given to improve the feed conversion of currently approved residual side stream materials. Potential resources from the agri-food production industry were surveyed to figure out if and to which percentual inclusion rate they can be used as a feed substrate for BSFL.

Results from long-term feeding experiments show that adapting composition and consistency of the feed substrate as closely to the biological needs of BSFL may result in a most efficient improvement of feed conversion ratios. In this course, specially adapted BSF breeding lines allow the best possible use of various regionally available feed components.

Digestible energy and protein requirements of yellow mealworms (*Tenebrio molitor*)

Juan José Pascual[1], Simone Vozzo[2], Sara Esposito[2], Gabriella Pontillo[2], Teresa Añon[3], Bruno Fasce[3], María Carmen López[1], Jorge Franch[1], María Cambra-López[1]

[1] Institute for Animal Science and Technology, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain
[2] Department of Veterinary Medicine and Animal Science, University of Napoli Federico II, via F. Delpino 1, 80137, Napoli, Italy
[3] Feedect, Calle Sierra Calderona, 3, 46180, Valencia, Spain

Corresponding author: jupascu@dca.upv.es

To optimize the growth performance of mealworms, it is essential to delineate their nutritional requirements at every growth stage. Using the nutritional value of the raw materials defined in our previous works, nine diets were formulated varying in digestible energy (L: 2235, M: 2461 and H: 2706 kcal DE/kg dry matter (DM)) and digestible protein (L: 75, M: 90 and H: 105 g DP/kg DM), identified with two letters, the first for DE and the second for DP. At the start of the trial, 24 g of eggs were included in 72 trays (10x16x7 cm; 8 replicates) in a climatic chamber (28ºC and 60% relative humidity). Diets were administered weekly in increasing amounts. Larvae survival, weight, feed consumption and conversion rate (FCR) were monitored at 28, 56 and 63 days of life. In each control, all larvae were mixed to avoid the previous effects, adjusting the number of larvae to ensure densities below 0.23 g/cm^2. At 28 days, larvae fed with H DE diet showed the highest survival (+8 percentage points; $P<0.05$), and those with H DP had the highest individual larvae weight (+14%; $P<0.05$). Thus, larvae production per tray was maximized with diets HM and HH at 28 days of life (on av. +40% concerning LL; $P<0.05$). At 56 days, larvae survival was maximized with L and M DE diets (on av. +4 percentage points) or H DP diet (+5 percentage points), and individual larvae weight was maximized with H DE diet (+7%) or M and H DP diets (on av. +8%) ($P<0.05$). Thus, larvae production per tray and FCR were optimized with diet HH at 56 days of life (on av. +40 and -36% concerning LL; $P<0.05$). Finally, larvae survival and individual growth were not affected by the diet during the last week, but the FCR was optimized in larvae fed with M and H DE diets (on av. -23%) or with L DP diet (-8%), showing HL diet the best FCR compared with LL (-35%) ($P<0.05$). Hence, we recommend 2700 kcal DE and 90 g DP/kg DM to optimize survival for the first month, 2700 kcal DE and 105 g DP/kg DM to optimize growth performance for the second month, and 2700 kcal DE and 75 g DP/kg DM to optimize FCR for the last week.

Bioreactor for Mass Production of Black Soldier Fly Larvae

Antti Vasala, Ari Riihimaa

Entoprot Ltd, Oulu, Finland

Corresponding author: antti.vasala@entoprot.com

Entoprot's EntoReactor is the first automated bioreactor system for growing insects. It is ideal for rearing black soldier fly larvae. In terms of productivity, one cubic meter of bioreactor space corresponds to roughly 170 square meters area covered by cultivation boxes (or 17 m^2 with 10 boxes are stacked).

We have realized that nowadays insect farming depends on either cheap labour or expensive automation. This is why have developed EntoReactor, a system suitable for companies of all sizes. Our goal was to minimize the use of space and manpower and maximize productivity. In general, the development of insects struggles with three major challenges: 1) how to prevent larvae from crushing 2) how to ensure adequate ventilation and 3) how to provide enough feed with sufficient mixing. We have solved these problems with our unique, patented insect bioreactor system. The EntoReactor has a slowly rotating drum with very efficient ventilation and automation which controls feeding, ventilation, temperature and humidification.

EntoReactor's ingenious internal structures prevent the larvae from crushing during the rearing process. The feed is added as a thick slurry with an automatic feed pump. Also dry feed can be added to the bioreactor. Feeding is based on the fed-batch principle. With such "on-demand" feeding, the larvae use the feed very efficiently. Dead weight does not accumulate inside the bioreactor and the conditions remain airy. Thanks to controlled feeding and efficient feed conversion, little frass is produced. EntoReactor is equipped with an automation platform that allows you to monitor and control the process over internet or intranet.

Non-chemical methods in stored-product insect control: potentials for their use for the disinfestation of mass rearing of edible insects

Christos G. Athanassiou, Marianna Rigopoulou, Christos I. Rumbos

Laboratory of Entomology and Agricultural Zoology, Department of Agriculture, Crop Production and Rural Environment, School of Agricultural Sciences, University of Thessaly, Phytokou Str., 38446, Volos, Greece

Corresponding author: athanassiou@uth.gr

During the last decades considerable advance has been made in the research on the protection of stored products from insect infestations with non-chemical methods. Mating disruption, heat and cold treatment (application of high or low temperatures), as well as biological control (use of predators or parasitoids), have been largely investigated in the recent years providing a viable means to control insect infestations in stored commodities. At the same time, the production of edible insects has witnessed a tremendous growth. However, although a lot of research has been dedicated to the optimization of edible insect production, the management of insect infestations in insect production plants has been overlooked. Several insect pest-species have been found to cause problems in insect producing facilities. For instance, pyralid moths may infest the feed in mealworm farms.[2] As the presence of insect pests in insect farms may lead to several problems, e.g. contamination of the produced insect protein or disruption of the production process, control measures are usually compulsory. However, the management of insect infestations in insect production facilities can be rather challenging, as the application of chemical insecticidal measures may have an adverse effect also to farmed insects. Therefore, insect control strategies in insect rearing units should focus on alternative, non-chemical management tools (e.g. extreme temperatures, biological control agents, mating disruption) that have been extensively evaluated and are currently used for the protection of stored products from storage insects. Lessons that can be learned from stored-product insect control will be discussed, in order to be taken into account for insect pest management in insect producing facilities.

Beyond carrots: evaluation of gelling agents as wet feeds for *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) larvae

Sofronios Zafeiriadis, Christina Adamaki-Sotiraki, Christos I. Rumbos, Christos G. Athanassiou

Laboratory of Entomology and Agricultural Zoology, Department of Agriculture, Crop Production and Rural Environment, School of Agricultural Sciences, University of Thessaly, Phytokou Str., 38446, Volos, Greece

Corresponding author: sof.zafeir@gmail.com

An integral part of mealworm diets, and particularly of *Tenebrio molitor*, is the source from which they obtain moisture. Though *T. molitor* larvae can survive without a moisture source, its provision greatly enhances their growth. However, the effect of different moisture sources in the rearing of *T. molitor* larvae has not been thoroughly investigated yet. Currently researchers from all over the world use an array of different moisture sources, making the comparison of the results between studies difficult. On the other hand, the industry mostly uses vegetables such as carrots and potatoes, which might not be the most efficient solution, as they deteriorate quickly and their quality can widely vary. In this study, we evaluated the use of 7 different gelling agents as moisture sources, i.e. agar-agar, carrageenans, guar gum, xanthan gum, sodium alginate, modified starch and pectin. Carrot slices served as control. Gelling agents are used in the food technology sector and in culture media, in order to change the viscosity of fluids and provide them with a semi-solid texture. They can alter the properties of a diet and provide researchers and farms with the potential of targeted nutrient delivery. In our experiments, 50 larvae were provided with 4 g of wheat bran, and supplemented with the different moisture sources 3 times per week. Once a week, larval survival and weight were recorded until the appearance of the first pupa. Our results show that all tested gelling agents can be efficiently used for *T. molitor* larvae rearing, with minimal implications to the larval growth. All moisture sources tested produced similar results, with carrot producing the highest individual weight (111.6 mg) and carrageenan the shortest development time (52 d). Based on our results, agar-agar, carrageenan, and sodium alginate have the highest potential to be used in laboratory settings, as well as for targeted nutrient delivery, while carrot is the most economically viable solution.

Diet diversification and component interactions for rearing *Tenebrio molitor* in bio-regenerative life support systems

Christian Schnorr[1], Nicole Buschle[1], Oliver Hensel[2]

[1] *Department of Food Technology, University of Applied Sciences Fulda, Germany*
[2] *Department of Organic Agricultural Sciences, University Kassel, Germany*

Corresponding author: christian.schnorr@lt.hs-fulda.de

The omnivorous nature, high protein content and efficient growth make mealworms an attractive candidate for bio-regenerative life support systems (BLSS). At last year's Insecta, a possibility to convert plant residues from cultivation through mealworms was presented. Substituting 20-40% of wheat bran by salad roots improved the feed conversion and growth rate. Plant residues from cultivation do however not provide sufficient nutrients for a complete substitution, and wheat bran is not available in currently planned BLSS. Therefore, a diet of side-streams from plant cultivation and processing as well as overproduction was designed.

This diet consisting of salad roots, potato peels and algae (Spirulina platensis) was investigated regarding feed conversion parameters using a mixture experiment design with upper boundaries of 60%, 80% and 30% respectively. Experiments were carried out with freshly hatched larvae of the same age, which were reared on wheat bran (28°C, RH 70%) to an individual weight of approx. 15 mg and then fed on the experimental diet until first pupae emerged.

Both efficiencies of conversion of ingested and digested food to body substance (ECI and ECD) had significant negative effects from single substrates, but synergistic effects between all diet component combinations. For the approximate digestibility (AD) only algae as a single substrate had a negative effect. The synergistic effects of algae with potato and roots were dominant for ECI, ECD and AD. Second-degree models were sufficient to describe the relationship within the experimental area (R_{adj} of 0.910, 0.930 and 0.999 for ECI, ECD and AD respectively) with all single substrate and interaction effects being significant.

These results prove that a diet can be formulated based on occurring side-streams in currently planned BLSS. Diet compositions could be identified that outperform wheat bran for all feed conversion parameters. Strong synergistic effects of Spirulina suggest its use as a dietary supplement. Future research should aim towards finding more synergistic effects between side-streams from processing, focusing on plants with a high content of carbohydrates.

Growth performance of mealworm larvae (*Tenebrio molitor*) related to particle size of conventional and by-product substrates from food processing

Vinzenz Klapper, Chris Henze

Fraunhofer Institute for Process Engineering and Packaging IVV, Dresden, Germany

Corresponding author: vinzenz.klapper@ivv-dd.fraunhofer.de

The global demand for protein rises due to population growth, urbanization, and changing diets, but traditional sources like livestock farming pose environmental and ethical issues. Thus, exploring alternative protein sources is crucial. Insects offer diverse proteins, yet sustainable substrates for feeding remain a challenge. This study focuses on optimizing mealworm cultivation in closed systems using food processing by-products.

An insect farming facility implementing modular cultivation was established. Automation and operator protection concepts were developed, focusing on maximizing larval yields. Substrate fragmentation studies using a laboratory centrifugal mill and industrial sieves aimed to optimize larval growth rates. During the larvae stage feeding parameters such as growth ratio (GR), the feed conversion rate (FCR), feed efficiency ratio (FER), feed conversion efficiency (FCE), waste reduction index (WRI) and the apparent total tract digestibility coefficient (ATTP) were recorded to quantify the feeding progress.

Cultivation involved four substrates in three categories: oats (standard feed), poultry feed (reference), wheatgrass, and potato peels (by-products), fragmented to varying sizes. It was found that certain particle sizes of the substrate were preferred compared to others. Furthermore, the utilization of the by-products showed promising results compared to conventional substrates and should be considered for a blended substrate. This lays groundwork for further research on substrate size and quality.

Further research is needed to enhance sustainability and food security. Utilizing insect frass as fertilizer offers additionally a sustainable waste recycling solution. Converting frass into thermal energy can replace coal or wood pellets. These avenues of research hold promise for revolutionizing the insect farming industry.

Do we have a drinking problem? – Importance of additional water in rearing of mealworms

Nils Th. Grabowski[1] , Juliane Hirnet[1], Malte Stern[1], Cornelia Schwennen[2], Jan-Berend Lingens[2], Marieke Herrel[3], Christian Visscher[2], Madeleine Plötz[1]

[1] *Institute of Food Quality and Food Safety, Hannover University of Veterinary Medicine, Hannover, Germany*
[2] *Institute of Animal Nutrition, Hannover University of Veterinary Medicine, Hannover, Germany*
[3] *Centre for Translational Studies, Hannover University of Veterinary Medicine, Hannover, Germany*

Corresponding author: nils.grabowski@tihohannover.de

Productive tenebrionids like *Tenebrio molitor, Alphitobius diaperinus* or *Zophobas atratus* are typically reared in boxes with a starch (e.g. wheat bran) and an additional source of water and nutrition, e.g. vegetables. However, the question arises if this amount of water is sufficient.

Larvae of the giant mealworm, *Zophobas atratus,* were raised in small boxes on 50g of milled wheat bran with different amounts of moisture given as addition of water to media, ranging from 2% to 8%, as 1ml, 2 ml, 3ml and 4 ml of water added, but no further fresh vegetables. Their growth was measured by weight gain of whole charges of 50 larvae over a 2-week period. It was observed that 2% water resulted in weight loss, while increasing the water content increased growth gradually from 14.4 to 30.1% compared to the starting weight.

The improved weight gain indicates that *Zophobas atratus* needs more moisture than commonly provided by vegetable food stuffs, therefore addition of moisture or water might benefit growth.

However, the presence of liquid water or high moisture encourages microbial contaminations and, especially with small larvae, carries the risk of drowning.

As a solution to this problem, we suggest the use of gelatine cubes with high water content prepared by extended boiling or autoclaving to the rearing box. Due to autoclaving, the cubes are less prone to bacterial and fungal growth. If growth occurs, the cubes can be easily replaced. In preliminary experiments, different stage larvae consumed most to all of the cubes before contamination occurred and there was no negative influence on growth. If this effect proves consistent and effective in further experiments, addition of gelatine cubes might be an easy way to add water in standardized form to mealworm lots.

Utilizing plant wastes in entomoponics: impact of strawberry and bean vegetative wastes on yellow mealworm (*Tenebrio molitor*) growth and composition

Wael Yakti[1], Simon Schulz[1], David Deruytter[2], Marcus Müller[1], Nadja Förster[1], Inga Mewis[1], Christian Ulrichs[1]

[1] *Humboldt-Universität zu Berlin, Berlin, Germany*
[2] *Inagro, Rumbeke-Beitem, Belgium*

Corresponding author: wael.yakti@hu-berlin.de

The integration of plant production and insect farming “entomoponics” is based on utilizing plant wastes as rearing substrates for insects, while insect frass is returned to nourish the plants. In the presented study, the vegetative wastes “leaves and stems” of strawberry (*Fragaria x ananassa*) and common bean (*Phaseolus vulgaris*) were incorporated into a wheat bran-based rearing substrate for the yellow mealworm (MW) *Tenebrio molitor* (Coleoptera: Tenebrionidae). The plant wastes were autoclaved and fermented with the fungus *Trichoderma reesei*, and mixed in 50:50 ratio with wheat bran. The MW were grown for 5 weeks on the substrates and the dry yield was compensated on the 50:50 strawberry leaves- wheat bran substrates, without differences between the treated and non-treated strawberry leaves. Replacing 50% of the wheat bran with the autoclaved (heat treated) pea waste did not significantly reduce the growth of the MW, but the growth was reduced when the pea wastes were fermented or untreated. The incorporation of pea wastes (treated or untreated) increased the Ca, K and Fe content in the produced MW, and the incorporation of strawberry leaves increased the Mn, Zn, and Fe. The findings offer insights into utilizing plant vegetative wastes as a partial supplement to insect rearing substrates, and the potential influence this supplementation may have on the growth and composition of the resulting insect biomass.

Brown seaweed *Ascophyllum nodosum-based* diets modulate the nutritional composition and gut microbiome of yellow mealworm (*Tenebrio molitor*) larvae

Linggawastu Syahrulawal, Prabhat Khanal

Animal Science, Production and Welfare Division, Faculty of Biosciences and Aquaculture, Nord University, Steinkjer, Norway

Corresponding author: prabhat.khanal@nord.no

Yellow mealworm (*Tenebrio molitor*) larvae (YML) have been shown to be a promising alternative source of nutrients for animal feed. Feeding substrates play a crucial role in the nutritional compositions of YML. In this study, we hypothesized that dietary inclusion of novel marine bioresources, such as seaweeds, can positively influence the nutritional profile and the gut microbiome of YML. Mealworm larvae were fed wheat bran (WB) or wheat bran with dried powder of the brown seaweed, *Ascophyllum nodosum* (50% dry matter inclusion; WB+SW) for a period of 16 weeks. Then, YML were harvested under fed or fasted (24 hr) conditions and evaluated for their nutritional compositions and the gut microbiome.

We found that the dietary inclusion of *Ascophyllum nodosum* in the diet of YML improved the nutritional value and altered the microbiota population in mealworms. In particular, our findings showed that the inclusion of 50% *A. nodosum* into the diet increased mineral content such as Cu, Na, and K, but lowered Mn ($P < 0.05$). The seaweed inclusion increased several long-chain fatty acids such as stearic acid (C18:0), gondoic acid (C20:1 trans), eicosadienoic acid (C20:2), heneicosanoic acid (C21:0), and behenic acid (C22:0), whereas decreased total of polyunsaturated fatty acid and n-6 fatty acid ($P < 0.05$). *A. nodosum*-based diet modulates the microbial communities which are dominated by members of *Firmicutes*, *Proteobacteria*, *Bacteroidota*, *Cyanobacteria*, and *Actinobacteria* in the gut of mealworm larvae.

Our findings revealed that dietary inclusion of marine-based alternative bioresources, such as seaweeds, could be an important approach in the future to improve the nutritional values of YML for animal feed applications.

Nutrient utilization by black soldier fly larvae (*Hermetia illucens*)

Andreas Lemme[1], Patrick Klüber[2]

[1] *Evonik Operations GmbH, Hanau, Germany*
[2] *Fraunhofer Institute for Molecular Biology and Applied Ecology, Gießen, Germany*

Corresponding author: andreas.lemme@evonik.com

Examining nutrient utilization and requirements of black soldier fly larvae (BSFL; *Hermetia illucens*) by classical feeding studies is problematic, as feed ingestion cannot be measured precisely because larvae live in their feed. Modelling nutrient flows by mass balancing offers an alternative approach. A growth trial with 5 treatments, graded levels of crude protein (9.8% (T1), 12.2% (T2), 14.5% (T3), 16.9% (T4), 19.3% CP (T5)) were tested. Starch content was constant and dietary CP level was increased by adding an amino acid mixture at the expense of depectinised apple pomace. After 24 days BSFL biomass was similar among T2 to T5 but was lower in T1 ($p<0.05$). Substrate conversion was higher in T1 compared to T2 to T5 ($p<0.05$). Substrate, BSFL, and frass were analysed for amino acids (AA) and nitrogen (N). Quantities of each sample were determined allowing for mass balance calculations. N-quantities from BSFL and frass did not sum up to substrate N amounts indicating (ammonia) losses. Those were minimized in T1 (5% N-losses) and gradually increased to T5 (31%; $p<0.05$). Sum of AA losses also increased but were higher (33 to 61%; $p<0.05$) indicating high non-protein N (NPN) in frass. With 41% and 31% retention of N (% of substrate) and AA was maximized in T2 ($p<0.05$) while it gradually decreased by 2.1% ($r^2=0.88$) and 1.6% ($r^2=0.84$) per % CP in substrate from T2 to T5. Retained nutrients relative to those which disappeared from substrate (retained+lost) may indicate how BSFL utilize ingested nutrients. Accordingly, N-utilization was highest in T1 (88%) and shrank by 5.0% per % CP ($r^2=0.94$), whereas AA-utilization peaked at 12.2% CP (46%) and then decreased by 2.9% per % CP ($r^2=0.88$) to T5. These findings suggest considerable transformation of AA into NPN. 57% to 84% of substrate AA were added as free AA but no free AA were detected in frass. Thus, BSFL can well utilize free AA. While sum of AA are reported here, there were differences of response of single AA. Although dietary fat content slightly decreased from T1 to T5, fat deposition in BSFL tripled from T1 to T2 ($p<0.05$) and then increased linearly by 14mg per % CP ($r^2=0.99$) indicating that CP was increasingly used as energy source. Accordingly, fat content in BSFL (% in DM) followed a quadratic response ($r^2=0.98$) peaking in T4.

Exploring the nutritional and techno-functional characteristics of black soldier fly protein at various phases of life

Kashif ur Rehman[1,3], Kemal Aganovic[1,2], Volker Heinz[1], Clemens Hollah[1], Janos-Istvan Petrusan[1], Karin Wiesotzki[1]

[1] German Institute of Food Technologies (DIL e.V.), Quakenbrück, Germany
[2] Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany
[3] Department of Microbiology, Faculty of Veterinary and Animal Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan

Corresponding author: k.rehman@dil-ev.de

This study examines the potential of the black soldier fly (BSF) as a sustainable protein source, with a specific emphasis on its life history parameters, nutritional content, and technological processability. The BSF was able to convert 49.26% of the substrate dry matter in an effective manner over the course of 12 days, which resulted in the production of 1.85 kg of larval biomass. The survival rate of the larvae was an outstanding 94%, and the food conversion ratio was 1.63, highlighting its excellent ability to transform organic materials into useful biomass.
Protein content varied significantly across different life stages: larvae contained 31.1%, pupae 39.0%, and adults 65.5% protein. Adults had a fat content of 22.3%, larvae 32.5%, and pupae 39.0% fat. Also, the ash content varied between larvae (6.1%), pupae (9.8%), and adults (4.5%). Carbohydrate levels ranged from 6.2% in adults to 13.6% in larvae and 19.3% in pupae.
The adult BSF protein showed higher solubility between pH 9 and 10. BSF larval protein showed better emulsification qualities, whereas pupae exhibited the maximum foam volume. The research also investigated the gelling characteristics, uncovering different temperatures at which gelation begins for larvae, pupae, and adults.
This study highlights the many capabilities of BSF and its larvae as a sustainable protein source, providing answers for organic by-product management, and resource utilisation. Furthermore, the techno-functional characteristics shown at different life stages suggest multiple uses in food and feed applications, potentially leading to the development of innovative products using protein obtained from BSF.

Evaluating by-products from food and feed industry on black soldier fly larvae rearing: Insight into nutritional composition and microbial communities

Kashif ur Rehman[1,3], Martina Kieβling[1], Kemal Aganovic[1,2], Sergiy Smetana[1,2], Volker Heinz[1], Clemens Hollah[1], Karin Wiesotzki[1]

[1] German Institute of Food Technologies (DIL e.V.), Quakenbrück, Germany
[2] Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany
[3] Department of Microbiology, Faculty of Veterinary and Animal Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan

Corresponding author: k.rehman@dil-ev.de

The study explores the complex connection between by-products of the food and feed industry, on the growth of black soldier fly larvae (BSFL), and the related microbial communities. As by-products carrot pomace, brewer's yeast, spent grain, and rape press cake were used and thoroughly analysed for their chemical composition, nutritional content, microbial count, and microbial composition. Subsequently, they were used individually as substrates for BSFL biomass production.

The analyses resulted in significant differences in the nutrient content and microbial communities of the substrates, leading to noticeable effects on larval biomass production, as well as nutritional and microbial composition of BSFL. Brewer's yeast stood up as the best substrate, resulting in the maximum larval weight increase (184 mg), larval crude protein content (61.1%), and crude fat content (24.3%). Investigation of fatty acids revealed unique patterns in BSFL raised on diverse substrates, indicating the possible utilization of insect-derived fats in a range of food and feed applications with significant quantity of unsaturated fatty acids (palmitoleic acid, oleic acid, linoleic acid, and alpha linolenic acid) in larvae fat biomass. Next-generation sequencing noted fluctuating variations in microbial populations in BSF larvae, at various taxonomic levels, which were impacted by the substrate. The research also examined alpha and beta diversity, revealing differing degrees of species richness and microbial community composition on various substrates and BSF larvae.

This work enhances our understanding of sustainable industrial by-product management and protein production systems by explaining how substrate selection affects the performance, nutrition, and microbial communities of BSF larvae. Future studies should investigate the functional roles of different microbial groups and their impact on larval health and environmental sustainability.

Consumer preference of meat obtained from broiler chickens fed a mixture of *Hermetia illucens* and *Tenebrio molitor* meals

Ilaria Biasato, Sara Bellezza Oddon, Zaira Loiotine, Achille Schiavone, Laura Gasco, Alberto Brugiapaglia

University of Turin, Grugliasco (TO), Italy

Corresponding author: ilaria.biasato@unito.it

The use of *Hermetia illucens* (HI) and *Tenebrio molitor* (TM) meals in diets for broiler chickens has previously been reported to influence meat sensory attributes (in terms of colour, juiciness, and flavour). However, no information is currently available about consumer perception of meat derived from broiler chickens fed a mixture of HI and TM meals. Therefore, the present study aimed to investigate the effects of HI and TM meals – alone and as mixture (1:1) – on meat sensory attributes of broiler chickens. A total of 420 1-day-old male broiler chicks were allotted to 7 diets (6 pens/diet, 10 birds/pen, 3 feeding phases): C (control), HI5 (5% HI meal), HI10 (10% HI meal), TM5 (5% TM meal), TM10 (10% TM meal), MIX5 (5% HI-TM mixture), and MIX10 (10% HI-TM mixture). At 38 days of age, 12 birds/diet were slaughtered, and their right breast was collected. In details, right breasts were cooked in bain-marie at 80°C for approximately 20 minutes to reach a heart T of 75°C, cut into $1m^3$-size cubes, and offered to 105 untrained assessors during a sensory panel. To minimize sensory fatigue, a balanced incomplete block design (BIBD) was employed by asking each participant to taste 4 samples only out of 7 ($t = 7$, $b = 105$, $k = 4$, $r = 60$, $\lambda = 30$). The degree of liking of meat colour, tenderness, juiciness, flavour and overall liking sensory attributes was rated on a 9-point hedonic scale. Data were analysed by SPSS software (One-way ANOVA, $P \leq 0.05$). Tenderness, juiciness and overall liking sensory attributes were significantly influenced by dietary insect meal inclusion ($P<0.05$). In particular, TM5, HI5 and HI10 meat displayed lower tenderness scores when compared to C group ($P=0.001$), with lower juiciness scores being also identified for TM5 diet than C ($P<0.05$). Furthermore, TM5 meat showed lower overall liking scores in comparison with C, MIX5 and MIX10 groups ($P<0.001$). Differently, colour and tenderness scores were analogous among the dietary treatments ($P>0.05$). In conclusion, TM meal at low inclusion level may determine a consumer depreciation of broiler meat, with the mixture of HI and TM meals not altering, however, the sensory attributes. Ongoing physico-chemical analyses of the meat will allow better characterizing these outcomes.

Evaluating the health impacts of insect-based dog food: a comprehensive literature review and critical analysis

Sonja Floto-Stammen[1], Chantal Vogt[1], Natalia Naranjo Guevara[2]

[1] *Fontys University of Applied Sciences, Venlo, The Netherlands*
[2] *New Generation Nutrition BV, s´Hertogenbosch, The Netherlands*

Corresponding author: s.flotostammen@fontys.nl

Dogs, revered as cherished companions and integral members of families, hold a significant position in the European market. The dog food sector has experienced notable growth both in volume and value, with consumer expenditure estimated at up to 300 euros per month. Concurrently, dog food trends closely mirror human food trends, with a pronounced emphasis on health. The integration of insect meal in dog food products is purported to address various health concerns, with approximately 35 insect-based dog food brands introduced to the European market by 2022, each boasting claims related to gut health and/or hypoallergenic properties.

