International Conference
Insects to Feed the World

Ede
The Netherlands
14 - 17 May 2014

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Poster abstracts

OVERVIEW OF ORAL PRESENTATIONS

Wednesday , 14 May 2014

	PLENARY LECTURES
09:00-09:15	**Objectives of the conference -** *Arnold van Huis, Wageningen University, The Netherlands*
09:15-09:45	**Setting the table for a hotter, flatter, more crowded earth: insects on the menu? -** *Sonny Ramaswamy, Director National Institute of Food and Agriculture, U.S. Department of Agriculture, Washington*
	HARVESTING FROM NATURE
09:45–10:15	**Anthropo-entomophagy in Latin America: An overview of the importance of edible insects to local communities -** *Eraldo M. Costa Neto, Brazil*
10:15-10:45	**Ethno-entomophagy in Asia and the Pacific: historical perspectives and future directions -** *Alan Yen, Australia*
11:15–12:35	**ORAL PRESENTATIONS IN PARALLEL SESSIONS**
	Harvesting from nature (room Schouwburg)
11:15-11:35	Everyday entomophagy in rural Laos: Understanding the heterogeneity of insect consumption in dairy life (Nonaka, K., Murayama, N., Natsuhara, K. and Ono, E.)
11:35-11:55	Semi-cultivating edible insects: A historical perspective and future prospects (Van Itterbeeck, J.)
11:55-12:15	Harvesting and nutrition value of edible wasps in southwest China (Zhao, M., Feng, Y. and Chen, X.M.)
12:15:12:35	The Amazonic strategy to utilize edible insects can be extended? (Paoletti, M.G. and Manno, N.)
	Harvesting from nature (room kernhem)
11:15-11:35	Prospects and constraints for the use of insects as human food and animal feed in West Africa (Kenis, M. and Hien, K.)
11:35-11:55	Entomophagy in contemporary Japan: Imported insects compensate for a decline in wild harvesting (Payne, C.L.R.)
11:55-12:15	The other food: the status of entomophagy in Botswana (Obopile, M.)
	Harvesting from nature (room Studio 2)
11:15-11:35	Entomophagous insects of Kanyakumari District, India (Basil-Rose M.R., Padua, J.C. and Punitha, A.)
11:35-11:55	What innovations to convert locusts invasions into a protein pulsed resource accessible to local population? (Randrianasolo-Rakotobe, H. and Rakotonandraina, N.)
11:55-12:15	Exploiting pest insects species *Sphenarium purpurascens* for human consumption: ecological, social, and economic repercussions (Cerritos Flores, R., Ponce–Reyes, R. and Rojas-García, F.)

PRODUCTION OF INSECTS AS FOOD AND FEED

PLENARY LECTURES

14:00-14:30	**Small-scale production of edible insects for enhanced food security and rural livelihoods: experience from Thailand and Laos** – *Patrick B. Durst (FAO) and Yupa Hanboonsong, Thailand*
14:30-15:00	**Insect diseases: what are they and how to avoid them?** - *Jørgen Eilenberg and Annette Bruun Jensen, Denmark*

15:30-17:10 **ORAL PRESENTATIONS IN DIFFERENT SESSIONS**

Projects (room Schouwburg)

15:30-15:50	GREEiNSECT: a multidisciplinary research project on potentials and barriers for insect-farming for food and feed in Kenya (Roos, N., Owino,V., Kinyuru, J., Ekesi, S., Courtwright, G., Drew, D., Hanboonsong, Y., Vantomme, P., Chamnan, C., Olsen, S.B., Jensen, A.B. and Ayieko, M.)
15:50-16:10	PROteINSECT- do European citizens accept the use of insects for animal feed & human food? (Smith, R. and Pryor, R.E.)
16:10-16:30	WINFOOD PROJECT: development and evaluation of Amaranth grain based complementary foods enriched with termites and fish (Kinyuru, J.N., Konyole, S.O., Onyango-Omolo, S.A., Owino, V.O., Owuor, B.O., Estambale, B.B. and Roos, N.)
16:30-16:50	Perspectives of insect industry in South Korea: Government policies and R&D strategies (Jeong, J.)

Silkworms as food and feed (room Kernhem)

15:30-15:50	Silkworms to resolve the world's food crisis - the most acceptable insect as food and feed (Prabhakar C.J., Akai, H., Sumida, M., Sohn, B.H., Wu Jenmai and Sirimungkararat, S.)
15:50-16:10	Ideal edible insect: High value, safety food and innovative products with complete value chain of eri silkworm (*Samia ricini* D.) in Thailand (Sirimungkararat, S., Saksirirat, W. and Wongson, D.)
16:10-16:30	Pury, a fine powder made from silkworm pupae as an alternate of nutritious food for human nutrition (Astuti, T., Kusharto, C.M. and Mas'ud, H.)
16:30-16:50	Insects: Potential of stable isotope tools for optimizing insect production management (Hood-Nowotny, R.)

Farming different species (room Studio 2)

15:30-15:50	High potential for mass rearing katydid (*Ruspolia differens*) and palm weevil (*Rhynchophorus phoenicis*) for food in the Lake Victoria basin (Nyeko, P, Okia, C.A., Nusula, N., Odongo, W., Nzabamwita, H.P., Ndimubandi, J., Jaronski, S. and Roininen, H.)
15:50-16:10	Edible mealworm species: the effect of diets composed of organic side stream material (Van Broekhoven, S., Oonincx, D.G.A.B., Van Huis, A. and Van Loon, J.J.A.)
16:10-16:30	The rearing and utilization of cockroach in Yunnan, China (Feng, Y., Chen, X.M. and Zhao, M.)
16:30-16:50	Two rearing substrates on *Tenebrio molitor* meal composition: issues on aquaculture and biodiesel production (Belforti M., Lussiana C., Malfatto V., Rotolo L., Zoccarato, I. and Gasco L.)
16:50-17:10	An aquatic worm production concept for the valorisation of food by-products (Laarhoven, B., Elissen, H.J.H., Temmink, H., Buisman, C.J.N.)

OFFICIAL OPENING

PLENARY SESSION

17:15-17:45	**African edible-insects: inventory, diversity, commonalities and contribution to food and nutritional security** - *Segenet Kelemu, Director General icipe (African Insect Science for Food and Health), Nairobi, Kenya*
17:45–18:30	**Opening statements** *Ernst van den Ende*, Managing Director, Plant Sciences Group, Wageningen University and Research Centre, the Netherlands *Hans Hoogeveen* JD MPA, Director General Agro at the Ministry of Economic Affairs, The Netherlands *Eduardo Rojas-Briales*, Assistant Director-General, FAO Forestry Department, FAO Headquarters, Rome

Thursday, 15 May

PLENARY