Nevertheless, scepticism has been raised by veterinarians and pet owners regarding the validity of these claims, emphasizing the necessity for scientific validation through clinical studies. Trustworthiness emerges as a crucial factor influencing consumer purchasing decisions and veterinarian recommendations regarding novel products. This study delves into the effects of insect-based dog food on canine health, particularly focusing on digestion and the immune system, through a comprehensive literature review. By critically evaluating the results of 15 medical and clinical studies conducted between 2020 and 2023, we assess the substantiation of claims concerning the health and well-being of dogs.

Our findings provide valuable insights into the actual evidence regarding the health implications of incorporating insect-based ingredients into canine nutrition. The significance of this research lies in assisting the dog food industry in formulating credible claims to foster consumer confidence in insect-based foods.

Cold storage of immature stages of black soldier fly to use as live feed

Andrea Resconi, Ilaria Biasato, Sara Bellezza Oddon, Zaira Loiotine, Laura Gasco

Department of Agriculture, Forest and Food Sciences, University of Turin, Italy

Corresponding author: andrea.resconi@unito.it

The use of live larvae of *Hermetia illucens* in the ration of farmed animals has shown positive influence in behaviour and subsequently in health and welfare. However, most of the times the insect farm is not in the immediate proximity of the facility that will receive the live larvae. Storage and transport at low temperatures could be necessary to preserve the larvae until consumption. The aim of this trial was to evaluate the feasibility of storing live larvae at cold temperature (6°C) in different storage methods. Treatments (5 replicates/treatment) were: quantity, 1kg (1) or 3kg (3), type of container, bucket (BU) or bag (BA) and with frass (F) or without ( ), e.g. 3BA= 3kg of larvae, bag, no frass. Daily, a sample of larvae was taken from each replicate, live and dead larvae were counted and the weight of the live larvae was recorded (day1, D1; day 2, D2; etc.). A replicate was considered over when 15±2% of the larvae were dead. Data were analysed by means of GLMM (IBM SPSS software, $P<0.05$). After 3 days of storage, all replicates had surpassed the mortality threshold and with no differences among treatments ($P>0.05$), although there was a trend that showed increased longevity with the 3kg treatments. Regarding mortality, at D1 there was no difference among treatments ($P>0.05$), at D2 the lowest mortality was observed in 3BAF, 3BA and 3BU ($P<0.05$) and at T3 it was in 3BUF, 3BAF, 1BU and 1BAF ($P<0.05$). There was a loss of weight of the live larvae during storage, starting from an initial average weight of 0.134g at day 0, it went to 0.124g at D1 ($P<0.001$), at D2 no difference from D1 ($P>0.05$) and at D3 weight dropped at 0.122 g ($P<0.001$). The treatment in which the larvae lost most of their weight was 3BU (0.122g, $P<0.05$), while the treatments which lost the least amount were 1BA, 1BAF, 3BA, 3BAF, 3BUF ($P>0.05$). In conclusion, storing live larvae at 6°C is feasible until 48h with losses that are under 10%, although with 10 mg average losses. Successive trials with different temperatures are needed to pinpoint the most successful type of storage method and the temperature which can permit to store live larvae longer.

Extraction of phenolic compounds with antioxidant activity from *Tenebrio molitor* beetles

Nuno Muñoz-Seijas, Helena Fernandes, Jose Manuel Dominguez, Jose Manuel Salgado

Industrial Biotechnology and Environmental Engineering Group "BiotecnIA", Chemical Engineering Department, University of Vigo, Ourense, Spain

Corresponding author: nunomuoz@gmail.com

Nowadays, the production of edible insects for human and animal feed is increasing. *Te-nebrio molitor* adults (beetles) are disposed for food uses due to their high amount of chitin. Nonetheless, it should be noted that other bioactive molecules are present in edible insects, such as phenolic compounds, which exhibit antioxidant properties.
The conventional treatments applied to extract phenolic compounds are often costly and require extended periods of extraction. In this work, we propose using four eco-conscious treatments to obtain phenolic compounds, that is, ultrasound-assisted extraction (UAE), microwaves-assisted extraction (MAE), CO2-based extraction and temperature-assisted extraction (TAE). Also, three solvents were tested for each extraction treatment: water, ethanol and water:ethanol mixture (1:1, v/v). Total phenolic compounds (Folin-Ciocal-teau), flavonoids, ortho-diphenols and antioxidant activity (2,2-diphenyl-1-picrylhydrazyl scavenging assay (DPPH), the iron chelating activity assay (ICA), the superoxide dis-mutase assay (SOD), and the ferric reducing antioxidant power assay (FRAP) were quantified after each extraction method.
Among the three solvents, water resulted in higher phenolic compounds and antioxidant activity released. Higher extraction of phenolic compounds (8.98 ± 0.03 mg GAE g-1 dry solid) was achieved using MAE. Similarly, ortho-diphenols were higher using MAE as treatment (14.5 ± 1.56 mg g-1 dry solid). However, the flavonoids release was lower when using MAE (0.048 ± 0.028 mg g-1 dry solid), while UAE was more effective to obtain these compounds (0.133 ± 0.094 mg g-1 dry solid). Furthermore, higher antioxidant activity was attained after the MAE treatment after quantification using the DPPH, ICA and FRAP assays. Nevertheless, the SOD assay revealed similar antioxidant activities released either using MAE (2.56 ± 0.13) and TAE (2.64 ± 0.65) treatments. This work presents a feasible valorisation pathway of *T. molitor* adults focusing on green methods, obtaining high-valued phenolic compounds with antioxidant properties.

Lipids extracted from *Hermetia illucens* reared on different substrates: evaluation of antimicrobial activity

Antonio Franco[1,2], Carmen Scieuzo[1,2], Rosanna Salvia[1,2], Valentina Pucciarelli[1], Sofia Ouazri[1], Francesco Iannielli[1], Miriam Viola[1], Ilaria Caivano[1], Luca Borrelli[3], Fulvia Bovera[3], Eric Schmitt[4], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*
[3] *University of Naples Federico II, Italy*
[4] *Protix BV, Netherlands*

Corresponding author: patrizia.falabella@unibas.it

As the challenge of antimicrobial resistance continues to escalate, there is a renewed focus on antimicrobial solutions derived from natural origins, particularly those made from advanced and environmentally sustainable materials. Insect lipids, characterized by their inherent antimicrobial properties, stand out as a novel potential antimicrobial compound. Given the pressing need for innovative molecules to combat antibiotic resistance, the fatty acid composition of insect lipids, notably those from *Hermetia illucens*, is being investi-gated as a promising avenue. To assess the antibacterial efficacy of *H. illucens* lipids, extraction was performed at the larval stage, and subsequent characterization ensued. Specifically, lipids from larvae fed on diverse substrates were extracted to ascertain whether and how the feeding substrate influences antimicrobial activity. Employing the Soxhlet method for extraction, the antimicrobial activity against both Gram-positive and Gram-negative bacteria was appraised. Notably, variations in antimicrobial efficacy were observed among larvae fed on different substrates, prompting an analysis of the specific fatty acid composition through gas chromatography. This investigation aimed to discern whether the observed differences in antimicrobial activity were linked to substrate-de-pendent variations in fatty acid composition. Statistically significant disparities were iden-tified in five fatty acids between lipids exhibiting antibacterial activity and those displaying none. Existing literature corroborates the acknowledged antibacterial properties of these fatty acids, thereby validating the hypothesis that they play a contributory role in the anti-microbial activity of *H. illucens* lipids. This study contributes to understanding of the po-tential of insect lipids as a valuable and customizable source of antimicrobial compounds, offering insights into the relationship between feeding substrate, fatty acid composition, and antimicrobial efficacy.

Target groups and product labelling preferences in insect-based food markets

Berlianti Puteri[1], Benedikt Jahnke[1], Malte Oehlmann[2]

[1] Department of Agriculture and Food Marketing, University of Kassel, Germany
[2] Chair of Marketing and Consumer Research; HEF World Agricultural Systems Center, Technical University of Munich, Germany

Corresponding author: puteri@uni-kassel.de

To appeal to consumers who are open to try insect-based food (IBF) ("potential early adopters"), producers could provide diverse food labels, creating informative and attractive product packaging. However, these potential early adopters have varying preferences and expectations regarding IBF, and this information is crucial for practitioners to create targeted marketing measures. Addressing this, the present study aims to identify segments among potential early adopters and determine their product attribute and labelling preferences.

We conducted two discrete choice experiments using a web-based survey in Germany with 922 participants, featuring meatballs and crackers from Swiss start-up Essento. We developed real product packaging designs incorporating six product attributes examined: nutrition (Nutri-score; Reference Intakes; none), sustainability (CO_2 neutral; soy free [meatballs]/palm oil free [crackers]; none), naturalness (100% natural ingredients; no additives; none), trust indicator (Stiftung Warentest [institutional]; ambassador endorsement [interpersonal]; none), insect labelling (with high-quality protein from mealworms; with high quality protein from insects) and price (1.99€ - 5.49€ [meatballs]/0.99€ - 4.49€ [crackers]).

Using latent class logit analysis, we identified four segments for each IBF, three of which classified as potential target consumer groups (segments 2, 3, 4). These segments vary significantly in price sensitivity and insect labelling preferences. While two segments showed price sensitivity (2, 3), only one displayed a clear preference for low-priced products (3). Segments with a higher preference for the product desired specific insect species information (2, 3), while more sceptical consumers favoured general insect labelling (4). Compared to the main focus of IBF marketing, sustainability and nutritional information were not the most important purchasing arguments for all consumers. Instead, our study showed the key role of naturalness and institutional trust indicator, suggesting a need for a marketing shift to emphasize the natural aspect of IBF and provide consumers with reassurance regarding food safety and quality.

Superheated steam drying (SSD) of black soldier fly larvae (Hermetia illucens) for the use in an Insect refinery

Christian Schmidle[1], Stephanie Dellien Bause[2], Günter Tovar[1,2], Susanne Zibek[1,2]

[1] *University of Stuttgart, Institute of Interfacial Process Engineering and Plasma Technology, Stuttgart, Germany*
[2] *Fraunhofer Institute for Interfacial Engineering and Biotechnology, Stuttgart, Germany*

Corresponding author: susanne.zibek@igb.fraunhofer.de

The implementation of superheated steam drying (SSD) technology in a biorefinery presents a promising avenue for the processing of insect larvae, which require drying prior to further processing.
In this study, black soldier fly larvae (Hermetia illucens) underwent superheated steam drying at five distinct temperatures (115°C, 140°C, 160°C, 180°C, and 210°C) for varying residence times (ranging from 60, 45, 30, 15, to 10 minutes, or until completely dry). Additionally, batch experiments using hot air drying were conducted with the same time and temperature variables for comparative purposes. The moisture content, visual appearance, and fatty acid composition of the dried larvae were compared. Drying kinetics of SSD and hot air were also analysed.
Preliminary results indicate that at temperatures approaching 133°C, superheated steam (SHS) drying demonstrates an improved drying constant (k) compared to hot air drying in batch processes. Drying at 115°C show for the first 30 min of drying time a slower drying rate than in the remaining time of the drying process, for higher temperatures this trend was not observed.
Future plans involve continuous experiments to optimize the SHS process for industrial-scale insect larvae processing.

Enhancing livestock nutrition: the benefit of chitin depolymerisation (Project: TeMoTech)

Patrick Sudwischer[1], Nina Kröncke[3], Angelika Grümpel-Schlüter[3], Mareike Kölln[3], Dirk Sindermann[4], Jörg Heidhues[4], Stefan Kirchner[4], Sven Wildförster[5], Felix Tometten[6], Werner Sitzmann[1,7], Verena Böschen[2], Sven Dänicke[3], Jeannette Kluess[3], Michael Hellwig[1]

[1] Chair of Special Food Chemistry, Technische Universität Dresden, Dresden, Germany
[2] International Research Association of Feed Technology e.V., Research Institute of Feed Technology, Braunschweig, Germany
[3] Friedrich-Loeffler-Institut, Institute of Animal Nutrition, Braunschweig, Germany
[4] GEA Westfalia Separator Group GmbH, Oelde, Germany
[5] DEVEX Verfahrenstechnik GmbH, Warendorf, Germany
[6] Kahl Holding GmbH, Reinbek, Germany
[7] Amandus Kahl GmbH & Co. KG, Reinbek, Germany

Corresponding author: p.sudwischer@iff-braunschweig.de

Insect-based feedstuffs offer a promising alternative to conventional animal feeds, despite the presence of chitin, a linear amino-polysaccharide predominantly found in larval cuticles. Chitin, categorized under Non-Starch Polysaccharides (NSP), constitutes a significant portion of the non-digestible crude fibre fraction, thus serving as an antinutritive factor. This study presents initial laboratory hydrolysis studies aimed at evaluating the effectiveness of chitin depolymerisation methods in enhancing the nutritional quality of insect-based feedstuffs. These studies intend to lay the foundation for further research and development in this field. Initial findings indicate promising results in terms of improving the digestibility and bioavailability of nutrients in insect-based feed formulations. The hydrolysis process can increase the availability of N-acetylglucosamine in the feed, thereby contributing to its enhanced nutritional value. Hydrolysis of the cuticle can be achieved using single enzymes or enzyme combinations, necessitating detailed consideration of substrate, reaction type, and desired end product. The objective was to achieve nearly complete hydrolysis of the chitin-protein matrix, thereby significantly enhancing the bioavailability of carbohydrates and cuticular proteins. Optimal reaction duration depends on the hydrolysis kinetics of the enzyme or chemicals and process parameters. Depolymerisation typically occurs via a multi-stage degradation process, with enzymatic hydrolysis conducted under milder reaction conditions (e.g., 35-45 °C, pH 5.6 buffered reaction medium). Furthermore, controlled formation of target products is achievable through reaction management in buffer media, minimizing the formation of by-products. Hydrolysis facilitates a notable increase (up to 7-12 %) in the available content of N-acetylglucosamine in the feed, enhancing its nutritional value.

The influence of the life cycle from larva to beetle on chitin and lipid composition as well as their pressing behaviour in dry processing

Verena Böschen[1], Patrick Sudwischer[1], Nina Kröncke[2], Werner Sitzmann[1,3]

[1] *International Research Association of Feed Technology e.V., Research Institute of Feed Technology, Braunschweig, Germany*
[2] *Friedrich-Loeffler-Institute, Institute of Animal Nutrition, Braunschweig, Germany*
[3] *Kahl Holding GmbH, Reinbek, Germany*

Corresponding author: v.boeschen@iff-braunschweig.de

The use of insects in animal feed and food is one way of meeting the growing global demand for protein. *Tenebrio molitor* is a promising insect that plays an important role in industrial production alongside *Hermetia illucens* on the current market. Insect rearing is characterized by lower emissions, lesser resource requirements, shorter life cycles and better feed conversion rates compared to conventional animal husbandry. The body composition of insects, which generally consists of water, protein, fat and a significant proportion of chitin, varies along their life cycle. Chitin, categorized under Non-Starch Polysaccharides (NSP), constitutes a significant portion of the non-digestible crude fibre fraction, thus serving as an antinutritive factor. It should also be noted that for use in the animal feed industry, protein and fat must be separated. Two processes, wet and dry processing, are currently established on the market for this purpose. In this study, dry processing was examined with regard to the residual moisture content of the dried insects, the chitin content and the stability of pressed lipids as well as the lipid composition along the life cycle of *Tenebrio molitor*. It can be assumed that the lipid composition depends on the respective developmental stage of the larvae and thus the protein meal quality varies. *Tenebrio molitor* larvae used in this study were reared under controlled conditions at 26 °C with 60-70 % relative humidity and were fed with wheat bran. After recording the data, larvae were frozen at 21 °C for 48 h in a freezer and stored prior to performing chemical analyses. To prepare the material for dry processing, the larvae of different ages were dried in an infrared dryer at 120 °C.

Determination of nutrition value and shelf life of fermented edible insects

Anja Vehar[1,2], Polona Jamnik[3], David Heath[1], Doris Potočnik[1], Marjeta Mencin[1], Ajda Ota[4], Matjaž Červek[4], Lenka Kouřimská[5], Martin Kulma[6], Ester Heath[1,2], Nives Ogrinc[1,2]

[1] *Department of Environmental Sciences, Jožef Stefan Institute, Ljubljana, Slovenia*
[2] *Jožef Stefan International Postgraduate School, Ljubljana, Slovenia*
[3] *Department of Food Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia*
[4] *Emona Development Center for Nutrition, Ljubljana, Slovenia*
[5] *Department of Microbiology, Nutrition and Dietetics, Czech University of Life Sciences, Praha Suchdol, Czech Republic*
[6] *Department of Zoology and Fisheries, Czech University of Life Sciences, Praha-Suchdol, Czech Republic*

Corresponding author: anja.vehar@ijs.si

Recent research has focused on developing various processing technologies to add value to insect biomass as food or feed ingredients, innovative products, and sources of new bioactive compounds. One such method is fermentation, a traditional food processing technology that can enhance sensory quality, increase nutritional value, eliminate anti-nutritional factors, enhance bioactive compounds, contribute to gut health through the involvement of beneficial microorganisms, extend shelf life, and reduce microbial hazards by inhibiting pathogenic organisms. In the conducted study, the effects of fermentation on three farmed insect species were investigated: mealworms (*Tenebrio molitor*), migratory locusts (*Locusta migratoria*), as well as house crickets (*Acheta domestica*), before and after the fermentation using *Lactobacillus plantarum* and a commercial meat culture for 48 hours. The lyophilized insects, before and after fermentation, were characterized in terms of their amino acid (GC-MS), fatty acid profiles (GC-FID) and oxidative stability (RapidOxy®). It was found that while the distribution of fatty acids and amino acids was species-specific, fermentation resulted in slight modifications to their profiles. Regarding oxidation stability, fermentation with the mentioned cultures reduced the induction time for fermented *Locusta migratoria* and *Tenebrio molitor*, a result not observed in *Acheta domestica*.

Impact of extended cold storage on egg and larval performances in *Tenebrio molitor*

Katy Paul[1], Qi Li[1], Anthime Masseron[1], Fanny Gagnepain-Germain[1], Aurelie Chauveau[1], Ruth Barral-Arca [2], Mohammed-Amin Madoui[3], Thomas Lefebvre[1], Eliaou Sellem[1]

[1] *Ynsect, RD Biotech, Evry, France*
[2] *Thermo Fisher Scientific, Villebon-sur-Yvette, France*
[3] *Institut François Jacob, CEA, Fontenay-aux-Roses, France*

Corresponding author: eliaou.sellem@ynsect.com

Unlike traditional farmed animals, the developmental plasticity exhibited by insects is one of the advantages offered by this new livestock, which could enhanced resilience and manageability in production. The control of insect life cycle by temperature could therefore be used for a number of purposes, such as transport, batch synchronization, breeding program, *etc*. In that way, the aims of the present study is to analyse the impact of extended cold storage on egg and post-hatching larval performances. In one hand, 3264 eggs (laid over a 6 hour period) were distributed across 33 plates with 96 wells each, to be stored at 5/12/15°C (11 each) and one additional at 28°C, in darkness and 60% relative humidity. Twice a week over 6 weeks, a single plate per treatment was transferred at 28°C. The hatching time and rate were monitored. On the other hand, 26 cups containing 96 post-hatching larvae were stored either at 5°C or at 15°C and one additional at 28°C, all in darkness and 60% relative humidity. Once per week over 6 weeks, a single cup per treatment was transferred at 28°C. Larval survival, growth, pupation and adult emergence rates were monitored. The results for both egg and larval stages showed that performances were less impacted at 15°C whereas lower temperatures induced mortality few days after cold storage starting. Eggs can be stored for up to 15 days at 15°C with a minimum hatching rate of 90%, although they accumulate energy, resulting in a reduction of 2 days in hatching time compared to the control. As for the larvae, a 6-week cold storage at 15°C has no impact neither on the larval survival (87% vs 94% for the control) and growth, nor on pupation (93% vs 92% for the control) and emergence rates (85% vs 86% for the control). However, larvae could reach faster the pupal stage compared to the control, suggesting here again energy accumulation during cold storage. These results suggest that extended storage at 15°C allows for the slowing down of egg and larval development without compromising their survival or developmental abilities, thereby opening up new management possibilities for insect farming.

Effect of dandelion-mulberry diet on the silkworm larval powder nutritional profile: a comparative analysis

Aleksandra Trajković[1], Saša S. Stanković[1], Marijana Ilić Milošević[1], Nataša Joković[1], Milenko Ristić[2], Danka Dragojlović[3], Vladimir Žikić[1]

[1] *Department of Biology and Ecology, Faculty of Sciences and Mathematics, University of Niš, Serbia*
[2] *Department of Chemistry, Faculty of Sciences and Mathematics, University of Priština in Kosovska Mitrovica, Serbia*
[3] *Institute of Food Technology, Novi Sad, Serbia*

Corresponding author: aleksandra.trajkovic2@pmf.edu.rs

Although sericulture has been deeply rooted in Asian cultural and academic tradition, the silkworm also held significant importance in European technology and research. The focus of utilization has expanded in recent times, with the Asian market and scientific community taking the lead in exploring added value products and pharmaceutical innovations.

Comparing silkworm derived products is challenging due to the lack of comprehensive data on breeding system components and processing due to differences among hundreds of races, hybrids and strains of *B. mori*. Voltinism, strain selectivity for specific diets, and the utilization of varieties of white mulberry, alternative host plants, and artificial diets significantly alter biological traits and thus, the raw material characteristics.

Previous studies have highlighted the significance of mulberry in achieving optimal nutritional profiles, while current research primarily concentrates on investigating by-products of the silkworm industry, such as pupal powder. In this study, we contrast two lyophilized larval powders (CREA – AA double-cross (126x125) x (129x127) nr.1a). One group was exclusively fed white mulberry leaves (MA), while the other group was reared on dandelion-mulberry diet in the proportion of 7:3 (COM). The standard AOAC methods revealed a similar crude protein and fat percentage, 73.27% and 68.69%, 9.31% and 9.58% as well as carbohydrate content (15.17 mg/g and 13.16 mg/g) for MA and COM, respectively. While the AA and FA compositions for both samples were qualitatively consistent, quantitative differences such as those for alpha-linoleic acid (74.51 % for COM and non-detectable for MA) indicate the possibilities for targeting desired raw material characteristics through diet alteration. Optimal silkworm farming could be achieved by establishing functional sericulture, which will prioritize factors other than silk yield.

Mass-based & nutritional life cycle assessment (nLCA) of crickets as human food

Aditya Francis[1], Nam Dang[2], Jakob Lewin Rukov[3], Kasthuri Arachchilage Nilanka Sarangi[1], Ever Hernandez Olivas[4], Sergiy Smetana[1,5]

[1] German Institute of Food Technologies – DIL e.V., Quakenbrück, Germany
[2] CrickeobintOne, Loc Hung, Loc Ninh, Binh Phuoc, Vietnam.
[3] Bugging Denmark, Copenhagen, Denmark
[4] Teagasc - Moorepark Food Research Centre, Fermoy, Co. Cork, Ireland
[5] Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany

Corresponding author: a.francis@dil-tec.de

Crickets offer sustainable protein for human and animal feed, especially with the European Food Safety Authority´s approval of house crickets (*Acheta domesticus*). Enhancing Western acceptance is crucial, backed by scientific evidence. This study uses Life Cycle Assessment (LCA) to analyse large-scale cricket flour production in Vietnam. Essential amino acid profiles were assessed based on the Digestible Indispensable Amino Acid Ratio (DIAAR) and digestible protein content. Three functional units were compared: 1 kg of cricket flour, protein and digestible protein, enabling comprehensive environmental impact comparisons. An LCA was also performed for a small-scale Danish industry producing cricket paste in reefer containers. Three scenarios were modelled in SimaPro V9.5.0.2 software (S1 – flour, S2 – paste, S3 – flour (S2+S1). Environmental footprint 3.1 methodology was used for impact assessment as the study followed product environmental footprint category rules for food and feed. Incorporating sustainable feeds (cassava leaf) and re-using by-products (frass) resulted in negative kg CO_2 eq emissions (-1.8 & -0.185) with a total emission of 5.59 kg CO_2 eq for 1 kg cricket flour. Flour exhibited high protein quality and digestibility (7.55 & 8.21 kg CO_2 eq). Environmental impacts were analysed for specific amino acids, revealing deficiencies in certain limiting amino acids, indicating higher impacts when adjusted according to 1kg. Cricket flour and paste comparison showed 48.30% lower paste impacts, but by protein amount, paste had 68.67% higher environmental impacts due to lower overall protein content. Environmental impacts considering cricket rearing stages at S1 had carbon emissions of 0.569 kg CO_2 eq, while S2 had 90.24% higher impacts. Results analysed for all scenarios and impact categories, aiding in scaling up production without additional environmental burden.

Occurrence of presumptive *Bacillus cereus* and *Bacillus cytotoxicus* in productive insects and their immediate production environment

Sophia Johler-Illic[1], Nils Th. Grabowski[2], Danai Etter[1], Amir Abdulmawjood[2], Michael Stern[3], Madeleine Plötz[2]

[1] *Institute for Food Safety, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland*
[2] *Institute for Food Quality and Food Safety, Hannover University of Veterinary Medicine, Hannover, Germany*
[3] *Institute for Physiology and Cell Biology, Hannover University of Veterinary Medicine, Hannover, Germany*

Corresponding author: nils.grabowski@tiho-hannover.de

Being ubiquitous, *Bacillus* spp. are classical elements of the farm microflora. The "presumptive *Bacillus cereus* group" (PBCG) merges several closely related species and is relevant for human health. *B. cytotoxicus* is a novel PBCG species associated with food poisoning. So far it has been typically isolated from dried vegetables, but also from dried insect products. The objective of this survey was to analyse samples of insects and of their primary production environment in terms of PBCG and *B. cytotoxicus* to evaluate the risk for the operator.

For each insect species (*Acheta domesticus, Gryllus assimilis, G. bimaculatus, Locusta migratoria, Hermetia illucens, Alphitobius diaperinus, Tenebrio molitor,* and *Zophobas atratus),* samples of raw animals (n = 3), Frass (3), and rinsing liquid form cleaned and stored rearing boxes (3) were drawn at the faculty's facilities for invertebrate studies. Total sample size was n = 72. PBCG culturing was done using the norm ISO 7932:2004. For *B. cytotoxicus*, samples were incubated on MYP (mannitol egg yolk polymyxin) agar at 50 °C and emerging colonies were afterwards confirmed via MALDI, as were selected other PBCG colonies.

PBCG occurred in all species and all matrices, but not in all species x matrix combinations. It was found regularly only in raw *Gryllus* spp. (2.7 – 3.1 $lg_{cfu/g}$) and tenebrionid frass (2.7 – 4.1 $lg_{cfu/g}$), missing completely in all other raw animal samples and occurring only occasionally (1 out of 3) in frass of other species. Rinse samples were typically free of PBCG except for *H. illucens* and *A. diaperinus* in which one sample per species was positive (2.0 – 2.6 $lg_{cfu/g}$). *B. cytotoxicus* was isolated only twice (1.8%), i.e. from raw *Z. atratus* and *G. bimaculatus* frass. PBCG were identified as *B. cereus* and (apathogenic) *B. licheniformis*.

Thus, the main sources for PBCG were frass and *Gryllus* spp. Handling them should be done with appropriate safety measures, e.g. a dust mask, not consuming foods etc.

Elemental bioaccessibility and endogenic nanoparticles in farmed insects: in search of quality sustainable food

Ignacio Machado[1], Andrés Suárez Priede[2], Mario Corte Rodríguez[2], David Heath[3], Ester Heath[3], Lenka Kouřimská[4], Martin Kulma[5], Jörg Bettmer[2], María Montes Bayón[2]

[1] Analytical Chemistry Area, Faculty of Chemistry, Universidad de la República, Montevideo, Uruguay
[2] Department of Physical and Analytical Chemistry, Faculty of Chemistry, University of Oviedo, Oviedo, Spain
[3] Jožef Stefan Institute, Ljubljana, Slovenia
[4] Department of Microbiology, Nutrition and Dietetics, Czech University of Life Sciences, Praha-Suchdol, Czech Republic
[5] Department of Zoology and Fisheries, Czech University of Life Sciences, Praha-Suchdol, Czech Republic

Corresponding author: imachado@fq.edu.uy

Despite the many advantages and the approval of four species by the European Food Safety Authority, a significant knowledge gap remains regarding the farming of edible insects, making the need for further in-depth chemical studies clear. In this regard, the present work investigated the *in vitro* bioaccessibility of aluminium, copper, iron, manganese, lead, selenium, and zinc in three farmed insects: *Tenebrio molitor*, *Locusta migratoria*, *Acheta domesticus*, and *Acheta domesticus* fed on a diet enriched in selenium. The INFOGEST static simulation protocol was employed for this task, followed by the subsequent determination by inductively coupled plasma mass spectrometry (ICP-MS). The high zinc bioaccessibility observed for all species (~92%) was one of the highlights, demonstrating the high nutritional value for this element. In addition, a higher accumulation of selenium was observed upon increasing exposure concentration, showing the possibility of insect food as a food supplement for this element. Among the detected soluble elements, the presence of nanoparticulated aluminium and iron species could also be proved using highly sensitive mass spectrometric techniques and transmission electron microscopy in some of the analysed samples. These nanoparticles were successfully quantified by single particle ICP-MS, while the use of high-performance liquid chromatography coupled to ICP-MS revealed their heterogeneous size distribution. In the future these nanoparticles will be subjected to future bioaccessibility experiments. Overall, the information obtained from this work will be valuable for the subsequent nutritional and toxicological assessment of farmed insects.

Decision support system based on Multi-Objective Optimization for sustainable insects production

Anita Bhatia[1], Nisrine Mouhrim[2], Ashley Green[3], Daniela Peguero[3,4], Alberto Tonda[2], Alexander Mathys[3], Volker Heinz[5], Sergiy Smetana[5,6]

[1] GreenDelta GmbH, Berlin, Germany
[2] UMR 518 MIA-PS, INRAE, Université Paris-Saclay, Palaiseau, France
[3] ETH Zürich, Zürich, Switzerland,
[4] Eawag, Dübendorf, Switzerland
[5] DIL e.V. – German Institute of Food Technologies, Quakenbrück, Germany
[6] Institute of Food Quality and Food Safety, University of Vet. Medicine Hannover, Foundation, Hannover, Germany

Corresponding author: s.smetana@dil-ev.de

Insect value chains are complex systems with non-linear connections among various economic, environmental, and social variables. Industrial stakeholders often require clarity in potential environmental impacts, social issues and economic costs for efficient decision-making. This study employed a modular life cycle approach to analyze insect production chains, considering economic, environmental, and certain social aspects within the frameworks of the EU projects SUSINCHAIN, ADVAGROMED, CIPROMED and GiantLeaps. Integration of results from separate modules was based on developed scaling factors. These factors were further used to design multiple production scenarios, employed for multi-objective optimization (MOO) and the design of a decision-support system (DSS). The DSS accounted for a mix of sustainability relevant factors. The DSS functions as an online tool available in open access and could be further optimized and programmed in future research. Moreover, MOO allows for identifying a larger range of optimal scenarios with varying objectives. For example, for the companies producing *Hermetia illucens* and operating at large scale in Germany the optimal from sustainability perspectives will be 5 feed scenarios: (1) 98.3 % brewery spent grains, 1.3% chicken feed; (2) 81.5 % brewery spent grains, 18.5% vegetable rests; (3) 81.8 % brewery spent grains, 8.4% vegetable rests, 7.3% chicken feed, 2.5% milling rests; (4) 67.4 % brewery spent grains, 14.1% vegetable rests, 18.5% chicken feed; (5) 91.6 % brewery spent grains, 8.4% chicken feed. Further research is needed (and planned) to identify a broader spectrum of optimal scenarios for a range of alternative protein sources as well as to validate MOO results through the real-life development of sustainable insect chains and to assess its 'optimality.'

Chemical and phytotoxic properties of black soldier fly frass derived from biosolids and other biowaste

Kristin Bohm[1], Gregory A. Hatley[2], Brett H. Robinson[3], María J. Gutiérrez-Ginés[3]

[1] *Reploid Group AG, Wels, Austria*
[2] *Institute of Environmental Science and Research Ltd., Christchurch, New Zealand*
[3] *University of Canterbury, Christchurch, New Zealand*

Corresponding author: bohm@reploid.eu

Frass of insect organic waste bioconversion can be a valuable biofertilizer. However, its fertilizer properties can be dependent on the organic waste used as feedstock. In this study, we assessed the potential of frass as fertilizer that was obtained from black solider fly (BSF)-based bioconversion of biosolids, food waste or wheat bran. We analyzed the chemical properties of the different frass types and performed phytotoxicity germination tests for radish and lettuce. We showed that the chemical composition and phytotoxicity of the frass were strongly dependent on the type of BSF larvae feedstock. Frass originating from biosolids and from wheat bran had highest phytotoxicity which was correlated with increased levels of ammonium and electrical conductivity. Initially, these feedstocks had significantly higher total nitrogen and accordingly lower C/N ratios compared to food waste. Frass derived from food waste showed lowest phytotoxicity which was correlated to low ammonium and electrical conductivity values. Interestingly, initially high concentrations of phytoavailable heavy metals in the biosolids were strongly reduced during the bioconversion process. Overall, this study demonstrated that frass from BSF-based bioconversion can be used as biofertilizer, but the type of feedstock should be considered when selecting application rates for different soil types and plants. Frass from bioconverted biosolids would need to be mixed with other fertilizer/soil conditioner raw materials or be applied in low rates (< 1%) to avoid phytotoxicity.

NeoMAG: transforming black soldier fly (*Hermetia illucens*) raw oil into a powerful antimicrobial feed additive

Gal Wittenberg, Yuval Baron, Amir Barzilay

NeoManna ltd., Tel Yosef, Gilboa RC, Israel

Corresponding author: gal.wittenberg@neomanna.com

NeoManna ltd. was founded in late 2022, aiming to offer sustainable animal health solutions rooted in circular economy. Focusing on the Black Soldier Fly (*Hermetia illucens*, BSF), our team of R&D researchers centers efforts on capitalizing on BSF's amazing capabilities. For example, we harness BSF raw materials and valorize them into potent products that promote animal health in livestock, aquaculture and pets. Our latest offering, NeoMAG™, is derived from BSF oil. The oil undergoes a proprietary process, converting its original triglyceride form into monoglycerides at exceptional efficiency. The resulting monoglyceride rich product possesses impressive antimicrobial properties. Initial trials on swine and broilers have shown promising safety and efficacy of NeoMAG™, with improvements in Feed Conversion Ratio (FCR), weight gain, and mortality rates. These results, achieved through diligent research and development, underscore our commitment bringing to market innovative, potent, and sustainable solutions. Registrations in the European Union and Israel mark progress, along with strategic collaborations with BSF producers, ensuring a sustainable oil supply. Collaborations with feed producers highlight NeoMAG™'s safety, sustainability, and cost-effectiveness as an alternative to antibiotics. Manufacturing is underway, with initial sales indicating a positive trajectory.

NeoManna develops additional BSF-based products, including NeoPRO™, a portent anti-inflammatory, aiming to offer a suite of products to address Anti-Microbial Resistance (AMR). As a member of the Israeli Innovation Authority BSF consortium, NeoManna contributes to collaborative initiatives promoting innovation and sustainability.

In conclusion, NeoManna is committed to sustainable animal health solutions, exemplified by NeoMAG™. Our ongoing dedication to research, partnerships, and product development positions us at the forefront of the industry.

Detection and evaluation of antimicrobial peptides produced by the BSF and induced by fungi

Itai Opatovsky[1,2], Neta Herman[1,2]

[1] *Insect Nutrition and Metabolism, Department of Nutrition MIGAL, Kiryat Shmona, Israel*
[2] *Department of Animal Science, Tel-Hai Academic College, Tel-Hai, Israel*

Corresponding author: itaio@migal.org.il

In today's medical field, the issue of antibiotic resistance poses an enormous threat. However, there is a new hope in the biomedical and pharmaceutical fields, and it comes in the form of antimicrobial peptides (AMPs). These small, naturally occurring molecules play a crucial role in the innate immune response of various organisms, including insects. The black soldier fly (BSF) is of particular interest in AMP research, as it encounters a diverse microbial environment during its life cycle in decaying organic matter. Exploring the protective effects of AMPs produced by the BSF against human pathogens holds the promise of valuable insights for the development of novel antimicrobial strategies.

Through LC-MS proteomic analysis of the BSF haemolymph, we have discovered 21 antimicrobial AMPs expressed under standard conditions. Majority of the identified AMPs were classified as type defensin and few as type lysozyme, attacin, and cecropin. Earlier studies and our own preliminary work have demonstrated the haemolymph’s antimicrobial effects against bacteria. However, until now, the potential impact of fungi on the expression of AMPs and the effects of AMPs on different fungi have remained unexplored.

To address these knowledge gaps, our research employs advanced techniques to detect and characterize AMPs produced by the BSF under normal conditions and in the presence of fungi, both at the RNA and protein levels. Additionally, we aim to assess the efficacy of these AMPs in preventing the growth and survival of various bacteria and fungi. By undertaking this study, we anticipate to provide valuable insights that could lead to potential applications in the medical and pharmaceutical fields.

Chitin and chitosan from insects: case of *Hermetia illucens* and *Schistocerca gregaria* extraction, characterization and valorization

Soukaina Elkadaoui[1,2], Manar Azzi[1,2], Jacques Desbrieres[3], Jamaâ Zim[4], Youssef El Hachimi[2], Abdelouahad Tolaimate[1]

[1] *Interdisciplinary Research Laboratory in Bioresources Environment and Materials, ENS, Cadi Ayyad University, Marrakech, Morocco*
[2] *Bioresource and food safety laboratory, FST, Cadi Ayyad University, Marrakech, Morocco*
[3] *University of Pau and Adour Countries, IPREM, Hélioparc Pau Pyrénées, Pau, France*
[4] *Department of Plant Protection, Hassan II Institute of Agronomy and Veterinary Medicine, Agadir, Morocco*

Corresponding author: elkadaouisoukaina@gmail.com

Breeding of the black soldier fly to produce proteins is accompanied by rejects during the life cycle of this insect. This work studies the valorisation of these rejects through the production of chitins and chitosans with controlled characteristics. An extraction process is developed with an order of treatments and reaction conditions that provide chitins with high contents. The exuviae present organic impurities which will be eliminated at the N-deacetylation reaction for pupae and after a purification treatment for chitosan from larval stages. All these chitins have an α structure although certain physicochemical characteristics of the larval exuviae are close to those presented by γ chitin. The N-deacetylation makes possible the valorization of all rejects by producing pure chitosans which retain a porous structure for the exuviae and fibrous for the adult. They are highly to completely deacetylated and their molar masses vary depending on the process and life stage.

The exploration of the desert locust as a chitinous source made it possible to highlight the levels of presence of chitin according to the morphological parts of the insect, to determine its content and evaluate its quality. Chitin is extracted from the whole body and separately from the morphological parts. Chitins are obtained after only deproteinisation treatments with contents of 10 to 12.5% and present an α chitin. The high degrees of acetylation of these chitins (92 to 96%) indicate that they are close to the native form. The N-deacetylation of chitins by KOH provides chitosans with low molar masses (11,000 to 21,000 g/mol). SEM shows that they have a fibrous structure except chitosan of the head which has a compact porous structure. This study shows that it is possible to prepare highly deacetylated chitosans (4 to 14%) with controlled molar masses according to the desired application.

Comprehensive material balance and composition analysis for the by-products from black soldier flies breeding facility as sustainable source for chitin and chitosan production

Muhand Elamin[1], Thomas Hahn[2], Günter Tovar[1], Susanne Zibek[1,2]

[1] *University of Stuttgart, Institute of Interfacial Process Engineering and Plasma Technology, Stuttgart, Germany*
[2] *Fraunhofer Institute for Interfacial Engineering and Biotechnology, Stuttgart, Germany*

Corresponding author: muhand.elamin@igb-extern.fraunhofer.de

Recently, waste treatment using black soldier fly larvae has aroused great interest. Therefore, research has focused on increasing the larval biomass and its fractionation into lipids and proteins. In contrast, chitin-rich by-products, namely prepupal exuviae shedding during the growth of seed larvae to prepupae, pupal exuviae left after metamorphosis of pupae to flies, and dead flies at the end of the insect life cycle, are considered low-value biomass and have not been studied previously. A review of the literature showed above remarkable variation in the reported chitin, fat, protein, and mineral contents of flies' by-products. This study aimed to establish a material balance for insect by-products to determine the most valuable source for the production of chitin and to evaluate its composition (fat, protein, carbohydrates, and mineral contents) for a prospective holistic utilization of the biomass.

The material balance data were obtained from a 38 m^3 bioreactor in a breeding facility. Ten batches of insect by-products were collected over three months to account for variations in biomass composition over time.

Pupal exuviae were identified as the most valuable biomass for chitin production and potentially extraction of minerals compared with other by-products, with a yield of 86 kg per ton of feed to the larvae, a chitin content of 13-18 %, an ash content of 18-29 % and a protein content of 8-22 %. The calculated yield of dead flies was 47 kg per ton feed, which can be a suitable source of chitin as well, based not only on the high chitin content (6-13%) but also on the possibility of extracting further valuable products, such as fat (22-28 %) and protein (31-33 %). In addition, the results of this study showed that using prepupal exuviae as a raw material for chitin production was not optimal because of the low yield of 12 kg/ton feed, although the chitin content was significantly higher (22-31 %) than in the other by-products. Overall, this study provides comprehensive knowledge on the yields and composition of the by-products of black soldier flies to turn these "waste streams" into an added value within insect farming.

Building a sustainable business with chitosan derived from black soldier fly larvae

Bob Holtermans[1], Russel Hawkins[2]

[1] *Insect Engineers, Horst, The Netherlands*
[2] *Nano Guru, Pretoria, South Africa*

Corresponding author: bob@insectengineers.com

In this paper we investigate the commercial sustainability of synthesizing chitosan from black soldier fly larvae for the agricultural industry herein referred to as BSF. Currently these skins are sold as frass which fetch a low price in a highly competitive market. Here we look at how to maximize the profitability of a BSF operation in a cost effective and efficient manner. Traditional methods of synthesizing chitosan from BSF require lengthy energy intensive processes with a low yield of 10% from the original weight of the BSF skins that are extracted from the larvae. The limitation of this method is that when dispersing the final chitosan in water the solution becomes very viscous at even as low as a 1% concentration of chitosan. This limitation is extremely inefficient and costly for the agricultural farmers to justify applying chitosan as a beneficial bio-agent to their crops. The solution has been to maximize the chitosan's surface area by nanosizing the chitosan thereby enabling that same 1% dosage to cover a surface area of ten times its original surface area. In addition, here we produce a nano chitosan complex where the chitosan nanoparticles are decorated with either nano magnesium hydroxide or nano zinc hydroxide to improve to overall antimicrobial efficacy, drought stimulus, growth stimulus, photosynthesis, and bio pesticidal properties all while being a biodegradable, bio nutrient, bioavailable, biosafe, environment friendly and cost-effective solution as a direct replacement for hazardous chemicals used in the agricultural industry. Using this method positive field trials have shown that this form of bio-agent at very low concentration of 50ppm opens an exciting future of agricultural bio-agent derived from BSF.

Biobased and biodegradable technical lubricants from insect fat of *Hermetia illucens*

Thomas Piofczyk[1], Harald Wedwitschka[2]

[1] *PPM e.V. Pilot Pflanzenöltechnologie Magdeburg e.V., Berliner Chaussee 66, 39114 Magdeburg*
[2] *DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH, Torgauer Straße 116, 04347 Leipzig*

Corresponding author: harald.wedwitschka@dbfz.de

Insect fats are a by-product of the *Hermetia* protein production process and efforts are being made to find additional uses for them that are economically viable. Preliminary investigations have identified insect fat as a potential raw material for the development of bio-olefins. Following a multi-stage purification process, insect fat free of suspended matter with a high content of saturated fatty acids (approximately 70%) and a high proportion of lauric acid was obtained. Based on current knowledge, it appears possible to develop loss lubricants, such as chain grease or hydraulic oil for the forestry sector, or lubricating grease for use in the marine sector, using insect grease. However, the raw grease properties require further processing, including refining, chemical modification/esterification, and additivation, in order to meet customary product specifications.

The research project 'BioLube - Development of bio-based and biodegradable high-performance lubricants based on insect fat for industrial applications' focused on developing an economical method for purifying and refining insect fat.

Currently vegetable oil-based fatty acid esters are the primary raw materials used in the production of biolubricants and insect fat has a comparable composition to other vegetable oils rich in saturated fatty acids. Insect fat has the potential to increase the availability of raw materials for biolubricant production in addition to rape seed oil, sunflower oil, palm oil, palm kernel oil and coconut oil.

The presentation will show results of material characterisation test with insect fat from *Hermentia illucens* and a refining concept for cost-effective production of novel bio-based and biodegradable lubricants will be discussed.

Lessons learned from using paused life-cycle BSF neonates in various industrial setups

Adi Abada, Victoria Berkun, Idan Alyagor

FreezeM Cryogenics Ltd. Nachshonim, Israel

Corresponding author: Idan@freeze-em.com

As the black soldier fly industry enters the scale up and maturation phase, there is a growing need to increase production efficiency, quality and consistency, while reaching desired market capacity and price parity with other protein sources such as fish meal. While first-generation companies took a vertically integrated approach, encompassing breeding, rearing, waste management, and processing, newer market entrants and existing players have recognized the operational and financial advantages of transitioning to a specialized, decoupled model. This model involves centralized BSF breeding (reproduction) hubs that supply multiple rearing facilities.

PauseM® represents a major innovation milestone to achieve simpler protein production in this evolving landscape. It offers pre-counted, ready-to-use packages of paused life-cycle neonates, featuring proprietary technology that ensures a minimal shelf life of 14 days in a user-friendly application.

Over the past few years, we have distributed PauseM® units to a variety of protein production sites worldwide, ranging from small-scale R&D farms to full-scale production facilities. These pilots resulted in valuable insights on protein production efficiency and standardization. These include insights about the flexibility of BSF in consuming a wide variety of feedstuff, the ability to significantly shorten rearing phase and increase yield at industrial scale, whilst reducing operational costs. I will present some of the pilots and key findings, as well as discuss future implications of the PauseM® technology on the future of effective insect farming.

Scientific declaration on insect sentience and welfare

Francis Maugère

Eurogroup for Animals, Brussels, Belgium

Corresponding author: f.maugere@eurogroupforanimals.org

In a 2023 Scientific Declaration on Insect Sentience and Welfare, coordinated by Eurogroup for Animals, scientists and philosophers expressed support for increasing research in insect sentience, and for the development and implementation of evidence-based welfare measures in insect farming. This Declaration aims at synthesising the most recent neurobiological and behavioural evidence on insect sentience and welfare. While scientific consensus on insect sentience remains uncertain, there is growing evidence suggesting that certain insect orders, including those of some farmed species, may experience pain. Moreover, various insect species exhibit behaviours indicative of cognitive complexity, including avoidance learning, risk aversion, site-specific grooming of injuries, and protection from further harm. These behaviours, coupled with the presence of homologous nociceptors akin to those in mammals, suggest pain responses in insects.

Prioritising the welfare of insects necessitates the development of tailored assessment tools. While some best practices, gleaned from evidence on black soldier fly, yellow mealworm, and cricket welfare, can be implemented, there is a pressing need for defining precise, species-specific welfare measures. These include considerations such as humane slaughter methods, appropriate anaesthetics, avoidance of pre-slaughter starvation, safe and appropriate feeding substrates, nutritional support, genetic editing prohibition, optimal densities, light conditions for photophobic species, and disease management protocols.

Insect producers can take up the issue of insect welfare as a priority, and work alongside researchers, animal welfare organisations, and policymakers, to develop welfare best practices. As for every animal product, demand from consumers and farmers for high-welfare products, product differentiation opportunities, and specific regulations will reward proactive action on insect welfare. Better rearing conditions can also be associated with better health and growth in insects and deliver better economic results. The insect farming sector has an opportunity to heed the latest results in insect welfare research and collaborate in developing efficient and implementable welfare best practices.

Viral levels and tissue tropism of *Acheta domesticus* densovirus throughout the house cricket production cycle

Jozsef Takacs[1,2,3,] Astrid Bryon[1], Annette B. Jensen[2], Joop J. A. van Loon[3], Vera I. D. Ros[1]

[1] *Wageningen University and Research, Laboratory of Virology, Wageningen, The Netherlands*
[2] *University of Copenhagen, Section of Organismal Biology, Department of Plant and Environmental Sciences, Copenhagen, Denmark*
[3] *Wageningen University and Research, Laboratory of Entomology, Wageningen, The Netherlands*

Corresponding author: vera.ros@wur.nl

The house cricket, *Acheta domesticus,* is a commonly reared insect for food and feed purposes. *Acheta domesticus* is often infected with Acheta domesticus densovirus (AdDV), a single-stranded DNA virus that can cause high mortality resulting in collapse of house cricket colonies. AdDV infection and disease outbreaks in cricket mass-rearing can be prevented by either obtaining virus-free crickets or reducing virus spread. To limit virus spread, a better understanding of how viral levels vary and how the virus is transmitted during cricket development is needed. Viral levels were measured throughout the rearing cycle using quantitative PCR on samples collected 1) simultaneously from different life stages present in the rearing room at a given time and 2) weekly from a single rearing container that was monitored during the successive stages of development. To study viral tissue tropism and to infer the route of virus transmission, viral levels were measured in various tissues from mated and non-mated adult crickets. Ovaries of both unmated and mated females and the spermatheca of mated females were collected, while testes and accessory glands were collected from unmated and mated males. Guts were collected from both genders. Our results showed that viral levels increased in the course of development of nymphs into adults. Interestingly, for both genders, unmated individuals had significantly lower viral levels than mated individuals. Furthermore, AdDV was present in every tested tissue, but at different levels. In both mated and unmated females, the gut and ovaries showed higher viral levels than the spermatheca of mated females. The dissected male tissues all had similar viral levels. The results presented suggest that AdDV is both horizontally and vertically transmitted among house crickets and provide relevant information for future work on establishing virus-free cricket lines.

Dietary protein:carbohydrate ratio affects the immune response of *Hermetia illucens* larvae

Sara Caramella[1], Daniele Bruno[1], Aurora Montali[1], Ilaria Armenia[1], Morena Casartelli[2,3], Gianluca Tettamanti[1,3]

[1] University of Insubria - Department of Biotechnology and Life Sciences, Varese, Italy
[2] University of Milan - Department of Biosciences, Milan, Italy
[3] University of Napoli Federico II - Interuniversity Center for Studies on Bioinspired Agro-environmental Technology (BAT Center), Portici, Italy

Corresponding author: gianluca.tettamanti@uninsubria.it

The saprophagous larvae of black soldier fly (BSF), *Hermetia illucens*, can be used as a source of protein and fat for the production of animal feed. BSF larvae are reared on decaying organic matter and thus are potentially exposed to various microorganisms that may impact on the quality of the derived insect products. To improve the safety of BSF-based biorefining products, it is essential to enhance the performance of the larva's immune system.

The present work aims at evaluating the impact of dietary protein:carbohydrate (P:C) ratio on the immune response of BSF larvae challenged with a bacterial mix of *Escherichia coli* and *Micrococcus luteus*. To this purpose, larvae grown on a protein- and a carbohydrate-rich diet were infected with the bacteria and then the antimicrobial activity of the haemolymph was evaluated. In particular, immunological markers of the cellular (number of circulating haemocytes, phagocytosis, and encapsulation activity) and humoral (lysozyme activity, activation of prophenoloxidase system, and expression of antimicrobial peptides) branches of the immune system were tested.

Our findings revealed significant variations in some cellular markers, such as phagocytosis and encapsulation, and a stronger inhibitory activity against bacteria in larvae reared on the protein-rich diet, suggesting the effective capability of the rearing substrate to affect the immune response. These data provide a starting point to improve the knowledge on the optimal nutrition parameters of the feeding substrate for BSF that can ensure an appropriate growth of the larvae and, at the same time, confer higher ability to counteract bacterial infections.

Unveiling the potential of reciprocal crossbreeding in black soldier fly (*Hermetia illucens*)

Roel Meyermans[1], Laurens Broeckx[2], Jef Mondelaers[1], Wim Gorssen[1], Steven Janssens[1], Nadine Buys[1], Sabine Van Miert[2]

[1] *Center for Animal Breeding and Genetics, Department of Biosystems, KU Leuven, Leuven, Belgium*
[2] *Centre of Expertise Sustainable Biomass and Chemistry, Thomas More University of Applied Sciences, Geel, Belgium*

Corresponding author: roel.meyermans@kuleuven.be

The increasing world population leads to a growing demand for animal protein both as food and feed, calling for sustainable solutions. Insects, such as the black soldier fly (*Hermetia illucens*, BSF) will play a crucial role in this future. Selective breeding has proven extremely valuable in plant and livestock species and holds immense potential in the field of farmed insects. Moreover, in various livestock sectors crossbreeding is a successful strategy to enhance the genetic value of progeny by exploiting heterosis. Nevertheless, to date, crossbreeding experiments in BSF have been scarce and not thoroughly explored. In this study, we present the outcomes of crossbreeding experiments conducted between four different BSF strains. The base populations (F0) were characterized and used for reciprocal crosses (F1). Subsequently, a second generation (F2) was created reciprocally from the different F1 crosses. All populations were reared at standardized pilot scale on chicken start mash in triplicate. Each generation (F0, F1, and F2) was evaluated for growth, feed conversion, survival rate and egg production. Larval growth of the F2 generation did not differ significantly from the average larval growth of the F0s. However, the F1 generation showed reciprocal differences of up to 32% in maximum larval weight. Furthermore, both F1 and F2 generations exhibited higher survival rates than the F0 generation. Egg production was 19% higher in the F2 generations compared to the average F0s. These results suggest that heterosis through crossbreeding may play an important role and calls for further exploration in the development of breeding strategies for BSF.

Effects of diet composition on immune responses of *Tenebrio molitor*

Rosemarie Tedeschi, Valentina Candian

Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Paolo Braccini 2, 10095 Grugliasco (TO) Italy

Corresponding author: rosemarie.tedeschi@unito.it

In large-scale production systems, insects can be easily subjected to microbial infections due to sub-optimal abiotic factors, limited space and excessive inbreeding, leading to increased disorders and mortality with serious economic losses. Since for insects as food and feed the use of antibiotics is to be avoided, new strategies to preserve the health of the farmed insects are required. The effectiveness of the insect immune system can vary depending on biotic and abiotic factors including quality and availability of feeding.

In this scenario the inclusion in the diet of a by-product that still has a high protein value or of some probiotics has been investigated.

The increase in weight and variation in the expression of genes coding for some antimicrobial peptides (AMPs) were evaluated in healthy and *Beauveria bassiana*-experimentally-infected *Tenebrio molitor* (Coleoptera, Tenebrionidae) larvae reared on different diets based on some by-products from local agro-food industries. Compared with the control group (100% wheat bran diet), an integration with brewer's spent grain reduced the larval development time while the average larval weight increased. Contextually an overexpression of AMPs' genes was observed. In contrast, a lower mortality was observed in *Pseudomonas entomophila*-infected larvae when *Lactobacillus paracasei* was added to the control diet. Moreover, an overexpression of the antifungal peptide Tenecin-3 was observed in *B. bassiana*-infected larvae, when the insects were administrated with *Lactobacillus reuteri,* while an overexpression of the antibacterial peptides Coleoptericin-1 and Cecropin-2 was observed in larvae infected with *P. entomophila,* when the insects were administrated with *L. paracasei.* In addition, increased antibacterial responses were confirmed by diffusion assays in solid medium using haemolymph extracted from larvae fed with brewer's spent grains or probiotics.

The possibility to modulate the immune responses of *T. molitor* larvae through the diet is a valuable opportunity to protect farmed insects against the attack of entomopathogens preserving consumers' health.

INSECTA 2024
Poster presentations

BSF gene pool characterization via neonate morphological measurements

Lyubomir Nikovski[1], Mirena Zhelezarova[1], Marco Tejeda[1,2], Marc Bolard[1,2]

[1] *NASEKOMO AD, Saedinenie Str. 299, Lozen Village, Sofia, Bulgaria*
[2] *Flygenetics AD, Saedinenie Str. 299, Lozen Village, Sofia, Bulgaria*

Corresponding author: lyubomir.nikovski@nasekomo.life

As the insect industry expands, the black soldier fly (Hermetia illucens) is gaining prominence in scientific research. Assessing newly hatched BSF larvae (neonates) can provide insights into their performance during later stages of development and their bioconversion capabilities. Implementing key performance indicators (KPIs) at this early stage could be an effective strategy for improving yields. Moreover, such assessments could be utilized as phenotypic traits for genetic improvement programs. Our study introduces a methodology for neonate size assessment. Four distinct gene pools obtained from Flygenetics AD were evaluated by collecting individuals from each pool immediately after hatching. Larvae were then anesthetized with acetone and photographed using a high-resolution imaging system. Digital image processing software was employed to extract data from the images, including body length and width.

The results revealed morphological variations between gene pools in early development compared to Nasekomo's main genetic line. This suggests that neonate quality assessment could be a valuable tool for identifying and selecting individuals with superior developmental potential. In the future, we plan to longitudinally monitor the growth patterns of these gene pools to identify correlations between neonate size, weight, and developmental trajectory. This information will further enhance our ability to select individuals with the highest potential for bioconversion efficiency.

Zinc's footprint: assessing its impact on black soldier fly larvae development and microbiota composition

Claudia Keil[1], Lotte Frooninckx[2], Laurens Broeckx[2], Dries Vandeweyer[3], Maria Maares[1], Ioanna Mantouvalou[4], Sabine Van Miert[2]

[1] TU Berlin, Institute of Food Technology and Food Chemistry, Department Food Chemistry and Toxicology, Berlin, Germany
[2] Thomas More University of Applied Sciences, Centre of Expertise Sustainable Biomass and Chemistry, Geel, Belgium
[3] KU Leuven, Department of Microbial and Molecular Systems, Research Group for Insect Production and Processing, Geel, Belgium
[4] Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Corresponding authors: c.keil@tu-berlin.de; dries.vandeweyer@kuleuven.be

Black soldiers fly larvae (BSFL), *Hermetia illucens*, have gained popularity in recent years because they can be reared on organic waste streams, brewery waste or by-products from the food industry. BSFLs are a healthy source of protein that can be added to poultry feed, fish feed, and other animals' diets. Considering future use in the EU food industry, Enorm Biofactory A/S already submitted a novel food authorization application to the European Commission in 2018 to sell BSFL meal as an ingredient in baked goods and snacks. The interest in *Hermetia illucens* extends to sectors such as insect biorefinery, cosmetics and textile industries. However, BSFL market penetration depends on continuously optimizing rearing and processing technologies.

Black soldiers fly physiology does not have a good understanding of micronutrient requirements and trace element networking. Zinc salts are known to improve the immune system and growth of livestock when fed in appropriate doses. Unfortunately, there aren't that many studies about zinc supplementation or the regulation of the zinc homeostasis in food- and feed-related insects.

This study aimed to scrutinize zinc's impact on growth, bioconversion efficiency, zinc bioaccumulation and microbiota of BSFL. The BSFL were grown either on a Gainesville diets or food waste-based diet, each spiked with three different amounts of $ZnSO_4$. High zinc levels adversely affected the growth, survival, and bioconversion of BSFL. The zinc content increased in a dose-dependent manner in the larvae, although there were some differences in absolute zinc amounts between the two independent feeding trails. Micro X-ray fluorescence imaging analysis were performed to visualize trace element distribution in BSFL's midguts in preparation for future molecular studies on zinc absorption mechanism. Regarding the microbiome, it was found that the bacteria community among the larvae and their frass differed considerably based on the feed they consumed. $ZnSO_4$ supplementation only slightly altered the microbiota composition in larvae or frass.

The results of the study provide important insights that may help in the future development of processes that optimize the rearing of BSFLs.

CIPROMED: a PRIMA project on the use of alternative proteins in the Mediterranean value chains

Sandra Grebenteuch[1], Daniel Pleissner[1], Christos G. Athanassiou[2], Christos I. Rumbos[2], Sergiy Smetana[3], János-István Petrusán[3], Annalisa Tassoni[4], Laura Gasco[5], Francesco Gai[6], Avi Shpigelman[7], Marimar Bravo Cadena[8], Wael Fraihi[9], Luis Conceição[10], Eran Gronich[11], Simona Paolacci[12], Vasileios Chalkidis[13], Loizos Georgiou[14], Reiner Stolzenberger[15], Adnane El Yaacoubi[16], Clara Mehlhose[17]

[1] *Institut für Lebensmittel- und Umweltforschung e.V., Germany*
[2] *University of Thessaly, La-boratory of Entomology and Agricultural Zoology, Greece*
[3] *Deutsches Institut für Lebensmittel-technik e.V., Germany*
[4] *Alma Mater Studiorum-University of Bologna, Italy*
[5] *University of Turin, Italy*
[6] *Italian National Research Council, Italy*
[7] *Technion - Israel Institute of Technology, Israel*
[8] *AlgaEnergy S.A., Spain*
[9] *nextProtein, Tunisia*
[10] *SPAROS Lda, Portugal*
[11] *Flying Spark LTD, Israel*
[12] *AquaBioTech Group, Malta*
[13] *ELVIZ S.A., Greece*
[14] *RTD TALOS Ltd, Cyprus*
[15] *Stolzenberger Bakery, Germany*
[16] *Green Development and Innovation Associa-tion, Morocco*
[17] *University of Göttingen, Germany*

Corresponding author: sandra.grebenteuch@ilu-ev.de

The current European agricultural production systems rely heavily on protein imports to meet the nutrient requirements of aquaculture and animal production, as well as for hu-man consumption. This situation is particularly true for the Mediterranean region, where drought and ecological deficits worsen the self-sufficiency of traditional protein supply chains. There is therefore an urgent need for efficient, viable, and locally produced alter-native protein sources.

Most agricultural management systems produce large quantities of livestock and crop residues, as well as a variety of by-products. It is estimated that annually 27% of our agricultural production is lost, amounting to 1.6 billion tons worldwide valued at $750 bil-lion per year. Similarly, one-third of all food produced for human consumption is either lost or wasted. These losses represent a significant pool of unused and underestimated resources.

The main goal of the CIPROMED project is to increase the stability and resilience of ag-ricultural and food production systems in the Mediterranean region by directly using lo-cally produced traditional crops and by enhancing the proteins from locally generated agro-industrial by-products. The focus will be on upcycling by utilizing insects and micro-algae for the valorization of by-products.

Generating optimal compound insect diets by tailoring locally available side-streams as substrate for black soldier fly rearing

Janos-Istvan Petrusan[1], Wael Fraihi[2], Sergiy Smetana[1,3], Mohamed Gastli[2], Christos Athanassiou[4], Christos I. Rumbos[4], Kemal Aganovic[1,3], Volker Heinz[1], Clemens Hollah[1], Karin Wiesotzki[1], Kashif ur Rehman[1,5]

[1] German Institute of Food Technologies (DIL e.V.), Quakenbrück, Germany
[2] nextProtein, 2091 Ariana, Tunisia
[3] Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany
[4] Laboratory of Entomology and Agricultural Zoology, Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, Volos, Greece
[5] Faculty of Veterinary and Animal Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan

Corresponding author: k.rehman@dil-ev.de

This study investigates whether locally accessible agri-food by-products may be applied as breeding substrates for black soldier fly larvae (BSFL) and used for compound larval diet. To match substrate options with EU use, restrictions were constantly observed. Brewery spent grains, grape pomace, and potato processing by-products were selected due to their local availability. These were analysed for physical and biochemical properties, composition, and suitability for BSFL rearing on a single substrate and co-conversion mixtures. Wheat bran and wheat gluten were added to the side-streams to modify the larvae diet's nutritional ratio. Optimal growing parameters for BSFL rearing on side-stream-based diets include 29±3.5 ^{o}C air temperature, 70±7% air humidity, and 14:10 light/dark cycle.

Furthermore, this study assesses how adjusting fat content to 5% and the protein-to-fiber (P:F) ratio to 1:1 affects larval development under various protein-to-carbohydrate ratios (P:C) (1:1, 1:2, and 1:3). Survival rate, development time, larval biomass production, and feed conversion ratio were evaluated. Diet 3 (T_3) with a P:C ratio of 1:3 had the highest survival rate, shortest development time, highest larval biomass production, and lowest feed conversion ratio compared to Diet 1 (T_1) and Diet 2 (T_2). The study suggests that the BSF treatment facility can efficiently process low-quality agri-food by-products with different compositions for consistent operation by modifying the P:C ratio to 1:3, keeping fat content at 5%, and maintaining a 1:1 P:F ratio, by including nutrient-rich side-streams.

Preliminary observation on the performances of *Hermetia illucens* larvae on contaminated agroindustry waste

Matteo Crosta, Maria Cristina Reguzzi, Filippo Cominelli, Emanuele Mazzoni, Paola Battilani

Department of Sustainable Crop Production, Università Cattolica del Sacro Cuore, Piacenza, Italy

Corresponding author: paola.battilani@unicatt.it, emanuele.mazzoni@unicatt.it

Hermetia illucens larvae can convert a wide range of organic substrates, like agroindustry waste, into more valuable products such as proteins, lipids, chitin, etc. However, the optimal larvae growth conditions (substrate moisture=60-80%, temperature=27-30°C), together with the natural fungal occurrence on crop residue, may lead to fungal development during the rearing. Therefore, this preliminary study aimed to evaluate the performance of *H. illucens* larvae reared on agroindustry wastes, also contaminated by fungi, focusing on the growth level and time to reach different developmental stages.

Two agroindustry peanut wastes were considered: i) poor waste (P), mainly composed of shells; ii) rich waste (R), with many broken or small pods, and seeds. The wastes were ground and mixed in different percentages (0-100%, step 10%) to obtain 11 feeding substrates. Three-day-old larvae (n=24/replicate) were reared on the feeding substrates for 10 days; chicken feed was used as control substrate (T); all substrates were rehydrated till to 70% moisture. To assess the growth of *H. illucens* larvae on contaminated waste, two spore suspensions (*Aspergillus flavus* and *Fusarium graminearum, 10^5* spore/mL) were spread on peanut waste P5R5 (50% P and 50% R) and T, and the larvae were added (n=10/replicate). The trial was manged in triplicate.

The increase in the R waste in the mix till to 50% led to higher larval growth and weight increase. The fungal contamination affected the growth and development of larvae depending on the feeding substrate. The growth of larvae reared on T was not affected by fungal inoculation, whereas *A. flavus* colonization of peanut waste caused a significant reduction of the larval weight increase. Considering the developmental phase, fungal contamination led to significant reductions in the number of pre-pupae, with the rate depending on the fungus.

These preliminary results highlighted the possibility of rearing *H. illucens* larvae on peanut waste even though the fungi may negatively affect the growth. Therefore, ongoing activities were set up to assess the response of the larvae to varying levels of fungal contamination.

The use of harmless by-products of food and agricultural production for the mass rearing of mealworm *Tenebrio molitor*, their effect on the microbial and nutritional composition, as well as the effect on the color of pupae and larvae

Peter Takáč[1], Milan Kozánek[1], Matúš Drienovský[1], Blanka Tobolková[2], Zuzana Rešková[3]

[1] Scientica, Ltd. Hybešova 33, Bratislava, Slovakia
[2] Department of Chemistry and Food Analysis, National Agricultural and Food Centre- Food Research Institute, Priemyselná 4, Bratislava, Slovakia
[3] Department of Microbiology, Molecular Biology and Biochemistry, National Agricultural and Food Centre- Food Research Institute, Priemyselná 4, Bratislava, Slovakia

Corresponding author: Peter@Scientica.sk

In our mealworm *Tenebrio molitor* (*TM*) mass rearing we focused on finding and identifying options that would significantly reduce breeding costs. We tried to use certain types of hygienically and microbiologically harmless biological waste, which is created in some processes of food and agricultural production. After preliminary testing of some breeding media, we selected apple and carrot squeezed pulps, which are produced during the production of fruit juices, for further experiments. We monitored developmental parameters during the entire larval development depending on the food used. We compared the effect of vegetable and fruit food on the length of larval development, larval weight and volume of food consumed. The results were compared with the control experimental group, where the larvae of *TM* fed during the entire development with standard food (technical flour, bran and oatmeal). Our experiments show that the best results were achieved in the control group, where the larvae were fed technical flour, bran and oat flakes. Comparable results were achieved in the group with larvae fed with carrot pulp, where the larvae were fed standard food in the first stage (4-5 instar) and subsequently with carrot pulp until the end of larval development. At the same time, we monitored the effect of changing the substrate on the micro-biological composition, especially on the presence of pathogenic microorganisms. We monitored the presence of pathogenic bacteria, coliform bacteria, *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella* sp., fungi and yeasts, and *Bacillus cereus*. We also did analysis of the nutritional composition of control group (dry matter, protein, fat, crude fiber and fatty acid profile) of *TM* larvae and pupae. In addition to the nutritional composition, the influence of the feeding substrate on the color of *TM* pupae and larvae was also compared.

The above results show that the feed substrate has a significant effect on the nutritional composition of TM larvae and pupae. And the most important result is that using fruit and vegetable pulps makes mealworm farming much cheaper.

Inclusion of food industry by-products and growers premix into feed for house crickets

Petra Škvorová[1], Hana Necpalová[2], Martin Kulma[2]

[1] Czech University of Life Sciences - Department of Microbiology, Nutrition and Dietetics, Prague, Czech Republic
[2] Czech University of Life Sciences - Department of Zoology and Fisheries, Prague, Czech Republic

Corresponding author: skvorova@af.czu.cz

The growth of the world's population will require the production of vast amounts of food. However, due to the limited area of pastures, it will be very difficult to meet this need with conventional food sources. This can lead to food shortages, especially of animal origin. It will therefore be necessary to look for new sources of animal protein, such as insects, which have a high nutritional value. House cricket (*Acheta domesticus*) has been approved as a new food since 2021 and is also considered as a farm animal and is therefore a new opportunity for organic farming.
The aim of study was to design a feed mixture based on local feeds, which are also by-products of the food industry: brewery spent grains, apple pomace, brewery yeasts and to compare it with a feed mixture for broilers, which is also most often used for breeding crickets. At the same time, the effectiveness of adding a vitamin premix to the feed was evaluated.
Text From the results, it is evident that although the change of feed had no significant effect on the content of crude fat, crude protein or ash content, the influence of the feed on mortality and also on the weight of the harvested crickets was proven. A very significant effect is also evident in the effect of the addition of vitamin premix. The groups that did not have the vitamin premix in the feed did not differ in nutritional values. However, there is a significant difference in mortality and harvest weight. It can therefore be concluded that although the vitamin premix has no effect on nutritional quality of house crickets, its absence causes higher mortality and, as a result, also a lower overall harvest weight of insects. The newly tested feed mixture based on a combination of brewery spent grains, apple pomace and brewery yeasts are suitable for feeding crickets, as it has not been shown to have a negative effect on the nutritional values or rearing characteristics of edible insects.

Quick scan to analyze suitability of small volumes of permitted by-products as substrates for BSF farming

Shannon den Engelsman[1], Natalia Naranjo-Guevara[1], Marian Peters[1] Karel van der Velden[2], Bob Laarhoven[3], Alex van Kuilenburg[4], Koen Volkers[5], Tom van Ravensberg[5], Paula Rijkens[6]

[1] New Generation Nutrition, Den Bosch, Netherlands
[2] Nijsen company, Veulen, Netherlands
[3] Syklus, Winsum, Netherlands
[4] Milgro, Rotterdam, Netherlands
[5] Ravenfeed, Haarlem, Netherlands
[6] Rijkens Food & Tech, Breda, Netherlands

Corresponding author: shannondenengelsman@ngn.co.nl

Addressing the urgent need for sustainable and cost-effective feed alternatives in the Black Soldier Fly (BSF) industry, this project studied the valorization of side-streams, particularly focusing on those that are currently underexploited due to seasonal availability or regulatory difficulties due to small volumes. This initiative is grounded in the recognition that such streams hold immense potential for transforming the local BSF farming by offering more sustainable, accessible, and, most importantly, cost effective substrates. By harnessing these underutilized resources, the project not only aimed to enhance resource efficiency but also to bolster sustainable agricultural practices and food security. By analyzing, 1) substrate suitability parameters, 2) insect life cycle development, 3) nutritional analyses, 4) legislation, and 5) environmental footprints, this project has developed an innovative quick scan decision-making framework. This innovative quick scan tool assists small or starting BSF farmers in systematically selecting and utilizing local organic by-products from agriculture and the food industry, integrating multidisciplinary analyses to ensure substrates meet legislative standards and minimize environmental impacts. Consequently, this tool enables the formulation of optimal feed mixtures that are both cost-effective and nutritionally complete, promoting BSF farming sustainability and operational efficiency. Moreover, by encouraging collaboration across the industry, the project underscores the collective effort required to maximize the utility of residual streams, driving the sector towards embracing more circular and sustainable practices.

Valorization of fruit byproducts through bioconversion by *Hermetia illucens* (Diptera: Stratiomyidae)

Carmen Scieuzo[1,2], Antonio Franco[1,2], Rosanna Salvia[1,2], Micaela Triunfo1, Francesco Iannielli[1], Andrea Boschi[1], Valentina Pucciarelli[1], Fulvia Bovera[3], Ambrogio Laginestra[4], Eric Schmitt[5], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*
[3] *University of Naples Federico II, Naples, Italy*
[4] *Total Energies EP Italia S.p.A, Potenza, Italy*
[5] *Protix B.V., Dongen, The Netherlands*

Corresponding author: patrizia.falabella@unibas.it

Bioconversion constitutes a biological mechanism wherein organic materials undergo a transformation into products of elevated biological and commercial significance. The lar-val stage of the black soldier fly, *Hermetia illucens*, is characterized by its exceptional voracity, enabling it to consume a diverse range of organic materials. To investigate the influence of various fruit byproducts on the insect's growth, final larval biomass, substrate reduction, bioconversion parameters, and larval nutritional composition, a cohort of 10,000 black soldier fly larvae (BSFL) was reared on 7.0 kg of one of three substrates (strawberry, tangerine, or orange), with a standard diet serving as a control. The findings underscore the successful ability of BSFL to thrive and develop on each of the designated diets. However, the substrates exhibited differential impacts on development time, growth rate, and final biomass, with strawberry emerging as the most advantageous substrate. While lipid and protein contents in BSFL remained consistent across larvae fed on differ-ent substrates, substantial variations were noted in ash, micronutrient, fiber, fatty acid, and amino acid contents. In conclusion, the outcomes suggest that the bioconversion process facilitated by BSFL offers a commercially promising avenue for the management of fruit waste. This approach holds potential for regional and national agrifood companies, providing a sustainable and environmentally friendly means of transforming fruit byprod-ucts into secondary products of heightened biological and economic value. The study introduces novel possibilities for industrial development, where fruit waste can be effec-tively disposed of or innovatively upgraded to yield secondary products such as BSFL biomass for animal feed or, prospectively, as an alternative protein source for human nutrition.

Fine-tuning the microbiome: strategies for mealworm gut optimization

Bernardo Antunes[1], Alissa Cakarcan[1], Julia Häbermann[1,2], Claudia Keil[2], Charlotte Rafaluk-Mohr[1]

[1] *Evolutionary Biology, Freie Universität Berlin, Berlin, Germany*
[2] *TU Berlin, Institute of Food Technology and Food Chemistry, Department Food Chemistry and Toxicology, Berlin, Germany*

Corresponding author: charlotte.rafaluk-mohr@fu-berlin.de

The production of animal protein for human consumption is a massive contributor to greenhouse gas emissions. Globally the food industry produces around 34% of anthropogenically produced greenhouse gasses, 72-78% of which come from the production of meat. This figure highlights the urgent need for climate friendly alternatives. Mealworms, the larvae of the mealworm beetle, *Tenebrio molitor*, have been registered as a novel food product in the EU since 2021 and is one of four insects that can be used for food and feed purposes in the EU. There remain, however, some challenges in the mass rearing of insects, both in terms of optimizing mealworm health and safety aspects for consumers. It is important to avoid introducing the kind of widespread use of antibiotics seen in the meat industry into insect farming to prevent disease outbreaks. Optimizing the diet of the mealworms through supplementation with trace elements and probiotics is a potential strategy to alleviate both the challenge of disease control without antibiotics while optimizing both mealworm and consumer health. In livestock farming, zinc is known to supplement the immune system and support growth and can have stabilizing effects on the microbiota when administered at the right dose. Adding probiotics can also help control the insect's microbiome and therefore the type of bacteria that might end up in the final product. By using trace elements and probiotics, we are developing feeding protocols that sustain *Tenebrio molitor*'s health, prevent disease outbreaks in insect cultures, and develop food and feed products of high safety. To maximize sustainability, we are also looking at the potential probiotic and trace element contribution of organic side streams to the insects' diet. To achieve this, we are testing the impact of supplementation regimes using fermented vegetables, trace element supplementation and the feeding of live probiotic bacteria on insect health in terms of survival and body weight as well as on the overall composition of the microbiota and trace element content of the larvae.

Closing the loop with sustainable recycling of lignocellulose rich organic (by-) products from rewetted peatlands for insect development and petfood production

Alexandra Rath[1], Jan-Berend Lingens[1], Madeleine Plötz[2], Nils Th. Grabowski[2], Clemens Hollah[3], Mossammad U. C. Sultana[3], Kashif ur Rehman[3], Christian Visscher[1], Cornelia Schwennen[1]

[1] *Institute of Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Hanover, Germany*
[2] *Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hanover, Germany*
[3] *German Institute of Food Technologies (DIL e.V.), Quakenbrück, Germany*

Corresponding author: alexandra.rath@tiho-hannover.de

The globally diminishing available resources lead to a growing interest in recycling of lignocellulose-rich organic by-products that were previously largely unusable for conventional agriculture use. A potential area-wide rewetting of peatlands for the purpose of revitalisation and CO_2-storage leads to the accumulation of such lignin-rich primary biomass.

This research investigates how, within paludiculture, lignocellulose-rich primary biomass from rewetted peatlands could be used for utilisation by insects, especially the larvae of *Hermetia illucens*, *Tenebrio molitor*, *Gryllus assimilis* and *Acheta domesticus*, by using mechanical, biological, thermal, and chemical pre-treatment techniques. The purpose is to break down the resistant lignocellulose structure and supplement it with co-products from agriculture and food production so that the insects can convert the pre-treated, low-grade material together with co-products into protein-rich biomass. These scalable and high quality raw materials can be further utilised as animal feed and provide a sustainable alternative for livestock and pets. In perspective, the insects obtained are also suitable for human nutrition.

The closed-loop character of this process could build a biological cycle from a by-product, which can so far mostly serve for energetic purposes. Considering the scarcity of resources, this practice is no longer contemporary. Therefore, this research highlights the shift towards a sustainable circular economy and the effective use of biogenic resources. Additionally, the technologically-biological utilisation of primary biomass for the decentralised establishment of a value chain through insect farming for local production of food and feed, as well as creating employment opportunities, can contribute to garnering broader societal acceptance for biodiversity-promoting measures such as the restoration of peatlands.

Size doesn't matter – Individual weight and length of *Zophobas atratus* larvae raised at 20 °C in relation to batch yield

Nils Th. Grabowski[1], Anna Polehne[1], Cornelia Schwennen[2], Jan-Berend Lingens[2], Juliane Hirnet[1], Marieke Herrel[3], Christian Visscher[2], Madeleine Plötz[1]

[1] *Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Hanover, Germany*
[2] *Institute of Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Hanover, Germany*
[3] *Centre for Translational Studies, University of Veterinary Medicine Hannover, Foundation, Hanover, Germany*

Corresponding author: nils.grabowski@tihohannover.de

Productive insects' development depends, among others, on temperature. Typically, insects are reared at 25 - 28 °C. However, energy may be expensive and contribute significantly to production costs. Lower temperatures may reduce costs but are known to affect productive parameters. The goal of this study was to assess individual larval weight and length in *Zophobas atratus* reared at 20 °C on a standard diet of 500 g wheat bran and fresh carrots *ad libitum*.

For that, n = 81 *Z. atratus* batches from colonies of max. 100 imagines were weighed weekly from the 1st to the 36th week of life. This weekly weight refers to the total biomass (animals, feed, and frass). From the 16th week until harvest, the mean weight [mg] and the length [cm] of 10 randomly chosen animals were recorded. Depending on the final biomass [% from the 1st week value], batches were categorised as "poor" (<25 %), "medium" (25 - <55 %), "good" (55 - <85 %), and "very good" (≥85%), and weight and length were calculated according to batch type and week of life.

Larval weight and length were affected by the week of life, but not by the batch type. From week 16 on, larval growth resp. length could be separated into three weight (I to III) and two length phases (A and B) with decreasing gradient angles, i.e. the older the larvae, the less pronounced growth. Both phases I (weight) and A (length) lasted from week 16 to 28. While phase B (length) took from week 29 to 36, this period in terms of weight could be divided into phase II (29 to 33) and III (34 to 36).

In this way, yields of batches were regarded as a question of animal numbers rather than individual weight. It should be stressed that this has been studied so far only for the temperature and the feeding regime mentioned above. Further research is necessary to assess weather changing these conditions will also lead to changes in this growth pattern.

Rearing house crickets using feed enriched by rapeseed and flaxseed oils

Jakub Folke[1], Lenka Kouřimská[1], Matjaž Červek[2], Petra Škvorová[1], Zora Kotíková[1], Martin Kulma[1]

[1] *Czech University of Life Sciences, Prague, Praha-Suchdol, Czech Republic*
[2] *Emona Nutrition Research & Development Department, Ljubljana, Slovenia*

Corresponding author: xfolj003@studenti.czu.cz

The dietary composition is known to have a significant influence on nutritional value of edible insects. Thus, the beneficial substances may be incorporated into insect biomass via their artificial supplementation into their diet. In this investigation, rapeseed pomace, rapeseed oil, and flaxseed oil were used as partial replacements for soybean meal and soybean oil in the diet of house crickets (*Acheta domesticus*). The study aimed to evaluate the temporal effects of these dietary supplements by subjecting the crickets to enriched experimental diets i) throughout their entire lifespan, ii) for ten and iii) five days before their harvest. Substituting soybean oil with either rapeseed oil or a combination of rapeseed and flaxseed oils exhibited a positive impact on the fatty acid composition. All experimental crickets demonstrated reduced levels of saturated fatty acids (SFA) and elevated levels of linolenic acid and monounsaturated fatty acids (MUFA). Prolonged supplementation correlated with higher MUFA levels and lower SFA levels. Additionally, dietary enrichment resulted in increased concentrations of α- and γ-tocopherols. Notably, the biomass harvested from crickets provided with experimental diets throughout their entire lifespan exhibited higher yields compared to the control group.

Effect of rearing duration on substrate related variations in the composition of the yellow mealworm

Rebecca Rüsch, Kathleen Oehlke

Max Rubner-Institut, Institute for Food Technology and Bioprocess Engineering, Karlsruhe, Germany

Corresponding author: kathleen.oehlke@mri.bund.de

Insects respond to different diets with changes in body composition. Furthermore, the body composition shifts towards higher fat contents with larval age. Both factors, i.e. substrate and harvesting weight, can therefore influence later product properties of insect-based food or feed ingredients.

The aim of this study was to investigate the influence of different substrates and larval weight on the chemical composition of the yellow mealworm (*Tenebrio molitor*). Larvae with a starting weight of 30 mg were reared on four different diets and were harvested at two weight stages (80 mg and 100 mg). The substrates consisted primarily of agricultural side streams, including wheat bran, rice bran, apple pomace, dried distillers' grains with solubles (DDGS), beet pulp and the micro algae *chlorella vulgaris*. These were mixed together in differing proportions to obtain the following diets: wheat bran as the control substrate, HPLF (High Protein Low Fat), LPHF (Low Protein High Fat) and CtrlA (control with algae). The larvae reached the desired weights after four to seven weeks. The proximate composition of the larvae was analysed using standard procedures. In 80 mg larvae, moisture content (63 % - 77 %), protein content (40 % - 50 % DM) and fat content (14 % - 30 % DM) showed significant variation. In 100 mg larvae, the differences were less pronounced: moisture content (58 % - 62 %), protein content (36 % - 38 % DM) and fat content (29 % - 36 % DM).

Both diet and weight related changes in mealworm composition can help to reach desired ingredient or product properties. Later harvesting times are favourable when constant product properties are important for further applications, due to the decrease in diet related variations. On the other hand, earlier harvesting times can be beneficial in terms of lower fat content and greater variation between groups, i.e. a broader product palette.

Unveiling trophic egg production in black soldier fly (*Hermetia illucens*): insights for mass rearing

Yulia Riabtseva, Bartosz Grodzki, Marco Tejeda, Marc Bolard

Nasekomo AD, Sofia, Bulgaria

Corresponding author: yulia.ryabceva@nasekomo.life

The black soldier fly (BSF*, Hermetia illucens*) is a promising insect for converting organic waste into protein for animal feed. Egg availability is crucial for continuous bioconversion, yet BSF egg-laying strategies remain poorly understood. This study investigates the production of infertile eggs in mated BSF females.

We measured the frequency of infertile eggs, their correlation with clutch size, and propose a hypothesis for their function. BSF were reared under controlled conditions. Daily for 20 days, two-day-old egg clutches were collected from mated females (n=20). Under a stereomicroscope, we determined egg fertility, counted total eggs, and percentage of infertile eggs. Data were analyzed using IBM SPSS Statistics.

Every clutch contained infertile eggs (6-16%). The percentage of infertile eggs positively correlated with clutch size ($r=0.971$, $p<0.001$). Notably, infertile eggs were dark green, contrasting with light beige fertile eggs.

The consistent presence, color difference, and observations of newly hatched neonates suggest trophic egg-laying in BSF. Trophic eggs, reported here for the first time in mated BSF females, might provision offspring or reduce sibling cannibalism.

Further research on the cause and adaptive benefits of this oviposition pattern will enhance our understanding of BSF reproductive biology and optimize mass rearing practices.

InProFarm, an Italian project to promote insect probiotic-assisted farming

Carlotta Savio[1], Rosemarie Tedeschi[1], Elisa Bigarella[2], Costanza Jucker[2], Elena Crotti[2]

[1] Department of Agricultural, Forest and Food Sciences, University of Turin, 10095 Grugliasco, Italy
[2] Department of Food, Environmental and Nutritional Sciences, University of Milan, via Celoria 2, 20133 Milan, Italy

Corresponding author: rosemarie.tedeschi@unito.it

This study is focused on the yellow mealworm *Tenebrio molitor* and the black soldier fly *Hermetia illucens*, two insect species mass-reared for feed and food purposes.
In these years, the identification of potential probiotics within microbiome of farmed insects and their application in mass reared environments have been investigated for recording the effects on insect growth, reproduction and health with the aim also to mitigate the presence of multiple stressors such as entomopathogens, temperature and high densities.
The aim of this project is to develop microbe-assisted strategies to enhance growth, reproduction, and immune responses of mass-reared insects through the administration of probiotic strains.
Probiotic administration could be helpful to exploit insect farming, by reducing the time required to obtain the larval biomass, by sustaining the rearing and by obtaining healthy and high-quality insects beside the presence of mixed stressors. Moreover, the study will unravel molecular mechanisms underneath the host-microbe interactions.
The study is focused on the characterization of the gut microbiota of both insect species reared on diets differing in nutritional value; the isolation and the screening of potential probiotic strains by evaluating their hydrolytic profile and ability to counteract pathogens; the bacterial probiotic administration to insects and the evaluation of insects' performances and metabolic and immune responses. The study underlines the importance to promote the development of healthy production of insects as feed and food.

Determining the gut microbiota composition of the yellow mealworm *Tenebrio molitor* in its rearing environment

Emilie Mollard[1], Marc Duong[1], Hicham El Alaoui[2], Frédéric Delbac[2], Valentin Ageorges[1]

[1] *Invers SA, Saint-Ignat, France*
[2] *Université Clermont Auvergne, CNRS, LMGE, Clermont-Ferrand, France*

Corresponding author: valentin.ageorges@invers.fr

During the last decade, insects have received increasing interest as an innovative source of alternative protein for both human food and animal feed. The yellow mealworm (*Tenebrio molitor*) is one of the best options due to its high protein content and ease of breeding and feeding. As in all livestock sectors, understanding and managing the microbiological aspects of mealworm production is crucial for ensuring quality and profitability. Until now, the scientific literature is limited in data on mealworm gut microbiota under large-scale rearing conditions, as the majority of studies have been conducted under controlled laboratory conditions. Thus, this study aimed to identify bacterial communities present in the gut microbiota of *T. molitor* under industrial rearing conditions. Regular sampling at various stages of larval growth was conducted, followed by DNA extractions and subsequent high-throughput sequencing, to reveal the bacterial phyla comprising the gut microbiota. Bacterial analyses of the mealworm rearing substrate (wheat bran) were also undertaken during this study. Firmicutes, Proteobacteria and Tenericutes were identified as the predominant phyla in *T. molitor* larvae, with variations in abundance across growth stages. In the rearing substrate, Proteobacteria, Firmicutes, Cyanobacteria and Actinobacteria were prevalent. The bacterial composition of the substrate was initially similar to the raw substrate (not in contact with larvae), then showed a gradual shift towards the bacterial composition of mature larvae. The renewal of the substrate and the quantity of frass emitted according to the weight of the larvae could explain these results. These preliminary results could provide further insight into the interaction between the insect's gut microbiota, its zootechnical performance and the conditions of its rearing environment. Further research in this area could enhance the efficiency and sustainability of insect-based protein production.

Probiotics to improve bioconversion and growth of black soldier fly larvae

Costanza Jucker, Elisa Bigarella, Serena Malabusini, Elena Crotti

Department of Food, Environmental and Nutritional Sciences University of Milan, via Celoria 2, 20133 Milan, Italy

Corresponding author: costanza.jucker@unimi.it

Hermetia illucens (Diptera, Stratiomyidae), also known as the black soldier fly, can successfully grow on several organic matters, converting them into larval biomass rich in protein and lipids. Today, the mass rearing of its larvae is of particularly attention for the production of alternative source of protein to be used in animal livestock. Insect gut microorganisms play an important role influencing different traits of the insect, as nutrition, growth and reproduction. Moreover, the supplementation of viable beneficial microbes in insect's diet is way to improve overall health status and prevent diseases in the mass rearing. This study intended to assess the influence of different agro industrial by-products on the larval gut microbiome, and explore whether probiotic supplementation could enhance BSF growth and bioconversion ability.

Brewer's spent grains, okara, potato selection waste and potato peels were used as larval growing media leading to different results in terms of growth and bioconversion; best results were obtained with okara, while on the other by-products the development was slower, and on potato peels a high mortality was assessed (67%). Therefore, we administered probiotic bacteria to BSF larvae reared on suboptimal diets to evidence any potential probiotic impacts on BSF larvae. Sporeformer bacteria and lactic acid bacteria, previously isolated from the BSF gut, were tested both considering active and heat-inactivated cells.

Supplementation with active bacteria indicated a potential positive influence, while higher final weights were achieved with the administration of heat-inactivated bacteria. However, heat-inactivated bacteria also resulted in a longer duration for the larvae to reach the prepupal stage. Overall, the supplementation of bacterial probiotics represents an intriguing strategy to improve BSF mass rearing.

Bioconversion of olive oil by-products by *Hermetia illucens*

Esther Rodríguez-González[1], María Dolores Hernández[2], Fernando Barroso[3], Raúl Hurtado-Ribeira[1], Luis Vázquez[1], Mónica R. García-Risco[1], Diana Martin[1]

[1] *Sección Departamental Ciencias de la Alimentación, Universidad Autónoma de Madrid, Madrid, Spain*
[2] *Instituto Murciano de Investigación y Desarrollo Agrario y Medioambiental, Murcia, Spain*
[3] *Departamento de Biología y Geología, Universidad de Almería, Almería, Spain*

Corresponding author: diana.martin@uam.es

Concerning agricultural by-products, a huge number of sources remains unexplored for insect feeding. One example are those derived from the olive oil industry, such as the problematic olive leaves, olive mill waste, “alperujo” or olive pomace. Therefore, due to the extraordinary bioconversion ability of *Hermetia illucens* (black soldier fly, BSFL), the main aim of this study was to explore the potential of valorization of olive oil by-products by using them in the feeding BSFL.

BSFL diets were based on laying hen feed (control diet) or partial replacement with the different by-products: dry olive leaves at 15%, 30% or 50% (OL15, OL30, OL50) and dry olive pomace at 30%, 50%, 70%, 90% (OP30, OP50, OP70, OP90). Each diet (15 kg, 1:2 ratio of dry feed to water) was produced in triplicate. A total number of 13.000 larvae (91 g) were reared per replicate for 12 days. Total larvae biomass gained (WG), growth rate (GR), bioconversion efficiency (BE), mass reduction (MR) and mass reduction index (MRI) were estimated at fresh basis. The proximal composition of the diets and the fresh larvae was analyzed.

Control larvae reached a WG of 157 ± 16 mg per larvae, at rate of 13 mg/d. Only in case of OL15, a significant same WG of 141 ± 25 mg than control was obtained, at rate of 12 mg/d. The rest of treatments caused significant lower WG and GR, being worse as the replacement level increased. Thus, OL50 reached 43 ± 7 mg per larvae and OP90, 51 ± 9 mg per larvae. Most diets did not differ on the BE, with a mean value closer to 13%, but being significantly lower for OP70 (9%) and OP90 (7%). MR was close to 80% for control diet, OL15 and OP30, with a MRI of 7%/day. The protein and lipid content of the larvae from control, OL15 and OP30 diets did not differ; but being lower the protein content of the larvae for the rest of diets.

Therefore, considering all the productive parameters together, dry olive leaves at 15% and dry olive pomace up to 30% can be used for BSFL feeding, reaching an excellent bioconversion of these by-products into nutritive BSFL meal.

Bioconversion of olive oil by-products by *Tenebrio molitor*

Virginia da Cunha[1], María Dolores Hernández[2], María José Sánchez-Muros[3], Tiziana Fornari[1], Raúl Hurtado-Ribeira[1], Emma Cantero-Bahillo[1], Diana Martin[1]

[1] Sección Departamental Ciencias de la Alimentación, Universidad Autónoma de Madrid, Madrid, Spain
[2] Instituto Murciano de Investigación y Desarrollo Agrario y Medioambiental, Murcia, Spain
[3] Departamento de Biología y Geología, Universidad de Almería, Almería, Spain

Corresponding author: diana.martin@uam.es

Olive leaves and olive pomace represent significant by-products originating from the olive oil industry, carrying considerable climate impact and economic management costs. Therefore, owing to the remarkable bioconversion capability of *Tenebrio molitor*, the aim of this study was to explore the potential valorization of olive oil by-products by incorporating them into mealworms feeding.

T. molitor diets were formulated based on wheat bran (control diet) or partial replacement with the different by-products: dry olive leaves at 15%, 30% or 50% (OL15, OL30, OL50) and dry olive pomace at 30%, 50%, 70%, 90% (OP30, OP50, OP70, OP90). Each diet (6 kg) was produced in triplicate. A mean number of 15.000 larvae (76.5 ± 23.7 g) of at least 4 weeks old and 1-1.5 cm of length were reared for each replicate of substrate until 11 weeks old. Total larvae biomass gained (WG), growth rate (GR), bioconversion efficiency (BE), mass reduction (MR) and mass reduction index (MRI) were assessed on a fresh basis. Additionally, the proximal composition of the experimental diets and the fresh larvae was analyzed.

Control larvae attained a WG of 45 ± 5 mg per larvae, at rate of 6 mg/week. Only in case of OP30, a significant same WG of 43 ± 4 mg than control was obtained, at rate of 6 mg/week. The rest of treatments caused significant lower WG and GR, being worse as the replacement level increased. Thus, OL50 reached 23 ± 2 mg per larvae and OP90, 14 ± 0.5 mg per larvae. Most diets did not differ on the BE, with a mean value close to 39%, but being significantly higher for OP90 (61%). MR was close to 32% for control diet, with a MRI of 4.5%/week. All the experimental treatments showed much lower MR values (in the range of 3-27%).

Therefore, considering all the productive parameters together, dry olive pomace up to 30% can be used for mealworms feeding, reaching an acceptable bioconversion of these by-products into nutritive *T. molitor* meal.

Bioconversion of quinoa husk by-product by *Hermetia illucens* and *Tenebrio molitor*

Virginia da Cunha[1], Esther Rodríguez-González[1], María Dolores Hernández[2], Carmen Vargas-García[3], Diego Martín Hernández[1], Emma Cantero-Bahillo[1], Diana Martin[1]

[1] *Sección Departamental Ciencias de la Alimentación, Universidad Autónoma de Madrid, Madrid, Spain*
[2] *Instituto Murciano de Investigación y Desarrollo Agrario y Medioambiental, Murcia, Spain*
[3] *Departamento de Biología y Geología, Universidad de Almería, Almería, Spain*

Corresponding author: diana.martin@uam.es

The world production of quinoa has tripled in the last 20 years. Expanding at a rate of 11%, the global quinoa market is projected to increase up to 1.4 billion by 2032. However, its expansion and intensification entail a large volume of husk, an emerging waste of poor value from the scarification of the grain performed to reduce its bitterness due to saponins. Some scarce studies have explored the use of husk for animal feeding, but with limited or unclear results. Therefore, due to the remarkable bioconversion capability of edible insects, the aim of this study was to explore the potential bioconversion of quinoa husk by *T. molitor* or *H. illucens*.

Diets were formulated based on wheat bran (control diet) or partial replacement with quinoa husk at 15%, 30% or 50% (Q15, Q30, Q50). Each diet (6 kg for *T. molitor* or 15 kg for *H. illucens*) was produced in triplicate. A mean number of 15.000 larvae (4 weeks old and >1 cm of length for *T. molitor*) or 13.000 larvae (*H. illucens*) were reared for each replicate of substrate until 11 weeks old (*T. molitor*) or 12 days old (*H. illucens*). Total larvae biomass gained (WG), growth rate (GR), bioconversion efficiency (BE), mass reduction (MR) and mass reduction index (MRI) were assessed on a fresh basis. The proximal composition of the diets and the fresh larvae was analyzed.

Control larvae attained a WG of 45 ± 5 mg per larvae, at rate of 6 mg/week for *T. molitor* and 157 ± 16 mg per larvae, at rate of 13 mg/d for *H. illucens*. Q15 and Q30 reached a significant same WG respect to the control for both insect species, while Q50 caused significant lower WG and GR. All quinoa levels for *H. illucens* did not differ on the BE, MR and MRI respect to control diet, while such similarity to control was only evident for Q15 in case of *T. molitor*.

Therefore, considering all the productive parameters together, quinoa husk up to 15% for *T. molitor* and 30% for *H. illucens* can be used for insect feeding, reaching an excellent bioconversion of these by-products into nutritive insect meals.

Effect of zinc and selenium on the growth of black soldier fly

Costanza Jucker[1], Serena Malabusini[1], Andrea Moradei[2], Matteo Ottoboni[2], Sara Savoldelli[1], Luciano Pinotti[2,3]

[1] *Department of Food, Environmental and Nutritional Sciences, University of Milan, via Celoria 2, 20133, Milan, Italy*
[2] *University of Milan, Department of Veterinary Medicine and Animal Sciences, 26900 Lodi, Italy*
[3] *CRC I-WE, University of Milan, 20134 Milan, Italy*

Corresponding author: costanza.jucker@unimi.it

Zinc (Zn) and selenium (Se) are two essential micronutrients involved in several biological functions in humans and animals. To guarantee an adequate intake, the use of various sources has been proposed. Among these, the possibility of biofortifying feed and food edible insects (e.g. *Hermetia illucens*, black soldier fly-BSF) may be an option. In this study, funded by Agritech National Research Center, we explored, as first step, the effects of the supplementation of inorganic feed grade Zn and Se into the substrates for rearing BSF larvae.

A mixture of two agro-industrial by-products okara and potato waste (50:50) was selected as rearing substrate, as well as a control diet (Gainsville). The substrates (okara+potato waste) were fortified as follow: I) 150 mg/kg of Zn; II) 0.3 mg/kg of Se; III) 150 mg/kg of Zn + 0.3 mg/kg of Se. Doses for both trace-elements have been selected on the base of other farm feed formulations. For each thesis, five replicates were set up containing 500 young larvae. Growth parameters, bioconversion ability and final biomass yield were measured. Experiments were conducted under dark conditions at 26°C and 60% relative humidity.

BSF larvae grew efficiently on the diets enriched with Zn and Se, without showing significant differences ($P>0.05$) with the control and the unfortified diets in terms of survival (always above 94%), developmental time and mean larval weight (overall mean 0,14 g). Only the total biomass collected at the end of the experiment was higher in the control diet ($P>0.05$). Substrate reduction and conversion efficiency were similar ($P>0.05$) within the experimental thesis.

These first trails indicate the feasible of adding Zn and Se in the rearing diet, but further studies need to evaluate the influence of the microelements on adult reproduction and the effective enrichment of the larval biomass produced.

Effects of feeding diets o on the survival, growth and reproductive performance of *Rhynchophorus phoenicis* Fabricius (Coleoptera: Curculionidae) in Ghana

Agartha Darkwaah Tando[1], Shadrack Kwaku Debrah[2], Rexford Appiah[3]

[1] *Department of Horticulture and Crop production. School of Agriculture and Technology, University of Energy and Natural Resources, Sunyani, Ghana.*
[2] *Department of Horticulture, University of Ghana, Accra, Ghana*
[3] *Legendary Foods Africa Limited, Kumasi, Ghana*

Corresponding author: agarthatandoh@gmail.com

Rhynchophorus phoenicis, F. (Coleoptera: Curculionidae) is a popular commercially important edible insect species in that has received increasing attention as a sustainable dietary source of nutrients either as a dried whole or as a processed insect product, particularly in West Africa and central Africa. Nevertheless, there is lack of information on suitable substrates and their effects on this species' performance (adult weight, fecundity, survival and development time) in rearing conditions, which would be a starting point mass production.

In this study, we experimentally evaluated the suitability of four substrates (pito mash, brew waste, spent corn meal, and palm kernel cake) for the growth and reproductive parameters of *R. phoenicis*. Mash palm yolk (inner core) was used as a control diet.

The results showed that pito mash could be used to feed *R. phoenicis* in insect farming systems. The highest larval survival rates were recorded when fed with brew waste and pito mash. Feeding the larvae with pito mash resulted in the shortest development times. Meanwhile, the highest mean weight was attained when individuals were fed on brew waste and pito mash. Lifetime fecundity of females fed on palm yolk was more than twice that of the other diets. These findings can contribute to the future design of commercial rearing systems for this economically crucial edible insect in captivity.

Circular Economy as a paradigm to integrate industrial waste as a feed resource for Black Soldier Fly Larvae

Aarati Upreti[1], Sundar Tiwari[2], Prabhat Khanal[1], Debasree Purkayastha[1]

[1] *Faculty of Biosciences and Aquaculture, Nord University, Skolegata 22, Steinkjer 7713, Norway*
[2] *Department of Agricultural Entomology, Agriculture and Forestry University, Chitwan-44200, Nepal*

Corresponding author: aarati.upreti@student.nord.no

Insects have been a primary focus to ensure sustainable future feed and food. Black soldier fly has been the crown jewel among the food and feed based-insect community. The need to have a better understanding of the feeding behavior of Black Soldier Fly Larvae in diverse food or waste is pivotal for large-scale industrialization. Circular economy has been a very talked about concept in these times of sustainable engineering. In Circular Economy, the waste from one industry can become the starting material or resource for the other industry. In this study, two different industrial wastes viz. bakery waste and rapeseed cake have been provided as feed to Black Soldier Fly Larvae. Chicken feed was used as a standard diet for understanding the overall performance of Black Soldier Fly Larvae. The final weight of the Black Soldier Fly Larvae in 12 days of treatment time was 113.91±3.35, 197.53±9.87, and 68.83±7.23 mg/larvae for Chicken feed, bakery waste, and rapeseed cake respectively. The growth rate followed the logistic growth curve with a growth rate of 0.47 day^{-1} for both the bakery waste and rapeseed cake whereas it was 1.02 day^{-1} for Chicken feed. While the growth rate for chicken feed was higher, the final weight for chicken feed was lower than the bakery waste. In the case of Rapeseed cake, both the growth rate and final weight were lower, however, sinigrin (allyl glucosinolate) responsible for the pungent taste and bitterness of rapeseed cake can be a plausible reason for such poor performance. The study implicates the need to design an incremental multiple waste feeding scheme for overall higher performance of Black Soldier Fly Larvae-based large-scale industries.

Substrate modifications for *Chironomus tentans* Fabricius (Diptera: Chironomidae): impact on survival, size, and mass

Maša Stojanović, Petar Ristić, Bogdan Jovanović, Aleksandar Tomić, Đurađ Milošević, Jelena Stojanović, Aleksandra Trajković, Dimitrija Savić Zdravković

Department of Biology and Ecology, Faculty of Sciences and Mathematics, University of Niš, Serbia

Corresponding author: dimitrija.savic@pmf.edu.rs

Non-biting midges are frequently used in toxicity assessments and as indicators of environmental quality due to their high sensitivity to environmental changes. The stability of rearing protocols is essential for ecotoxicological and climate studies, as well as research and development in the aquaculture industry. Given that most laboratory stocks originate from wild-caught specimens, different species exhibit performance plasticity, making stock maintenance and reliable testing challenging.

This study focuses on substrate adjustment for lab-scale optimization in insect production systems by investigating cost-effective modification of the standard substrate as prescribed by OECD guidelines. All possible combinations of standard substrate ingredients have been tested on survival rate, size and mass. The highest larval survival rates were observed in substrates composed of a sand and peat mixture, and of coarse sand alone (85% and 82%, respectively), marking them as the most suitable sediment types. Clay and peat mixture, and peat alone, resulted in the highest larval mortality (65% and 46%, respectively) and are therefore not recommended for future use in bioassays.

Trials on standard and peat + clay, as well as fine sand substrates, exhibit significantly greater mass than those on all other substrates. None of the larvae survived in treatments without substrate. Larvae ingest food particles smaller than 1 mm, suggesting the possibility that larvae might mix finer-grain substrate with food, thereby reducing the actual amount of food ingested and decreasing their mass and size. Our results show a satisfactorily high survival rate on both fine and coarse sand, with larvae reared on fine sand showing slightly lower survival rates, as well as significantly greater mass and length than all other larvae. Considering these findings, and in alignment with the existing data, it can be concluded that utilization of fine coarse sand is the optimal choice for further exploration across all studies.

Strategy for feeding high moisture feeds to *Tenebrio molitor*

Christian Schnorr[1], Nicole Buschle[1], Oliver Hensel[2]

[1] *Department of Food Technology, University of Applied Sciences Fulda, Germany*
[2] *Department of Organic Agricultural Sciences, University Kassel, Germany*

Corresponding author: christian.schnorr@lt.hs-fulda.de

When rearing insects, their feed is generally considered the major critical point in terms of cost and sustainability. Feed conversion parameters are used to compare different feeds. These require the determination of the feed ingested based on occurring feed residues. The feeding strategy for *Tenebrio molitor* can be a crucial tool to minimize feed residues and to avoid the preprocessing of feed.

Up to now separation is successfully enabled for dry feed by either waiting until all feed given is ingested completely or by processing the feed (e.g. by agglomeration, extrusion, or sieving). For wet feed these methods are suboptimal. Waiting risks microbial contamination and processing removes moisture. Since wet feed is ingested at a higher rate than its dried form, a form of controlled feeding is necessary.

The solution proposed is to give only as much feed as can be eaten daily. 18 hours after feeding, rearing units are inspected for residues. If no residues are visible, the mass fed after 24 hours is increased by 5%. Otherwise, it will remain constant, until mealworms have grown sufficiently to ingest all feed given within 18 hours. This is assumed to minimize feed residues without impairing larval development due to starvation.

This assumption was tested in two experiments with salad roots as high moisture feed and other dry feed components. Larvae of similar age were reared from 10-15 mg per larvae to pupation with a starting mass of 1.5 mg feed in dry mass per larvae per day. The amount of feed residues and the survival rate were recorded to evaluate the feeding strategy.

It has been found that this strategy provides an alternative to the processing of dry feed and allows for high moisture feeds to be integrated into diets with no apparent impairments in larval development. The error in determining ingested feed is almost negligible because the mass of feed residues is minimized. These benefits however come at the cost of a labor-intensive daily feeding regime.

This strategy for wet feeds can be improved by testing different incremental steps as well as applying automated visual inspections to include information about the degree of underfeeding.

Circular Economy as a paradigm to integrate industrial waste as a feed resource for Black Soldier Fly Larvae

Aarati Upreti[1], Sundar Tiwari[2], Prabhat Khanal[1], Debasree Purkayastha[1]

[1] *Faculty of Biosciences and Aquaculture, Nord University, Skolegata 22, Steinkjer 7713, Norway*
[2] *Department of Agricultural Entomology, Agriculture and Forestry University, Chitwan-44200, Nepal*

Corresponding author: aarati.upreti@student.nord.no

Insects have been a primary focus to ensure sustainable future feed and food. Black soldier fly has been the crown jewel among the food and feed based-insect community. The need to have a better understanding of the feeding behavior of Black Soldier Fly Larvae in diverse food or waste is pivotal for large-scale industrialization. Circular economy has been a very talked about concept in these times of sustainable engineering. In Circular Economy, the waste from one industry can become the starting material or resource for the other industry. In this study, two different industrial wastes viz. bakery waste and rapeseed cake have been provided as feed to Black Soldier Fly Larvae. Chicken feed was used as a standard diet for understanding the overall performance of Black Soldier Fly Larvae. The final weight of the Black Soldier Fly Larvae in 12 days of treatment time was 113.91±3.35, 197.53±9.87, and 68.83±7.23 mg/larvae for Chicken feed, bakery waste, and rapeseed cake respectively. The growth rate followed the logistic growth curve with a growth rate of 0.47 day^{-1} for both the bakery waste and rapeseed cake whereas it was 1.02 day^{-1} for Chicken feed. While the growth rate for chicken feed was higher, the final weight for chicken feed was lower than the bakery waste. In the case of Rapeseed cake, both the growth rate and final weight were lower, however, sinigrin (allyl glucosinolate) responsible for the pungent taste and bitterness of rapeseed cake can be a plausible reason for such poor performance. The study implicates the need to design an incremental multiple waste feeding scheme for overall higher performance of Black Soldier Fly Larvae-based large-scale industries.

Protein pattern of black soldier fly larvae fed on Nepalese agro-industry waste

Nisha Kharel[1,2], Sundar Tiwari[1], Bhola Gautam[1,2], Prabhat Khanal[2], Debasree Purkayastha[2]

[1] Department of Agricultural Entomology, Agriculture and Forestry University, Chitwan-44200, Nepal
[2] Animal Science, Production and Welfare Division, Faculty of Biosciences and Aquaculture, Nord University, Skolegata 22, Steinkjer 7713, Norway

Corresponding author: karishma.subedi@student.nord.no

Globally, Black soldier Fly has been one of the major commercially reared insects. There is an increased demand of the black soldier fly larvae-based protein feed. The substrate fed to the black soldier fly larvae has a pertinent impact on the overall final protein content of the feed. This feed can be a potential alternate for Nepal as a developing country having struggles with local poultry feeds. However, it is also important to understand whether the agro-waste management and feed industry can be integrated. In this study, two agro-industry based wastes viz. vegetable waste and chowmein waste were fed to black soldier fly larvae. Each treatment had a three replicates and commercial Chicken feed was used as a reference diet. Four different larval densities 1, 3, 5 and 7 Larvae/cm^2 were tested to understand the impact of larval density on black soldier fly larvae performance. The highest crude protein in the final black soldier fly larvae was found with the vegetable waste with 3 Larvae/cm^2 (28.60±4.25% dry weight basis). The lowest crude protein content was in the chowmein waste with 3 Larvae/cm^2 (13.04±0.37% dry weight basis). The crude protein content of final black soldier fly larvae in vegetable waste and chowmein waste and reference diet chicken feed across densities varied between 16-30%, 13-26% and 25-29%respectively. The study observed that feeding Black Soldier Fly larvae with vegetable waste at a density of 3 larvae/cm² generated the highest crude protein content. This shows that combining agro-industry waste management with insect-based protein feed production could help reduce feed shortages in developing nations such as Nepal.

Digital planning and tracking for continuous quality improvement and process optimization in edible insect farming

Arun Das, Levi Wang

ACTA-Soft UG, Dachau, Germany

Corresponding author: arun.das@acta-soft.com

In an insect farm housing thousands of breeding containers, efficiency and maintaining high-quality standards are paramount. Structured information regarding the growth stage of the insects, their health conditions, conducted and planned work steps, and other relevant data must be readily available at all times. This information is essential for ensuring smooth operations, promptly addressing any incident, and systematically evaluating different breeding conditions and feed materials to continuously optimize the farming process.

To address these needs, the project group NeoBreed has developed a cloud-based application. This digital tool enables the planning of work steps for a breeding cycle, scheduling and assigning tasks to operators, documenting work steps and related data throughout the breeding cycle, and automatically evaluating and visualizing key performance indicators (KPIs) of the breeding cycle. Additionally, the application allows for the management of suppliers, food, and other consumables, including tracking their quantity and quality in the digital warehouse, ensuring seamless logistics and quality control.

Furthermore, a computer vision-based module is currently being developed to automatically capture and analyze relevant growth parameters (such as color, weight, health, and vitality) of the insects throughout the entire breeding cycle. This module will provide a high-quality data foundation for rapid alarming of abnormality or incidents, continuous process optimization, thereby enhancing sustainable competitiveness in the insect farming industry.

Effects of *Tenebrio molitor* larva incorporation in the piglet diet

Didier Gaudré[1], Lorena Sanchez[2], Rémi Chausse[3], Rosa Castellano[4], Paul Barneron[5]

[1] *IFIP-institut du porc, La Motte au Vicomte, 35650 Le Rheu, France*
[2] *Ynsect, 1 rue Pierre Fontaine, Campus 3 - Bâtiment 2, 91000 Evry, France*
[3] *ARC Nutrition, Crenan, 27, 22800 Le Foeil, France*
[4] *Vilofoss, Z.I. de la Gare, 22690 Pleudihen sur Rance, France*
[5] *MG2mix, La Basse Haye, 35220 Chateaubourg, France*

Corresponding author: didier.gaudre@ifip.asso.fr

This trial was conducted to assess effects of feeding dried defatted mealworm meal (Tenebrio molitor larva) on growth performance, the blood profile and faecal dry matter content of weaning pigs. A total of 260 weaning pigs (28 days of age, mean body weight of 9.03 kg) were assigned to one of four treatments based on sex and body weight in 10 replicates, with 6-7 pigs per pen in a randomized complete block design. All pigs were given ad libitum access to feed and water. Two-phase feeding programs (phase 1 from day 0-14, phase 2 from day 14-42) were used. Supplementation of dried defatted mealworm meal (75 % protein, 10 % fat) was 0, 3, 6 or 9 % in the phase 1 diet and 0, 4, 8 or 12 % in the phase 2 diet at the expense of soy products. Average daily gain, average daily feed intake and blood profile did not differ significantly whatever the diet percentage of mealworm meal. During phase 2, the feed conversion ratio of the 2 diets that contained the highest percentage of mealworm meal were significantly worse than that of the control diet. The faecal dry matter content was significantly better with the highest mealworm meal compared to the control. Overall, this trial indicated that dried defatted mealworm could be used as a concentrate protein ingredient for weaning pigs up to 3-4 % without affecting the performances.

Optimised nutrient supply for dual-purpose chickens - Adapted rations, alternative protein sources, effects and adaptation options (slowFeedChickIns)

Annemarie Kaiser[1], Christian Visscher[2], Daniela Werner[3], Elias Schmelzer[4], Gerriet Trei[1], Helene Pluschke[3], Inga Günther[5], Julia Hankel[2], Oliver Schlüter[6]

[1] *Eberswalde University for Sustainable Development, Eberswalde, Germany*
[2] *University of Veterinary Medicine, Hannover, Germany*
[3] *Johann-Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forests and Fisheries, Institute of Organic Farming, Trenthorst, Germany*
[4] *Bioland Beratung GmbH, Mainz, Germany*
[5] *Ökologische Tierzucht gGmbH, Augsburg, Germany*
[6] *Leibniz Institute for Agricultural Engineering and Bioeconomy, Potsdam, Germany*

Corresponding author. sebastian.fuchs@oekotierzucht.de

The overall objective of the project is to improve the performance of the organic husbandry system for dual-purpose chickens under the aspects of resource-efficient raw material procurement, optimization of feeding and animal welfare. This is to be achieved by reducing the overall energy input in general and the proportion of emission-sensitive methionine-rich feed components by exploiting the feed intake regulation capacity of the animals and by using insects or macroalgae as regional protein sources.

The focus here is on the integration of two different insect species (*Acheta domesticus/Musca domestica*) and macroalgae (*Palmaria palmata*/n.n.) into the feeding regimes of various utility crosses currently used in the organic farming sector. In the development of the above-mentioned alternative protein sources, a further focus of the project is the detailed examination of the upstream production cycles of the feed components and the creation of nutrient profiles. The feed intake behavior and suitable protein sources for the subsequent trials will be evaluated in two rounds of selective trials. Identified suitable protein sources are then further investigated with regard to precaecal digestibility.

Based on the results, different nutrient-reduced rations upgraded with protein sources identified in section one will be compared with currently valid feeding recommendations on experimental and practice farms. In addition, an ecological and economic evaluation of the downstream processes and products is carried out by means of partial life cycle assessment and economic potential analysis.

Antibacterial and anticancer activity of the peptide fraction extracted from the haemolymph of *Hermetia illucens*

Carmen Scieuzo[1,2], Antonio Franco[1,2], Rosanna Salvia[1,2], Fabiana Giglio[1], Roberta Rinaldi[1], Mariarita Rubino[1], Emine Derin[1], Federica De Stefano[1], Angela Pascale[1], Maria Monti[3], Flora Cozzolino[3], Alessandro Sgambato[4], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*
[3] *University of Naples Federico II, Italy*
[4] *Università Cattolica del Sacro Cuore, Italy*

Corresponding author: patrizia.falabella@unibas.it

The extensive use of chemotherapy and conventional antibiotics has led to the emergence of anti-drug resistance phenomenon. To address this crisis, attention is turning to antimicrobial peptides (AMPs), as they offer advantages over conventional antibiotics, including low levels of resistance, broad-spectrum activity with minimal host toxicity, and synergistic effects with antibiotics. The interaction between AMPs and the membranes of microorganisms is based on electrostatic bonds, between positively charged AMPs and the negatively charged membranes of microorganisms. This interaction is influenced by the presence of teichoic acid in Gram-positive bacteria and lipopolysaccharides in Gram-negative bacteria. The mechanisms of action of AMPs can be membranolytic or non-membranolytic. Similarly, cancer cells, characterized by a negative net charge, engage in electrostatic interactions with AMPs because of their high expression of anionic mole-cules on the outer membrane. AMPs can more effectively destroy cancer cell membranes due to the increased fluidity and abundance of microvilli on the cell surface. Once inside the cell, AMPs alter the integrity of negatively charged mitochondrial membranes, leading to the release of pro-apoptotic proteins. Insects, particularly the species *Hermetia illu-cens*, are a rich source of AMPs. Our research aims to identify pharmacologically active molecules from *H. illucens* to develop alternative antimicrobial and anticancer drugs or to support existing therapies. Antimicrobial properties were evaluated against Gram-positive and Gram-negative bacteria, while antitumor effects were evaluated on various cancer cell lines. This research holds promise for addressing global health challenges related to antibiotic resistance and the need for effective anticancer therapies.

Hermetia illucens chitosan for the preservation of fresh cherry tomatoes

Dolores Ianniciello[1], Rosanna Salvia[1,2], Carmen Scieuzo[1,2], Micaela Triunfo[1], Anna Guarnieri[1], Andrea Boschi[1], Roberta Rinaldi[1], Antonio Franco[1,2], Giovanni Lomonaco[1], Antonio Dolce[1], Maddalena Ventura[1], Angela De Bonis[1], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*

Corresponding author: patrizia.falabella@unibas.it

Chitin is a key structural component of arthropod exoskeletons and yeast and fungi cell walls. Insect-derived chitin is gaining increasing attention as an alternative and more sustainable source to crustaceans. Among insects, the Diptera *Hermetia illucens* is a very promising source of chitin, as its larvae, but especially waste products of its breeding (pupal exuviae and dead adults) that can be used as source of the polymer. Chitosan, the deacetylated derivative of chitin, with antibacterial, antioxidant, and film-forming pro-perties, is a promising biopolymer for food applications, particularly as edible coatings to improve the shelf life of fresh fruit and vegetables. Chitosan-based coatings reduce de-hydration and slow down microbial and fungal deterioration, ripening and senescence. Due to its high nutritional content, the tomato (*Solanum lycopersicum*) is one of the widely consumed fruits. Tomato packaging plays a key role in post-harvest preservation, due to its perishable and climateric nature. Tomatoes undergo biochemical ripening and respi-ration during the post-harvest period, affecting their degradation and possible sene-scence. In this study we produced chitosan from chitin extracted from *H. illucens* pupal exuviae using two separate deacetylation methods: heterogeneous and homogeneous. Chitosan (0.5% and 1% concentrations) was applied to the tomatoes by spraying and dipping and fruits were stored at RT and 4°C. Weight loss, physico-chemical parameters, total phenols, total flavonoids, and changes in antioxidant activity of tomatoes were in-vestigated for a storage period of 30 days. The heterogeneous chitosan kept all parame-ters stable. The spraying method was more effective in reducing weight loss and pH va-riation. Chitosan produced from *H. illucens* performed similarly to commercial chitosan in terms of protection. These preliminary findings are encouraging to validate *H. illucens* as an alternative source of chitosan.

Effect of *Tenebrio molitor* larvae protein on physicochemical and functional properties of soy-based set type yogurt

Dongseop Lee[1,2], Ma Yizhan[1], Yookyung Kim[1]

[1] *Department of Human Ecology, Graduate School, Korea University, Seoul, Republic of Korea*
[2] *Interdiciplinary Program in Sustainable Living System, Graduate School, Korea University, Seoul, Republic of Korea*

Corresponding author: yookyung_kim@korea.ac.kr

Soybean, a sustainable plant-based raw material with high nutritional value, is utilized in making soy yogurt, which typically has a hard structure. To improve its texture to more closely resemble cow's milk yogurt, we investigated the incorporation of water-soluble mealworm protein as a partial replacement for soymilk. The study compared soy yogurt fermented from 5% mealworm protein (SMY) to both cow's milk yogurt (CY) and traditional soy yogurt (SY) in terms of physicochemical and functional properties.
After 8 hours of fermentation, all three yogurts exhibited pH values below 4.6 (CY: 4.33, SY: 4.24, SMY: 4.35), meeting the FDA's standard requirement. The titratable acidity decreased to 0.66% in SMY compared to CY (1.03%) but was similar to SY (0.60%). The incorporation of mealworm protein resulted in lower L* values (85.70) but higher a* (-2.02) and b* values (11.34) compared to SY (L*: 89.36, a*: -3.66, b*: 10.18) and CY (L*: 92.01, a*: -3.12, b*: 4.38).
Regarding nutritional composition, soy-based yogurt (SY: 4.11%) exhibited a higher protein content than CY (3.52%). The replacement of soymilk with mealworm protein increased the protein content to 4.46% in SMY. In addition, the free amino acid content of SMY significantly increased more than that of CY, with the presence of arginine, which was absent in SY.
Moreover, SMY exhibited enhanced antioxidant activity, with higher total isoflavone (32.80 mg/g) and polyphenol content (0.36 GAE/g) compared to SY (20.89 mg/g and 0.35 GAE/g) and CY (not detected isoflavone and 0.29 GAE/g), respectively. Also, SMY (115.79 mg/mL) had a lower IC50 value for DPPH scavenging activity compared to CY (155.09 mg/mL) and SY (244.73 mg/mL). In conclusion, replacing mealworm protein in soy-based yogurt improved its nutritional profile and enhanced its antioxidant activity, suggesting its potential as a sustainable, functional food product.

Preliminary investigation of the chemical composition of black soldier fly larvae

Luka Irenej Pečan[1], Ema Luna Karara Geršak[1], Alenka Levart[2], Aleš Kuhar[1]

[1] *Biotechnical Faculty, University of Ljubljana, Department of Animal Sciences, Chair for Agrarian Economics, Policy and Law, Ljubljana, Slovenia*
[2] *Biotechnical Faculty, University of Ljubljana, Department of Animal Sciences, Chair of Nutrition, Ljubljana, Slovenia*

Corresponding author: luka.irenejpecan@bf.uni-lj.si

Black soldier fly (*Hermetia illuscens*) larvae are increasingly recognised as a sustainable solution to contemporary nutritional challenges due to their diverse chemical composition, which has the potential to meet the dietary needs of various livestock and companion animals. Their accessibility, ease of cultivation, high substrate conversion rates, and versatility have spurred research into their utilization. This study aims to investigate the chemical composition of black soldier fly larvae and the factors influencing it, with implications for sustainable nutrition solutions.

Weende analysis was conducted to determine the content of crude fat, crude protein, dry matter, and crude ash in black soldier fly larvae. Additionally, methods for fluoride determination were employed to assess the impact of larval age and substrate composition on fluoride content. Larvae were subjected to different feeding regimes and durations to evaluate the variations in chemical composition.

The study revealed significant variations in the chemical composition of black soldier fly larvae influenced by both age and substrate composition. Dry matter content was highest in larvae predominantly fed corn bran for 30 days, while the lowest was observed in larvae fed a mixture including tomatoes, chicken feed, and sugar beet for 16 days. Similarly, crude ash content varied, with the highest levels observed in larvae fed chicken feed for 17 days and the lowest in those fed primarily corn bran for 30 days. Protein content ranged from 11.2 to 15.3 g per 100 g of fresh sample, with larvae fed chicken feed for 17 days exhibiting the highest protein content. Fluctuations in lipid components were also noted, with larvae fed corn bran and water for 30 days exhibiting the highest lipid content. The total fluoride content varied among samples, with the highest observed in larvae fed a combination of tomatoes, corn bran, and sugar beet for 15 days. However, significantly lower levels were found in larvae fed chicken feed and water for 17 days.

The findings of this study underscore the potential of black soldier fly larvae as a sustainable source of nutrition. Their diverse chemical composition, influenced by factors such as age and substrate composition, holds promise for addressing contemporary nutritional challenges. Further research into optimal feeding regimes and cultivation practices is warranted to fully harness the potential of black soldier fly larvae in promoting a more sustainable food system.

Comparison of mealworm (*Tenebrio molitor* larvae) protein characteristics with whey and soy protein

Seokjin Kim[1,2], Ruyang He[1], Insang Cho[1], Yookyung Kim[1]

[1] *Department of Human Ecology (Food and Nutrition), Graduate School, Korea University, Seoul, Republic of Korea*
[2] *Interdiciplinary Program in Sustainable Living System, Graduate school, Korea University, Seoul, Republic of Korea*

Corresponding author: yookyung_kim@korea.ac.kr

In this study, we evaluated mealworm protein (MP) as a potential alternative protein source by comparing its proximate compositions, amino acid contents, physicochemical properties (water holding capacity, WHC; oil holding capacity, OHC; emulsifying activity index, EAI; emulsifying stability, ES), and antioxidant activity with whey protein (WP) and soy protein (SP). MP was extracted using an alkali method, whereas WP and SP were sourced commercially.

MP exhibited a protein content of 72.14% (compared to 85.36% for WP and 74.00% for SP), with the highest total amino acid content (239.78 µg/mL) and total essential amino acids (79.56 µg/mL), which is 1.69 times that of SP. MP also displayed a similar amino acid composition to WP and had comparable levels of total branched-chain amino acids (35.45 µg/mL). Furthermore, MP demonstrated high lysine content (12.82 µg/mL), addressing a common deficiency in plant-based proteins. Regarding physicochemical properties, MP had the highest ES (95.18%) and a comparable OHC (1.75%) to WP and SP. However, MP had lower WHC (3.28%) and EAI (0.14%) than SP (WHC: 6.79%; EAI: 0.21%), while being similar to WP (WHC: -0.41%; EAI: 0.18%). Meanwhile, MP showed the highest antioxidant activity, supported by its ability to achieve the lowest IC_{50} values for DPPH radical scavenging (2.38 mg/ml) and the highest total polyphenol content (12.36 mgGAE/g). These findings suggest that MP could serve as a promising alternative protein source, offering not only high nutritional value but also excellent functional properties for various food applications.

Zinc-enhanced porous biomaterials from mealworm proteins

Martina Klost[1], Claudia Keil[2], Maria Isabel Ramirez-Huerta[1], Stephan Drusch[1], Pavel Gurikov[3,4]

[1] TU Berlin, Institute of Food Technology and Food Chemistry, Department of Food Technology and Material Science, Berlin, Germany
[2] TU Berlin, Institute of Food Technology and Food Chemistry, Department Food Chemistry and Toxicology, Berlin, Germany
[3] Laboratory for Development and Modelling of Novel Nanoporous Materials, Hamburg University of Technology, Hamburg, Germany
[4] gel-it GmbH, Osnabrück, Germany

Corresponding author: martina.klost@tu-berlin.de; c.keil@tu-berlin.de; pavel.gurikov@tuhh.de

Edible insects have been recognized as a promising alternative food source because of their high nutritional value and sustainable production. However, in western countries eatable insects are met with neophobism and consumer scepticism. One of the issues the food industry can address is developing insect protein products that overcome consumers' "disgust factor". Yellow mealworm (*Tenebrio molitor*) was the first insect species authorized in Europe as safe for human consumption. Mealworm protein-based porous bio-gels have the potential to be used for a variety of food applications.

With our study we investigated how pH (pH 5.5 and 7.5) and zinc concentration (0 M, 0.1 M, and 0.3 M) affected the rheological properties and gel structure of heat-induced mealworm protein gels. These gels are discussed in terms of gelation kinetics and types of interactions that are involved, as well as microstructure and rheological behavior.

Further investigation focused on combining solvent exchange with supercritical CO_2 drying to produce aerogels or freeze-drying to produce cryogels from mealworm protein gels. Protein gels obtained from both drying methods were characterized using Fourier transform infrared spectroscopy (FTIR), Brunauer–Emmett–Teller (BET) volume and high-resolution scanning electron microscopy. Retention of zinc was evaluated via energy-dispersive X-ray spectroscopy. Both drying methods were suitable to obtain dried porous mealworm protein biomaterials. Drying mainly affects surface area and pore hydrophobicity, but not secondary structure or zinc content of the gels.

The results from this study demonstrate that mealworm proteins possess excellent structuring and functional properties, which could make them an attractive ingredient for food applications.

Effect of different pressure-time combinations on high hydrostatic pressure treated mealworm paste: evaluation of protein oxidation and denaturation

Lisa Muchow[1,2], Giacomo Rossi[1], Oliver Schlüter[1,3]

[1] *Leibniz Institute for Agricultural Engineering and Bio-economy, Potsdam, Germany*
[2] *University of Applied Science, Berlin, Germany*
[3] *University of Bologna, Department of Agricultural and Food Sciences, Piazza Goidanich 60, 47521 Cesena, Italy*

Corresponding author: grossi@atb-potsdam.de

High hydrostatic pressure processing (HHP) is a non-thermal treatment method recently introduced in the food industry with the aim of increasing microbial safety while preserving the most important quality parameters. However, despite several advantages has been associated to this treatment, products submitted to HHP often show instability, with higher lipid and protein oxidation having been observed. Defining the best combination between time, pressure and temperature is therefore crucial for guarantying the best results in terms of microbial safety and nutritional quality.
The aim of this study was to investigate the effect of HHP on protein quality of *Tenebrio molitor* paste. Paste produced by milling fresh mealworm larvae were alternatively submitted to HHP at pressure levels of 200, 400, or 600 MPa. For each pressure, five different treatment times (5, 15, 30, 45, 60 min) were applied. An untreated control was also prepared. Protein concentrates (purity > 80%) were generated by extracting the protein fraction from pre-defatted pastes. Protein solubility, concentration of carbonyls, thiols and disulphides as well as fluorescence and FT-IR spectra were recorded.
Overall results display a significant reduction in protein solubility for samples treated at 600 MPa, whit the lower solubility detected after 5 and 15 min of treatment. Slight although non-significant increases in thiol content, and decreases in tryptophan fluorescence intensity were also observed, regardless by the pressure level applied. Maximum Tryptophan intensities measured at excitation wavelength of 280nm exhibited the greatest reduction at 200 MPa (34%) and 400 MPa (39%), while smaller reduction was measured at 600 MPa (29%). Secondary structure of the protein was significantly affected by the treatment, with a progressive reduction in β-sheet structures observed after treatments at 200 MPa and 400 MPa, and a slight increase after 600 MPa treatment. Concentration of Schiff's bases (determined through fluorescence analyses with excitation maximum at 350nm), disulphides, and carbonyls did not show any significant change, regardless by the considered pressure-time combination. Overall, these data shows that HHP can be a viable option for edible insect stabilization, with pressure of 600 MPa being the best option for guarantying high safety standards while preserving the initial nutritional quality.

Establishing a front-end baseline: Influence of homogenization and pasteurization options on separation

Jorge González Mira, Christian Kling

ANDRITZ Gouda B.V., Waddinxveen, The Netherlands

Corresponding author: jorge.gonzalezmira@andritz.com

The insect industry is growing and becoming more industrialized. To extract the full value from the larvae, efficient and sustainable processing is needed to enable to production of highest quality protein and oil products. Wet rendering is the best choice, as it delivers highly defatted protein meal with high protein and low oil content, resulting in a product with a long shelf life. At the same time, it is more sustainable than other processing methods.

With the new Food Innovation Xperience center (FIX) in Gouda (NL), ANDRITZ is in the unique position of being able to reproduce all process steps on a pilot scale in a single location, from larvae intake to final products. This enables ANDRITZ to look at the whole line, instead of focusing on single units. In most cases, optimal results are achieved by examining and improving the interactions between different unit operations.

In this presentation, the focus is on the first steps of wet rendering. ANDRITZ will show the effect of different homogenization and pasteurization technologies on the three-phase separation. The aim is to enhance the process and increase oil yield without compromising efficiency of the dewatering process, striving for maximum efficiency. ANDRITZ will show the differences between several upstream operations and their benefits for de-greasing.

Different cutting and milling technologies are used for homogenization. The aim is to achieve evenly sized particles without building an emulsion that then needs to be broken in later stages during separation. ANDRITZ will compare different technologies and test the effect during the pasteurization and separation steps.

For pasteurization, direct and indirect heating technologies are available on industrial scale. Options include tubular heat exchangers, scraped surface heat exchangers, direct steam injection or radiation assistant technologies, like microwaving. ANDRITZ will show the impact of different technologies depending on the homogenization and how this effects the separation.

All operations are conducted at pilot-scale, meaning results and learnings can be directly transferred to the industrial scale. Lab-scale-only methods are excluded.

As a result, this comprehensive work provides a conclusion on front-end processing of larvae to achieve the best possible separation of proteins and fats.

The first insight into full-fat locust meal in Golden Retriever food and its influence on blood biochemistry and faecal microbiota

Ahmed Ibrar, Fatma Inal

Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, Selçuk University, Konya, Turkey

Corresponding author: vetrao6@gmail.com

To overcome the food crisis of the future food chain, the discovery of alternative protein sources is a need of the hour and an insect meal is at the top of the list of alternative protein sources from the last decade. The current trial is the first application of full-fat locust meal (LM) in the dog (Golden Retriever) diet. During the trial 15 mixed-sex Golden Retriever dogs were fed three diets: control diet, with no LM and 14% chicken meal (CM); LM7 – with 7% full-fat LM and 7% CM; LM14 – with 14% full-fat LM and no CM for 15 days. On the fifteenth day fresh faecal samples were collected for evaluation by sequencing the 16S rRNA gene and blood samples were collected for blood profile evaluation. The blood serum profile including creatinine, AST, ALT, ALP, cholesterol, and triglyceride did not vary with the addition of LM in dog food whereas BUN, glucose, and amylase were significantly reduced. The faecal microbiota remained unchanged with the addition of LM except for Actinobacteria at the phylum level, *Coriobacteriia* at the class level were increased whereas *Clostridiales* and other genera at the genus level were found to decrease with the addition of LM in dog food. It can be concluded from the present study that the replacement of CM with LM in dog food can be done without major negative consequences on the health status of dogs. It can even be beneficial for dogs having kidney problems and diabetic issues.

Effect of grasshopper meal-based diet on growth performance, organ weight and carcass characteristics of broiler chicks

Cordelia Ebenebe[1], Valentine Okpoko[2], Shirley Obinwa[1], Chidera Ekeocha[1], Benedethe Ezenyilimba[1], Philippa Ifeyinwa Afomezie[3]

[1] *Department of Animal Science, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*
[2] *Department of Biology, Admiralty University of Nigeria, Ibusa, Delta State, Nigeria*
[3] *Department of Zoology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*

Corresponding author: ci.ebenebe@unizik.edu.ng

Devastation of crop fields by swarming grasshopper has for long been a problem in most large scale crop farms especially in Northern Nigeria, its utilization as food and feed is a way to turn the menace to better use. This study evaluates the effects of grasshopper meal based diet on growth performance and carcass quality of broiler chicks.

One hundred and twenty day-old broiler chicks purchased from Agrited commercial hatchery were used for the experiment. Four experimental diets were formulated with grasshopper meal inclusion levels at 0% (T1), 50% (T2), 75% (T3), and 100% (T4). Thirty broiler chicks were randomly assigned to each of these four dietary treatments for six weeks, after one week of acclimatization of the birds in the experimental units. Each treatment was replicated two times with 10 chicks per replicates and 30 chicks per treatment. During the six weeks period of the study, the birds were subjected to similar managerial practices and sanitation while monitoring the feed intake and weight changes. At the end of the rearing period, four birds were randomly selected from each of the dietary treatment, fasted for twelve hours and slaughtered for carcass assessment. Data generated were analysed using SPSS Version 22 ANOVA for Completely Randomized Design while Means were separated with using LSD Post Hoc Test.

The result showed that birds on T2 recorded the highest feed intake of 4.24 kg while the least record was in T1 (3.84 kg). However, T4 recorded the highest weight gain of 2.22kg, while T3 had the least weight gain record of 1.98kg. The organ weight measurements followed the same trend as birds in T4 recorded the highest significant value in all the organ weight measurements. Carcass characteristics also followed the same trend. Grasshopper meal is therefore recommended for in partial or complete replacement of fishmeal in broiler diet.

Comparison of the impact of different solar drying methods on the quality attributes of black soldier fly (*Hermetia illcens*) larvae

Manal Lehmad[1], Patrick Lhomme[2], Youssef El hachimi[1], Naji Abdenouri[3]

[1] *Laboratory of Bioresources and Food Safety, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco*
[2] *Laboratory of Zoology, Research Institute for Bioscience, Mons University, Belgium*
[3] *Laboratory of Control and Computing for Intelligent Systems and Green Energy, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco*

Corresponding author: manal.lehmad@ced.uca.ma

The Black Soldier Fly Larvae (BSFL) is a promising insect rich in nutrients such as protein and fat, offering a sustainable solution within the framework of a circular economy and serving as a novel alternative for food and feed production. The drying process of the larvae plays a pivotal role in converting the product into flour and facilitating storage. This study aims to assess various solar drying methods, taking into account drying kinetics and the quality of the resulting dried products. Methods considered include indirect solar drying utilizing a hybrid solar-electric dryer, greenhouse drying, and direct sun drying. Hybrid drying emerged as the most rapid method, exhibiting a 16.66% reduction in drying time compared to greenhouse drying and a 150% reduction compared to direct solar drying. Protein content was determined by Kjeldhal method using a nitrogen-to-protein conversion factor of 4.76. Notably, protein levels varied significantly, with larvae dried in a greenhouse exhibiting the lowest values—18.6% and 17.63% lower than indirect and direct solar drying, respectively. The use of an indirect solar dryer demonstrated superior efficiency compared to other solar methods. The treated larvae exhibited enhanced nutritional, physicochemical, and microbiological quality compared to both solar and conventional drying techniques. Moreover, this method proves to be highly competitive in the market, offering economic sustainability and environmental friendliness.

Nepalese poultry farmers attitude towards insect as an alternate feed

Karishma Subedi[1], Ujjal Tiwari[1], Prabhat Khanal[2], Debasree Purkayastha[2]

[1] Department of Agricultural Economics and Agribusiness Management, Agriculture and Forestry University, Chitwan-44200, Nepal
[2] Animal Science, Production and Welfare Division, Faculty of Biosciences and Aquaculture, Nord University, Skolegata 22, Steinkjer 7713, Norway

Corresponding author: karishma.subedi@student.nord.no

Insect feed has been a sustainable alternative for the ever-increasing poultry industry throughout the globe. The feed regulatory obligations in the developing countries have been more welcoming to adopt such alternate feed as a preferred choice in poultry farmers. Nepal is one such developing country with high import flux of soyabean and maize as poultry feed. The feed accounts for 70% of the total production cost in the poultry industry. The farmers in such developing countries are looking for cheaper and sustainable alternate feeds and insects are a good fit to this crisis. This study conducted a detailed preference analysis to understand the perception of commercial scale poultry farmers. The study was conducted on 200 poultry farmers. Farmers expressed a keen readiness to embrace insect-based feed solutions, provided they are available at a more economical price point compared to conventional feeds. The major challenges found based on preferential ranking method are: Rank 1. The feed is not proven yet, Rank 2: It is a new product, Rank 3: Since the Insect production industry is not in place it is not Practical, Rank 4: Farmers had issues with aesthetics, Rank 5: They believed it was expensive. The study observes price fluctuation control and feed quality as a plausible solution for insect feed adoption in Nepal. Further research and collaborative efforts among stakeholders will be essential to realize the full potential of insect feed in transforming poultry farming practices in developing nations.

Fighting ecotoxicity of pesticides using an instant biosensor based on insect cells

Sandra Friedrich[1], Neha Malagimani[1], Stefanie Michaelis[2], Joachim Wegener[1,2]

[1] *Institute of Analytical Chemistry, Chemo- and Biosensors, University of Regensburg, Germany*
[2] *Fraunhofer EMFT, Fraunhofer Institute for Electronic Microsystems and Solid State Technologies, Regensburg, Germany*

Corresponding author: sandra.friedrich@chemie.uni-regensburg.de

The worldwide pesticide consumption continuously increases. Alongside climate change or habitat alterations, this trend emerges as one of the key contributors to insect population declining. Thus, research on easy, fast and sensitive methods for identifying ecotoxic pesticides has gained utmost importance supporting the development of safer and environmentally friendly pest control strategies.

This study presents a cell-based sensor to identify harmful impacts on insects in less than one hour assay time. The sensor utilizes Sf21 cells derived from *Spodoptera frugiperda* (fall armyworm). For performing a toxicity assay, suspensions of Sf21 cells are seeded in multi-well plates with integrated planar thin-film electrodes made from gold in each well. The pesticide of interest is added to the cell suspensions and the electrochemical impedance of the electrodes is then followed with time. As cells behave electrically like insulating particles, the impedance of the electrode reveals the time course of cell adhesion to the electrode, which turned out to be a very sensitive indicator for cell viability. By freezing the Sf21 sensor cells inside the wells and storing the cell-loaded multi-well electrode arrays at -80 °C, the cell-based biosensor is assay-ready immediately after thawing the cells within minutes providing independence of a cell culture laboratory.

Dose response curves were recorded with the optimized sensor for five different pesticides: Careo®, Bi 58®N, Saprol®, Fonganil® Gold and Banvel® M. Validation against the commercial, biochemical WST-1 assay revealed good agreement with respect to the concentrations of half-maximum impact (EC_{50}). In some cases, EC_{50} values were significantly below the concentration of use as recommended by the manufacturer.

The cell-based sensor offers advantages over assays based on living insects as it is reproducible, fast and provides high throughput. It facilitates the determination of toxic effects of formulations sensitively, time resolved and in a concentration dependent manner. A benchtop device that performs thawing of cells and sample addition in a fully automated way is work in progress.

Advancing biodiversity conservation through AI-driven acoustic monitoring of insects

Shreyas M. Guruprasad, Urs Liebau, Iaroslav Trofimenko

Center for digital GreenTech, August-Wilhelm Scheer Institut für digitale Produkte und Prozesse GmbH, Clausthal-Zellerfeld, Germany

Corresponding author: urs.liebau@aws-institut.de

Insect populations, particularly pollinators, are facing unprecedented declines worldwide, posing significant threats to ecosystem stability, agricultural productivity, and global biodiversity. To address this pressing challenge, we propose an innovative approach to biodiversity management through the utilization of AI-driven automated monitoring systems, with a specific focus on acoustic-based signal analysis. Our conceptual framework integrates advanced AI algorithms with acoustic sensors to enable real-time monitoring of insect populations and behavior in diverse ecosystems. By capturing and analyzing acoustic signals emitted by insects, such as their flight patterns, mating calls, and foraging activities, our automated monitoring systems offer a non-invasive and efficient means of assessing insect abundance and distribution.

The significance of our proposed approach lies in its ability to provide timely and accurate data on insect populations, facilitating informed decision-making for biodiversity conservation and ecosystem management. Through the deployment of predictive modeling techniques, we aim to forecast changes in insect populations in response to environmental factors, habitat alterations, and climate change, thereby enabling proactive conservation strategies. Furthermore, our research underscores the importance of insect pollinators in ecosystem functioning and agricultural productivity. By quantifying the contributions of pollinators to crop yields and quality, we highlight the economic and ecological benefits of conserving insect biodiversity.

Our AI-driven approach to biodiversity management aligns with UN SDGs, promoting environmental sustainability and resilient ecosystem. By leveraging acoustic-based signal analysis and AI technologies, we seek to enhance our understanding of insect ecology and foster interdisciplinary collaborations for effective biodiversity conservation. Our work presents a novel and interdisciplinary framework for addressing the urgent need for insect biodiversity monitoring and conservation. Through the integration of AI-driven automated monitoring systems with acoustic-based signal analysis, we aim to advance scientific knowledge, inform evidence-based policies, and promote sustainable development practices for the preservation of global biodiversity.

Tenebrio molitor hemolymph: a complex machinery which protects against pathogens

Valentina Candian[1], Elena Crotti[2], Rosemarie Tedeschi[1]

[1] *Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Paolo Braccini 2, 10095 Grugliasco (TO) Italy*
[2] *Department of Food, Environmental and Nutritional Sciences, University of Milan, via Celoria 2, 20133 Milan (MI), Italy*

Corresponding author: valentina.candian@unito.it

The farming of edible insects is an alternative strategy for the production of protein-rich food and feed with a low ecological footprint. Different organic-biomasses, characterized by a different nutrient content, have been proposed for the insect mass rearing. However, diet variations may influence the insect-associated microbiota with a possible impact on its physiology and immunity. These interactions have been mainly investigated for the gut microbiota, neglecting all those microorganisms that instead reside in the hemolymph and that could have a role in insect immune responses. The HeMiTool (Hemolymph Microbiome of insects: a promising Tool to develop innovative strategies to control pests and protect beneficials) project aims to fill in this gap of knowledge providing a deep characterization of the hemolymph microbiome dynamics in *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) mature larvae. In particular, it aims to characterize the hemolymph microbial communities, their function in relation to the host and their interplays with hemolymph biochemical and cellular parameters. Insects reared on different diets as well as diseased ones, following bacterial/fungal challenge, are investigated. For each diet, pools of hemolymph samples are collected from healthy and laboratory-infected larvae and subjected to high-throughput sequencing analysis of the 16S rRNA gene and ITS2 fragment. Moreover, the impact of the nutritional composition of the diet on hemocytes diversity/abundance and the environmental factors affecting the hemolymph microbiota are studied. Finally, diffusion assays in solid media will be set up for evaluating the hemolymph antimicrobial activity. Clarify these aspects will be of paramount importance to identify factors and biological interactions essential for insect survival and that could be modulated for safeguarding healthiness in large-scale insect rearing.

Expanding bioremediation of poultry manure with black soldier fly larvae

Carolina Ligeiro[1,2], Ana Maria Machado[1], Rafaela Fantatto[1], Clarice Souza[1,2], Leonardo Gaston Guilgur[1,2], Daniel Murta[1,2]

[1] Ingredient Odyssey SA - EntoGreen, Santarém, Portugal
[2] CiiEM – Centro de Investigação Interdisciplinar Egas Moniz, Caparica, Portugal

Corresponding author: carolina.ligeiro@entogreen.com

The global demand for food, has led to significant challenges in managing the livestock manure generated, posing environmental and public health risks. The exploration of innovative approaches like bioremediation using black soldier fly (*Hermetia illucens*, BSF) is needed. This study investigates the potential of BSF in bioremediating poultry manure though a large-scale trial. Building upon insights from a preliminary trial, the study aims to validate and expand upon initial findings by scaling up the process. By utilizing 144 crates per group, the experiment seeks to assess the feasibility of converting manure into valuable biomass. Key advantages of BSF larvae bioremediation include reduced greenhouse gas emissions, pathogen suppression and minimal water requirements. The study also evaluates larval weight, odour and substrate temperature, as well as microbiological and heavy metal assessments. Preliminary results indicate comparable trends in temperature evolution and larval biomass between control and test groups. The large-scale trial is critical for substantiating the efficacy of BSF larvae in poultry manure bioremediation. Its finding promises to revolutionize waste management practices, informing sustainable agricultural strategies that mitigate environmental risks and enhance productivity.

Should Europe be concerned with locust attacks?

Reyyan Gübür[1,2], Marc Birringer[1]

[1] *Fulda University of Applied Sciences, Fulda, Germany*
[2] *Kassel University, Kassel, Germany*

Corresponding author: reyyan.guebuer@oe.hs-fulda.de

Locust swarms have been studied mainly in the Global South, particularly in East Africa, the Middle East and Asia, where they have caused the most damage. Consequently, there is a significant amount of literature focusing on outbreaks and experiences from this region. As a result, regions like Europe, who have been less affected are in a blind spot. Yet, Europe is more vulnerable that it seems at first glance, with growing exposure and possibly damaging consequences if this risk is not taken seriously. While climate change has varying effects from region to region, Europe will not be spared by global heating, desertification, heavy rains, storms and wind, mild winters, which are all ideal conditions for locusts growth. Italy, Greece and France have already experienced locust attacks in the past. Considering the development of climate conditions, Europe is facing a steadily growing risk, with Southern Europe and the Mediterranean region in the fore-front. This region constitutes an essential share of the agricultural output of the EU. Overall, a third of European agriculture could be exposed, which can create an economic risk and social injustices, especially in the context of inflation and weakening of supply chains. However, Europe has some possibility for action. This paper advocates for risk management and future oriented strategies to anticipate risks and prepare solutions. In this process, the EU can learn from the experiences of the Global South and take its responsibility in the multilevel governance needed to fight this biological pest. This would create opportunities for cooperations with the Global South and enhance resilience.

An analysis of the methods employed to dry edible insects using a life cycle assessment

Hursit Degirmenci[1], Onder Altuntas[1,2], Hulya Altuntas[2,3]

[1] *Faculty of Aeronautics and Astronautics, Eskisehir Technical University, 26555, Eskisehir, Turkey*
[2] *Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany)*
[3] *Faculty of Science, Department of Biology, Eskisehir Technical University, 26140, Eskisehir, Turkey*

Corresponding author: hursitdegirmenci@eskisehir.edu.tr

Drying is the process of water removal from solid and liquid products, typically driven by heat. It helps preserve fresh foodstuffs, reduce packaging, storage, and transportation costs, and modify flavor and texture. The current drying methods for materials are natural, traditional, and clean energy. Natural drying exposes fresh agricultural materials to sunlight but has limitations like large areas and long drying times. Traditional drying uses hot air, causing environmental pollution and an energy shortage. Clean energy drying uses air or solar-driven power cycles, offering energy savings, emission reduction, and improved drying quality. Solar energy is promising for application in drying systems like solar tunnels, greenhouses, and photovoltaic greenhouse drying.

This study examines the Life Cycle Assessment (LCA) of various drying techniques employed (natural-, traditional- and clean energy-dryings) for the edible insects with the SimaPro 7.2. LCA is the optimal tool for evaluating the environmental impact of a product, process, or activity from its inception to its conclusion. Insect larvae's moisture content ranges from 60% to 74%, and a 7-month shelf-life can be achieved by drying edible insects such as cricket and BSFL powders to approximately 5 g/100 g moisture content.

The LCA analysis results for the natural-, traditional- and clean energy-dryings are calculated for weighted impact and 3 impact categories. The weighted impacts of natural-, traditional- and clean energy-dryings were calculated as 72.2, 425.77 and 243.20 mPts, separately. The highest Human Health Impact, Ecosystem Quality Impact and Resource Impact were calculated as 1,59E-05 DALY, 8,42E-08 species.yr and 0,0042 $ for traditional-drying methods. The lengthy drying period of natural processes can cause them to have social effects. Clean and renewable energy methods should be used, and research should be carried out in this area to accomplish the required dryness faster.

InSAFE - Securing the future of the UK's insect farming industry

Gesa Reiss[1], Amandine Collado[2], Katie McDermott[1]

[1] *School of Biology, University of Leeds, Leeds, United Kingdom*
[2] *Entocycle Ltd, London, United Kingdom*

Corresponding author: g.c.reiss@leeds.ac.uk

InSAFE, an industry-led research project, will inform the development of protocols, codes of practice (CoP), and standards for Black Soldier Fly Larvae (*Hermetia illucens*) rearing facilities spanning a range of production scales, from containerised units, such as EntoExplore, to large facilities.

Industry-wide documentation that aligns with regulation or existing accreditation schemes does not exist in the UK but is crucial to the development and future viability of the emergent insect farming industry as this will be required to unlock new and lucrative markets.

Legislation on the use of processed animal proteins, a lack of H&S protocols, CoP, and Food Safety Standards for insect rearing is curtailing the growth of the UK insect farming industry and limits revenue streams, such as frass, oils, chitin, to be developed. Removing constraints for commercial operations to utilise cheap yet non-permissive feedstocks for rearing BSFL would unlock the full potential of novel insect farming systems. These systems could significantly raise the volumes of insect proteins as ingredient for animal feeds, and valorise livestock slurries alongside human sanitation waste. However, these feedstocks are environmental sources of veterinary and medical antimicrobials that are selection agents for antibiotic resistance genes (ARGs) in the gut and environmental microbiomes. Livestock and human gut microbiomes are also a source of zoonotic pathogens and ARGs in the environment and agricultural food chain, hence pose a risk to human health.

InSAFE will analyse the microbiome, pathogen loads, presence of Anti-Microbial Resistance (AMR) genes, and heavy metal content of permissive and non-permissive feedstocks prior to, and after, insect bioconversion, alongside analysis of BSFL and by-products such as frass. Uniquely, faecal samples will be collected from the operators of BSFL rearing facilities at Entocycle (permissive feedstock) and the University of Leeds' National Pig Centre (non-permissive feedstock) before and after exposure to rearing environments to monitor pathogen load and associated risk to human health.

InSAFE will produce essential documentation for the operation of insect farms, to produce energy efficient, sustainable protein safely at scale, supporting the expansion of this alternative protein source for the UK.

Replacing fishmeal in the aquaculture sector: social, economic and ecological evaluation of novel protein sources

Eva Landgräber[1,2], Önder Altuntas[1,3], Hülya Altuntas[1,4], Giacomo Rossi[1], Oliver Schlüter[1]

[1] Leibniz Institute for Agricultural Engineering and Bio-economy, Potsdam, Germany
[2] German Institute of Human Nutrition Potsdam-Rebrucke (DIFE), Nuthetal, Germany
[3] Faculty of Aeronautics and Astronautics, Eskisehir Technical University, Eskisehir, Turkey
[4] Faculty of Science, Department of Biology, Eskisehir Technical University, Eskisehir, Turkey

Corresponding author: grossi@atb-potsdam.de

The raping increases of the aquaculture sector is leading to an increasing demand for proteins sources to be used as fish feed. Fishmeal (FM) is the primary component of fish feed, consisting mainly of waste and by-products from fish rearing and processing, as well as small wild-caught fish. Continuous production of FM is leading to negative environmental consequences on the marine ecosystem. Exploration of novel, cost-effective and sustainable alternatives such as bioflocs, duckweed, algae and insects is therefore needed. This study focuses on the environmental, social and economic impact of these novel sources on the aquaculture sector. The most recent literature is considered and results are summarized with the aim of draft a final consideration on the sustainability of replacing traditional FM with novel protein sources.

The recent literature suggests that bioflocs, duckweed, algae and insects can partially replace FM without any adverse effect on fish growth parameters. However, addition of these alternatives to fish feed might influence the proximate composition and organoleptic properties (odor, color, taste/texture) of fish fillet. Economical evaluation, which should always be carried out before embracing a shift on the animal diet, should not only be limited on the goal of profit maximization, but it should also consider the "satisficing" concept, evaluating several pros and cons connected with the new business model. Different consumers may indeed react in a different manner, with some people more emotionally involved on the sustainability aspect, being willing to pay an extra cost for the final product. Political supports should also be considered. Life Cycle Assessment conducted on the production of FM and the new protein sources has shown that the environmental impact of different biomasses is extremely variable, being influenced mainly by the production technology applied, the initial raw material and the energy sources. However, the overall impact, express in terms of damage to human health, ecosystem and resources, seems to support the idea of replacing FM with novel protein sources, with a progressive reduction in impact observed when increasing percentages of FM were replaced by, for example, insect meal.

Hermetia illucens chitin and chitosan: characterization for application in cosmetic and pharmaceutical fields

Micaela Triunfo[1], Rosanna Salvia[1,2], Carmen Scieuzo[1,2], Anna Guarnieri[1], Dolores Ianniciello[1], Antonio Franco[1,2], Giovanna Donnarumma[3], Beatrice Coltelli[4], Angela De Bonis[1], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*
[3] *University of Campania "Luigi Vanvitelli", Italy*
[4] *University of Pisa, Italy*

Corresponding author: patrizia.falabella@unibas.it

Chitin and chitosan, as natural polymers, have considerable technological and economic importance with several applications in various fields. Chitin, the structural element of arthropod exoskeletons and the cell walls of fungi and yeasts, undergoes deacetylation to obtain more soluble derivatives, such as chitosan. The growing demand for these pol-ymers has prompted the exploration of alternative sources, such as insect bioconverters, including *Hermetia illucens*. This study aimed to develop an efficient procedure for chitin purification and chitosan production from different biomasses obtained from *H. illucens* breeding. Chitin extracted from larvae, pupal exuviae, and adults showed yields, chemical characteristics and purity comparable to commercially available crustacean-derived chi-tin. The chitosan production methodology demonstrated substantial differences in deacetylation efficiency, yield, DD and crystallinity, favoring the heterogeneous method. Spectrometric, diffractometric, and morphological characterizations confirmed the simi-larity of the produced chitosans with the commercial polymer, with variations observed in lower viscosity and Mw. Chitosan from *H. illucens* exhibited distinct characteristics de-pendent on deacetylation method and chitin decolorization, affecting DD and Mw. Biolog-ical properties relevant to biomedical and cosmetic applications were evaluated, indicat-ing promising radical scavenging activity and anti-inflammatory potential. In particular, heterogeneous chitosan proved to be effective in reducing the expression of pro-inflam-matory cytokines and modulating the expression of antimicrobial peptide HBD-2. This study serves as a basis for correlating the specific physical-chemical, morphological, and biological characteristics of *H. illucens* chitosan samples with the targeted applications of interest.

Antimicrobial properties of the chitosan of the bioconverter insect *Hermetia illucens*

Carmen Scieuzo[1,2], Rosanna Salvia[1,2], Anna Guarnieri[1], Micaela Triunfo[1], Dolores Ianniciello[1], Antonio Franco[1,2], Giovanni Lomonaco[1], Sofia Ouazri[1], Fabiana Giglio[1], Federica De Stefano[1], Angela De Bonis[1], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*

Corresponding author: patrizia.falabella@unibas.it

Chitin and its deacetylated derivative, chitosan, have wide applications in the bio-medical and pharmaceutical sectors. The growing demand for these biopolymers has stimulated the exploration of alternative sources to crustaceans, which are currently the main indus-trial source. Insects, particularly the bioconverter diptera *Hermetia illucens*, have gained prominence due to their ability to utilize waste materials, such as pupal exuviae and dead adults, for the extraction of chitin and subsequent conversion to chitosan. Chitin and chi-tosan exhibit crucial properties, including biocompatibility, biodegradability, nontoxicity, antioxidant attributes, humectant characteristics, and antimicrobial activity. The increas-ing prevalence of drug-resistant pathogens, resulting in antimicrobial resistance, has made conventional antibiotics increasingly ineffective. Natural alternatives, including chi-tosan, are emerging as a promising and safe solution. After protonation under acidic con-ditions, chitosan demonstrates the ability to inhibit the proliferation of bacteria, fungi and yeasts. This inhibitory mechanism involves electrostatic interactions between the NH3+ groups of chitosan and the negatively charged regions of bacterial membranes, encom-passing both Gram-negative and Gram-positive strains. The antimicrobial efficacy of chi-tosan is contingent upon specific chemical-physical characteristics, notably molecular weight and deacetylation degree, as well as experimental conditions like temperature and pH. The assessment of chitosan antimicrobial activity involved two experimental ap-proaches: the agar diffusion test and microdilution assay. Both bleached and unbleached chitosan derived from larvae, pupal exuviae, and dead adults of *H. illucens* induced the formation of inhibition zones, indicative of the biopolymer ability to impede microbial growth. This significant property was further confirmed through microdilution assay, re-vealing minimum inhibitory concentration (MIC) values ranging between 0.3 mg/ml and 0.15 mg/ml against both Gram-negative and Gram-positive bacteria.

Chitosan from *Hermetia illucens:* an innovative and sustaina-ble coating for strawberry preservation

Micaela Triunfo[1], Anna Guarnieri[1], Dolores Ianniciello[1], Giovanni Lomonaco[1], Mariarita Rubino[1], Leonardo Coviello[1], Antonella Vitti[1], Maria Nuzzaci[1], Rosanna Salvia[1,2], Carmen Scieuzo[1,2], Patrizia Falabella[1,2]

[1] *University of Basilicata, Potenza, Italy*
[2] *Xflies s.r.l, Potenza, Italy*

Corresponding author: patrizia.falabella@unibas.it

Strawberries, a highly favored fruit among consumers, are renowned for their popularity but also for its high perishability. The structural integrity of the fruit postharvest typically endures for only a brief period under standard storage conditions. To address the rapid deterioration of strawberries and extend their shelf life, an alternative approach involves treating them with a biodegradable and health-friendly compound, the chitosan. Due to its inherent antifungal and antimicrobial properties, this bio-coating serves as a protective barrier, offering defense against external agents and inhibiting the growth of molds and fungi that contribute to the accelerated decay of the fruit. The potential of chitosan derived from *Hermetia illucens* pupal exuviae to attenuate the deterioration of the native straw-berry cultivar "*Melissa*" (*Fragaria x ananassa*) was investigated. Strawberries were sub-jected to storage conditions at room temperature, 4°C, and mixed storage conditions (4°C+RT). The findings demonstrated that chitosan from *H. illucens* outperformed com-mercial polymer in food preservation, effectively stabilizing and improving crucial post-harvest parameters. Specifically, decolorized chitosan exhibited superior efficacy in miti-gating physicochemical changes (weight loss, pH, and soluble solids content) and pre-venting fungal decay in treated strawberries. On the other hand, no decolorized chitosan proved more functional in preserving and enhancing the nutraceutical properties (total phenolic and flavonoid content, total anthocyanins, and antioxidant activity) of the treated strawberries. These observed results substantiate the viability of employing insect-de-rived chitosan, particularly the one derived from *H. illucens* pupal exuviae, as a substitute for crustacean chitosan in the preservation of post-harvest fruits. This research provides valuable insights into the potential applications of insect-based chitosan in enhancing the postharvest quality and extending the shelf life of strawberries, contributing to sustainable and health-conscious fruit preservation practices.

Hermetia illucens chitosan for the preservation of fresh fruits

Rosanna Salvia[1,2], Carmen Scieuzo[1,2], Micaela Triunfo[1], Anna Guarnieri[1], Dolores Ianniciello[1], Antonio Franco[1,2], Giovanni Lomonaco[1], Emine Derin[1], Antonio Dolce[1], Maddalena Ventura[1], Angela De Bonis[1], Patrizia Falabella[1,2]

[1] University of Basilicata, Potenza, Italy
[2] Xflies s.r.l, Potenza, Italy

Corresponding author: patrizia.falabella@unibas.it

Chitosan properties make it an ideal natural polymer for preserving and extending the shelf-life of fresh foods. Chitosan-based bioactive films effectively prevent microbial contamination and spoilage in fruits, vegetables, eggs, and meat. Currently, the primary commercial source of chitin is waste from the marine food busi-ness, specifically crustacean shells. Due to limited availability and sustainability of crustaceans, insects, especially bioconverters, offer a promising alternative source of chi-tin and chitosan. This study focuses on using pupal exuviae, a byproduct of *Hermetia illucens* farming, to formulate coating solutions applied to fresh fruits. Pupal exuviae were used as we verified that they are the most effective insect biomass for chitosan produc-tion. Apricots (*Prunus armeniaca*), nectarines (*Prunus persica*), and peaches (*Persica vulgaris*) were coated with 0.5% and 1% unbleached and bleached chitosan and stored at room temperature and 4°C. The chitosan coating impact on fruits was measured during storage, including weight loss, total soluble solids content, and pH. The study assessed the impact of insect chitosan also on the development of mould on fruit skin, finding it to be as effective or better than commercially available crustacean chitosan in maintaining stable post-harvest physicochemical parameters in fresh apricots, nectarines, and peaches. Fruits stored at controlled temperature show more significant effects than those stored at room temperature. There are no significant differences between the effect oft the two tested concentrations or between bleached and unbleached chitosan. These pre-liminary results suggest that pupal exuviae of *H. illucens* can be used to produce and utilize chitosan in the food industry.

Hermetia illucens: this insect has a finger in every pie

Ilaria Chillin, Rim Hamze, Maria Cristina Reguzzi, Filippo Cominelli, Emanuele Mazzoni

Department of Sustainable Crop Production, Università Cattolica del Sacro Cuore, Piacenza, Italy

Corresponding author: emanuele.mazzoni@unicatt.it

Black soldier fly (BSF), Hermetia illucens, is a fast growing and really promising insect species, especially recommended as one-step solution to the threatened Earth's sustain-ability due to its several applications, firstly in feed industry, where it has been studied extensively for practical purposes, but also in sectors indirectly related to agriculture. Growing interest was recorded, in recent years, for the possible use of BSF larvae as a "tool" to convert agro-industrial waste into high quality proteins, lipids and/or micronutri-ents, today mainly exploited in feed sector, but with possible implications in other indus-tries such as textile, biomedicine, pharmaceutical, agriculture, biofuel, etc. Despite being mostly used for this purpose, BSF has gained attention recently due to the possible ex-traction of chitin and its derivative, chitosan, which are used in multiple industrial pro-cesses and produced by adults and exuviae too. BSF is also a source of peptides that could be exploited in food packaging, in the production of antibacterial, antiviral or anti-fungal drugs or considered as processing tools to improve bio-chemical reactions. Re-cently, even the frass is being used not only as fertilizer or soil improver for plant cultiva-tion but also as feed in aquaculture and excellent results were recorded for its application in hydroponics. In addition, fungi and bacteria analyzed and extracted from BSF gut mi-crobiota, are involved in waste management, veterinary, agricultural, and pharmaceutical industries. Bibliometric analysis and citation evolution profile were conducted in BSF's field, analyzing more than 400 articles and publications, to assess the evolution of interest over the last 10 years (2014–2024). The most involved research sectors, productive au-thors and nations were identified to obtain a clearer general picture of the most interesting and innovative opportunities involving BSF conducted in this decade. The final aim of this analysis was to explore the recent innovative applications of BSF to further stimulate the research process and contribute to discovering new possibilities in several fields and to stimulate curiosity of stakeholders.

Development of bio-based and biodegradable high-performance lubricants based on insect fat for industrial applications

Harald Wedwitschka[1], Franziska Schindler[2], Thomas Piofczyk[3], Arian Nek[4]

[1] *DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH, Leipzig, Germany*
[2] *Hermetia Baruth GmbH, Baruth/Mark, Germany*
[3] *PPM e.V. Pilot Pflanzenöltechnologie Magdeburg e.V., Magdeburg, Germany*
[4] *Danico Biotech GmbH, Kelkheim/Ts, Germany*

Corresponding author: harald.wedwitschka@dbfz.de

The poster will give an overview of the project structure and first results of the 'BioLube' research project which aimed to develop an economical method for producing, purifying, and refining insect fat for use in the biolubricant sector. Part of the project work was the generation of a database of suitable feed materials for the rearing *of Hermetia Illucens*, including feeding trial results from laboratory and pilot scale trials. Various raw materials have been tested, such as by-products from potato, apple, sugar beet, and soy processing. The tests have shown that the ratio of water and organic matter in the feed, as well as the conversion efficiency, have a significant impact on substrate side production costs and plant throughput. Additional tests were conducted to adjust the fatty acid composition of insect fat during the rearing process, with the goal of optimizing the quality of the raw fat. The aim of the project was to actively influence the fatty acid composition of insect fat by controlling biological feed conversion. The objective was to shift the ratio of polyunsaturated to saturated fatty acids in insect fat and adjust the acid spectrum to certain high-quality single fatty acids. It is important to note that polyunsaturated fatty acids (PUFAs) have a negative impact on lubricant quality due to their high reactivity. In feeding trials in lab scale with fat-free standard feed medium and saturated and unsaturated fatty acid containing additives, the interaction of the fatty acid composition of the feed material and the final insect raw fat was investigated. It was shown that a targeted selection of the feed material can result in low concentrations of PUFAs in the raw fat. This could help avoid the expensive process of hardening the fat, reducing biolubricant production costs. The final part of the project was the development of a cost-effective process to purify the product and produce bio-based and biodegradable high-performance lubricants from insect fat.

Integrating insect frass to promote productivity of fava bean crop

Adnane El Yaacoubi[1,2], Soufiane Khuili[3], Abderrazzak Ettaleby[1], Abderrahim Elgharbi[1], Christos I. Rumbos[4], Christos G. Athanassiou[4]

[1] *University Sultan Moulay Slimane, Higher School of Technology Khenifra, Khenifra, Morocco*
[2] *Association Green Development and Innovation, Ain Taoujdate, Morocco*
[3] *University Sultan Moulay Slimane, Faculty of Science and Technology, Beni Mellal, Morocco*
[4] *University of Thessaly, Laboratory of Entomology and Agricultural Zoology, Volos, Greece*

Corresponding author: a.elyaacoubi@usms.ma

Fava bean is one of the most important food crops in the world for human food, containing high rate of protein in seeds and considered as a great source of nutrients, such as potassium, calcium, magnesium, iron and zinc. However, this crop is facing issues of inadequate soil fertility, saving environmental impacts. The use of insect frass as a biofertilizer showed recently positive outcomes. This study explored the potential effect of frass of the black soldier fly, *Hermetia illucens*, as a multipurpose organic fertilizer amendment for enhancing fava bean yield and productivity in Morocco. Field trials were carried out in Ain Taoujdate according to a randomized block design. Based on the frass nitrogen (N) content and the N rate used as reference for fava bean crop, six treatments (with 3 replications each) were evaluated: negative and positive controls, 25, 50, 100 and 200%, corresponding to 1.09, 2.18, 4.35 and 8.7 tons of frass/ha, respectively; 100% representing the reference rate. Morphological, agronomic and physiological parameters were assessed, encompassing seed germination, plant development, yield and height, flowering timing, root and shoot dry matter, leaf count, leaf area and chlorophyll content. Our results highlight the effectiveness of BSF frass application for optimal fava bean growth under Moroccan climate conditions.

Resource recovery from the biowaste of commercial insect industry

Debasree Purkayastha, Prabhat Khanal

Production and Welfare Division, Faculty of Biosciences and Aquaculture, Nord University, Skolegata 22, Steinkjer 7713, Norway

Corresponding author: debasree.purkayastha@nord.no

Insect industry has been one of booming industries in the food and feed sector. The industry has been a champion arena to achieve many of the Sustainable Development Goals (SDG) Such as SDG 2 (Zero hunger), SDG 12 (Sustainable consumption and production) and SDG 13 (Climate action). The commercial insect industry broadly addresses two major concerns: Land intensive livestock production to compensate the Protein demand and Waste management. Overall, the insect industry is founded on the core values of Sustainability and Circular economy. However, the scale at which the insect industry is going it is inevitable to generate biowastes in different forms. For instance, the Black Soldier Fly which is one of the largest commercially grown insects will generate 361 ton of dead adults every day apart from pupae exuviae. It is important to prioritize the pathways to extract value out of such biowaste from insect industry. The Insect Chitin has potential to accomplish the growing Chitin market demand while ensuring that the insect industry remains integrated to its circular economy and sustainability principles. In this study, chitin was extracted from Mealworm (*Tenebrio molitor*) adult and Black Soldier Fly (*Hermetia illucens*) adult. The chitin content in *Hermetia illucens* adults was higher than the *Tenebrio molitor* adults. The Fourier Transform Infrared (FTIR) study confirmed that both the extracted chitins were α-Chitins. Both the chitins obtained were porous with fibrils. The crystallinity and the thermogravimetric properties of the chitin extracted from *Hermetia illucens* adults and *Tenebrio molitor* adults differed considerably. Both the chitins can find wide applications in manufacturing of plastics, in textile industry and in wastewater treatment technology. There is a need to establish environmentally friendly and economic chitin extraction processes to ensure the overall circularity and sustainability of the insect industry.

ChitoColour: effective textile finishing made from recycled chitosan

Lena Muri, Luisa Mackrodt

Kunsthochschule Burg Giebichenstein, Halle (Saale), Germany

Corresponding author: lena.muri@edu.fh-joanneum.at; luisa.mackrodt@burg-halle.de

Insect farming has become increasingly popular in Europe, with the exuviae of the black soldier fly being a residual material. Chitosan, a versatile biopolymer derived from insect exuviae, has a wide range of properties and can be effectively utilized for textile water treatment and finishing, among other applications.

European textile dyeing factories are required to comply with stringent regulations for water treatment. Water treatment procedures can benefit greatly from the use of bio-based compounds for coagulation and flocculation. Insect chitosan, a local resource, has shown great potential in binding residual dyes from dyeing wastewater. The resulting hydrogel, when dissolved in acetic acid, can be used for textile finishing.

Two promising hydrogel processing technologies have been identified through conducted experiments: printing it onto a textile and blowing the hydrogel onto waste fibers.The printing technique uses dyed chitosan due to its textile-stabilizing and adhesive properties. This enables direct printing of patterns and functional elements, such as those on a backpack. Additionally, the seams can be glued with the same material, effectively reducing material usage. The backpack's textile can be shredded and recycled into new textile at the end of its life cycle, which improves its environmental impact.

The blowing technique can effortlessly combine hydrogel with recycled clothing fibers to produce a composite material. The hat was used as an exemplary demonstration of this technology. The procedure entails utilizing dissolved chitosan as a binding agent to attach fibers blown onto a mold with compressed air.

Chito Colour provides ideas for alternative textile production strategies and more resilient resource flows, thus contributing to a more sustainable use of clothing. Additionally, it can increase our understanding of insects as material suppliers for the fashion industry.

Take it to the farmers; increased access to Fertigro (BSFF fertilizer) combined with education on good agricultural practices improves farmer use and 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], 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-Straße 8, 07745 Jena, Germany

Corresponding author: 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 avocados 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 at all. Training of farmers on GAP was conducted through farmer field schools by field agents. Fertigro adoption, 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. The study revealed that improved access to fertigro not only increased farmer adoption but increased yields in tomatoes, tea, potatoes, avocados and coffee 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.
The conclusion of the study was that augmenting farmers access to fertigro alongside education on good agronomic practices can substantially increase farmer access, yields, improve their return on investment, and ultimately contribute to achieving Sustainable Development goal 2, zero hunger.

Unveiling the dynamics of insect-based food markets: insights from the French landscape

Yekta Akhbarifar[1], Jules Brion[2], Victor Villain[2]

[1] *GRESEC Laboratory, Université Grenoble Alpes, Grenoble, France*
[2] *PACTE Laboratory, Université Grenoble Alpes, Grenoble, France*

Corresponding author: victor.villain@univ-grenoble-alpes.fr

Entomoculture, a recent phenomenon, presents a striking disparity in the economic development of insect-based food production companies in France. While some entrepreneurs secure significant funding for business expansion, others struggle to scale up, and some are compelled to dissolve their ventures due to financial challenges. This paper explores the underlying factors driving these divergent trajectories.

Drawing on a mixed-method approach involving semi-structured interviews, ethnographic observations, and analysis of grey literature and press articles, our findings reveal that the social trajectory of entrepreneurs significantly influences their ability to access networks and leverage crucial resources for business growth.

Moreover, public policies play a pivotal role in shaping business competitiveness. When governmental frameworks support business innovation, companies gain essential resources to compete internationally and attract investment.

Additionally, the influence of interest groups cannot be overstated. While entrepreneurs from larger companies may engage in European-level advocacy, those from smaller enterprises primarily benefit from national-level regulatory oversight and knowledge exchange.

Our study underscores the critical role of policies and interest groups in shaping the insect-based food market. By understanding the interplay between entrepreneurial trajectories, policy support, and the advocacy efforts of interest groups, stakeholders can better navigate and contribute to the development of this burgeoning industry.

Mediatization of edible insects in France: poor coverage and limited knowledge

Yekta Akhbarifar[1], Jules Brion[2], Victor Villain[2]

[1] *GRESEC Laboratory, Université Grenoble Alpes, Grenoble, France*
[2] *PACTE Laboratory, Université Grenoble Alpes, Grenoble, France*

Corresponding author: yekta.akhbarifar@univ-grenoble-alpes.fr

This study delves into the social and communication-related challenges surrounding the mediatization of edible insects, focusing on involved actors and discourses. Following the contaminated blood affair, French mass media have assumed a crucial public health role, particularly concerning food risks. They actively promote health-focused discourse on food, contributing to the “nutritionalization of food knowledge” and covering public health nutrition campaigns since 2001. Despite institutional discourse advocating for insect consumption as a solution to food security and environmental issues, there is a significant gap between this and actual consumption by European consumers. Our research scrutinizes media portrayals of these issues, given their role as consumers’ primary information source on Novel Foods.

To identify knowledge elements on edible insects and arguments for their consumption, we employed a qualitative-quantitative methodology, including content and lexicometric analysis of 190 press articles from French generalist press archives on Europresse database (e.g., *Le Monde*, *Le Figaro*, *Le Parisien*). Semi-structured interviews with stakeholders including researchers, insect farmers and chefs, supplemented our analysis.

Our findings reveal limited and sporadic media coverage of edible insects, with information primarily surfacing during key events like report releases or regulatory changes. Industrial stakeholders dominate discourse, with economic themes prevailing in our corpus. Simplified scientific arguments promoting health and environmental benefits contribute to the “nutritionalization” and “ecologization” of the edible insect question. Conversely, while interviewees discuss production challenges and potential risks, French media tend to overlook these subjects.

These results highlight the lack of specialized information of edible insects in French media, transforming scientific arguments into promotional discourses. The coverage imbalance has resulted in disengagement within the public sphere regarding the issue. At the same time, the avoidance of challenging issues on the sanitary and environmental levels, both for industries and consumers, differs controversies on the subject.

Digital product passport for global insect supply chain

Urs Liebau, Gabriel Sultan, Iaroslav Trofimenko

Center for digital GreenTech, August-Wilhelm-Scheer Institute, Clausthal-Zellerfeld, Germany

Corresponding author: urs.liebau@aws-institut.de

By 2050, the world population will surpass 9.7 billion people. Insects, as an alternative animal feed, are a key solution to the increasing demand for protein. However, insect protein production is not well recognized and trusted due to a lack of transparency. Our project aims to showcase the complete chain of cultivation, production, and transportation of insects through an AI-driven digital product passport.

The market for insect products is growing inexorably, and the range of new products is expanding. Insects serve as a source of natural and pure protein, and the process of producing insect products is environmentally friendly, gaining popularity. Nevertheless, the inability to fully verify the conditions under which insects are reared, kept, and transported creates skepticism about products made from insects. This skepticism hinders the development of the industry and, consequently, the ecological and digital transformation required in our time.

The digital product passport can address this problem by enabling transparency and accessibility of information. In our project, we aim to present a data collection system for a digital product passport based on blockchain technology. This system allows for data recording, real-time automated monitoring and tracking, and data validation. With the help of a digital passport based on blockchain technology, it becomes possible to access comprehensive information about the origin of insects, their feed, transportation routes, and storage and rearing conditions. This will make the industry more transparent and significantly enhance its development prospects.

Addressing the welfare of mealworm farming at Ÿnsect

Eliaou Sellem, Thomas Lefebvre

Ynsect, RD Biotech, Evry, France

Corresponding author: thomas.lefebvre@ynsect.com

While insect farming has gained a growing attention as a promising solution to address global challenges in food security, ensuring the welfare of this new livestock must also be regarded paramount for ethical, ecological and economic reasons. Ÿnsect, world leader in mealworm farming, considers the welfare of farmed mealworms and beetles as an integrative part of its business. Its engagement in a proactive and positive approach of “care ethics” towards its insects in farms and research centers (3R), aims at better understanding, monitoring and respecting their essential needs and health, while insect welfare standards are still in debate. Among the multiple actions initiated by the company, R&D team has paid a deep attention to better characterize normal behavior and physiological requirements, including a specific focus on the response to mechanical stress. The resulting findings, unexplored so far, provide some useful tolerance thresholds allowing engineers to improve the design of rearing equipment while respecting the welfare of insects. In the same way, the development of performance indicators, called KIWIs - Key Insect Welfare Indicators - is being deployed to monitor welfare conditions on farms and prevent health hazards. Fully aware that this complex subject is still in its infancy, Ÿnsect is committed to promote awareness and research, and is keen get involved in elaborating standards in mealworm farming.

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Company presentations

Zero waste protein factories: bio feasibility testing as a pivotal step to empower the industry for waste-to-protein conversion

Katharina Unger

LIVIN farms AgriFood GmbH, Vienna, Austria

Corresponding author: katharina@livinfarms.com

In Europe, an estimated 20% of the total food production, equivalent to 88 million tonnes annually, is currently lost, incurring an associated cost of approximately 143 billion euros. Notably, about 30% of this food waste occurs during processing and manufacturing stages, generating substantial organic byproducts, ranging from 5,000 to 10,000 tons annually for a typical food manufacturer. EU countries are committed to the United Nations sustainable development goal of reducing food waste by 50% by 2030. Many companies have prioritised the reduction of food waste as a core sustainability objective.

The integration of insect farming has emerged as a prospective solution to mitigate food waste and promote a circular economy. A growing number of companies are adopting insect farming as a revenue-generating, zero-waste strategy.

This abstract delves into the potential of utilising Black Soldier Fly Larvae (*Hermetia illucens)* for waste to protein conversion. Through a comprehensive evaluation of biological feasibility with the latest available data, the abstract demonstrates the economic and sustainable viability of these factories.

Bio feasibility is a critical process in maximising the utilisation of BSF Larvae for waste upcycling. The process begins with a detailed analysis of the physical properties of the available material. Moving to feed formulation, creating diverse types of feed, rigorously testing and optimising for the best bioconversion potential. Scaling up to industrial mass, the chosen feed undergoes more testing, refining the processes for large-scale efficiency. In the quality check stage, final products like protein powder, lipids, and frass are thoroughly assessed through certified laboratory analyses. Factory planning is then informed by the resulting mass balance. Upon completion of bio feasibility testing, tailored recommendations are provided to optimise the utilisation of Black Soldier Fly Larvae and inform sustainable factory planning for waste upcycling.

Strategizing success in insect farming: business models, constraints, and project management

Artur Kühl

REINARTZ GmbH & Co. KG, Neuss, Germany

Corresponding author: a.kuehl@reinartz.de

Introduction: This presentation delves into the intricacies of establishing a successful insect farming business, focusing on the selection of a suitable business model, understanding operational constraints, navigating through the stages of development, and managing the project effectively in a dynamic environment.

Business Model Selection: The cornerstone of a thriving insect farming venture lies in choosing the appropriate business model. This segment explores various models ranging from small-scale, community-focused operations to large-scale, industrial production systems. We examine case studies illustrating how different models align with specific market needs, resource availability, and scalability objectives.

Operational Constraints and Profitability: A critical examination of the constraints in insect farming is pivotal for profitability. Factors such as cost of production, technological requirements, labor skills, and supply chain logistics are discussed. Strategies for minimizing costs, optimizing processes, and maximizing yield will be presented, drawing on real-world examples and best practices in the industry.

Development Stages and Pitfalls: The journey from conceptualization to operationalization involves multiple stages, each with its unique challenges and pitfalls. We outline these stages, from market research and feasibility studies to production and market entry. Common pitfalls, such as underestimation of resources and regulatory hurdles, are discussed with an emphasis on proactive mitigation strategies.

Project Management in Dynamic Environments: Effective project management is crucial in adapting to the dynamic nature of insect farming. This section introduces a project management framework tailored for insect farming ventures.

Conclusion: This presentation aims to equip participants with comprehensive insights and practical tools for establishing and managing a successful insect farming business. By understanding the critical factors that influence business model choice, addressing operational constraints, navigating development stages, employing effective project management techniques, and adapting to legislative environments, entrepreneurs and investors can position their insect farming ventures for long-term success and profitability.

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Heft 55	4th IFAC / CIGR Workshop Control Applications in Post – Harvest and Processing Technology (CAPPT 2006) 26th–29th March 2006, Potsdam, GERMANY	2006
Heft 56	Computer-Bildanalyse in der Landwirtschaft Workshop 2006	2006
Heft 57	Kontrolle der Frische in der Nacherntekette von Ökogemüse	2006
Heft 58	Entwicklung eines innovativen Dekontaminationsverfahrens als Technologieantwort auf zukünftiges Qualitätsmanagement im Nacherntebereich	2006
Heft 59	Experimental Studies and Mathematical Modelling of Solar Drying System for Production of High Quality Dried Tomato	2007
Heft 60	13. Workshop Computer-Bildanalyse in der Landwirtschaft & 4. Workshop Precision Farming	2007
Heft 61	Energiepflanzen im Aufwind Wissenschaftliche Ergebnisse und praktische Erfahrungen zur Produktion von Biogaspflanzen und Feldholz	2007
Heft 62	14. Workshop Computer-Bildanalyse in der Landwirtschaft	2008

Heft 63	Experten-Workshop Lagerung von Holzhackschnitzeln	2008
Heft 64	Postharvest unlimited 2008	2008
Heft 65	Vom Agrarrohstoff zu neuen Produkten – Verfahrenstechnische Forschung im Nacherntebereich	2009
Heft 66	16. Arbeitswissenschaftliches Kolloquium des VDI-MEG Arbeitskreises Arbeitswissenschaften im Landbau	2009
Heft 67	Monitoring der methanbildenden Mikroflora in Praxis-Biogas-anlagen im ländlichen Raum: Analyse des Ist-Zustandes und Entwicklung eines quantitativen Nachweissystems	2009
Heft 68	Wieviel Biogas steckt in Pflanzen? Abschluss- Symposium des „Biogas-Crops-Network“ (BCN) 7. Mai 2009 Potsdam	2009
Heft 69	Image Analysis for Agricultural Products and Processes 27 to 28. Aug. 2009 Potsdam	2009
Heft 70	5th International Technical Symposium on Food Processing, Monitoring Technology in Bioprocesses and Food Quality Management 31. Aug. to 02. Sept. 2009 Potsdam	2009
Heft 71	Einsatz von Biogas in PEM-Brennstoffzellen	2009
Heft 72	Teilflächenspezifische Grunddüngung	2009
Heft 73	16. Workshop Computer-Bildanalyse in der Landwirtschaft 04. Mai 2010 Braunschweig	2010
Heft 74	Erschließung von Nachhaltigkeitspotenzialen durch Nutzung innovativer Sensortechnologien – *Prozesskette Getreide* –	2010
Heft 75	Erschließung von Nachhaltigkeitspotenzialen durch Nutzung innovativer Sensortechnologien – *Prozesskette pflanzliche Frischeprodukte* –	2010
Heft 76	International Workshop The future of the quarter individual milking 14.–15. September 2010 Potsdam	2010
Heft 77	A flow cytometric approach to monitor the effects of gentle preservation techniques in the postharvest chain	2011
Heft 78	17. und 18. Workshop Computer-Bildanalyse in der Land-wirtschaft 05. Mai 2011 Stuttgart und 09. Mai 2012 Osnabrück	2012
Heft 79	2. Öffentliches Symposium des „BCN“ BiogasPOTENZIALE Erkennen, Erforschen, Erwirtschaften	2012
Heft 81	19. Workshop Computer-Bildanalyse in der Landwirtschaft 2. Workshop Unbemannte autonom fliegende Systeme in der Landwirtschaft 06.–07. Mai 2013 Berlin	2013

Heft 82	3rd Global Workshop on Proximal Soil Sensing	2013
Heft 83	19. Arbeitswissenschaftliches Kolloquium des VDI-MEG Arbeitskreises Arbeitswissenschaften im Landbau 11.–12. März 2014 Dresden	2014
Heft 84	Prozessmikrobiologie in landwirtschaftlichen Biogasanlagen Schlussbericht zum Forschungsverbund BIOGAS-BIOCOENOSIS	2014
Heft 85	Sensoren.Modelle.Erntetechnik Kolloquium zur Verabschiedung von Dr. Ehlert 27. Mai 2014, Potsdam-Bornim	2014
Heft 86	Phosphor für die Landwirtschaft – Strategien für eine endliche Ressource 11. Juni 2014, Potsdam-Bornim	2014
Heft 87	Biofilme in Biogasanlagen – Struktur, Einfluss auf die Biogas ausbeute und Optimierung technischer Systeme zur Rückhaltung der mikrobiellen Biomasse BIOGAS-BIOFILM	2015
Heft 88	20. und 21. Workshop Computer-Bildanalyse in der Landwirtschaft 3. Workshop Unbemannte autonom fliegende Systeme (UAS) in der Landwirtschaft 26. Mai 2014, Osnabrück und 06. und 07. Mai 2015, Braunschweig	2015
Heft 89	International Biochar Symposium: Biochar Contibution to Sustainable Agriculture 28th – 29th May 2015, Potsdam	2015
Heft 90	ISHS Symposium 2016 “Sensing Plant Water Status” Methods and Applications in Horticultural Science 05th–07th October 2016 Potsdam	2016
Heft 91	10th International FRUTIC Symposium Quality and Safety of Fresh Horticultural Commodities February 07, 2017	2017
Heft 92	Etablierung eines *core*-Mikrobioms für Biogasanlagen Genom-Sequenzierung von Isolaten aus Biogasanlagen und Mapping von Metagenom-Datensätzen BIOGAS-CORE	2017
Heft 93	22. Workshop Computer-Bildanalyse und Unbemannte autonom fliegende Systeme in der Landwirtschaft 23. Workshop Computer-Bildanalyse in der Landwirtschaft 21. April 2016, Wernigerode und 27. April 2017, Potsdam-Marquardt	2017
Heft 94	Leitfaden für die Trocknung von Arznei- und Gewürzpflanzen	2017
Heft 95	Entwicklung von molekularen Markern und Nachweisverfahren auf Basis der quantitativen (realtime) PCR zum Monitoring von prozessrelevanten Mikroorganismen als Frühwarnsysteme für Prozessstörungen	2017

Heft 96	Cold atmospheric pressure plasma treatment of food matrices: Tailored modification of product properties along value-added chains of plant and animal related products	2017
Heft 97	INSECTA. Conference 2017 07th–08th September 2017, Berlin, Germany	2017
Heft 98	Storability of broccoli – investigations of optical monitoring, chlorophyll degradation and predetermination in the field	2018
Heft 99	24. Workshop Computerbildanalyse in der Landwirtschaft 25. April 2018, Zürich	2018
Heft 100	INSECTA 2018. International Conference 05th–07th September 2018, Giessen, Germany	2018
Heft 101	6th International Conference on Machine Control and Guidance 1–2 Oct 2018, Berlin, Germany	2018
Heft 102	25. Workshop Computerbildanalyse in der Landwirtschaft 17th 2019, Bonn, Germany	2019
Heft 103	INSECTA 2019. International Conference 05th–06th September 2019, Potsdam, Germany	2019
Heft 104	Transformation Strategies in Agriculture	2021
Heft 105	INSECTA 2021. International Conference 08th – 09th September 2021, Magdeburg, Germany	2021
Heft 106	INSECTA 2022. International Conference 14th – 16th September 2022, Gießen, Germany	2022
Heft 107	INSECTA 2023. International Conference 13th – 14th September 2023, Magdeburg, Germany	2023
Heft 108	INSECTA 2024. International Conference 14th – 16th May 2024, Potsdam, Germany	2024

If you are interested please contact:

Leibniz-Institut für Agrartechnik und Bioökonomie e.V.
Max-Eyth-Allee 100
14469 Potsdam
GERMANY

E-Mail: atb@atb-potsdam.de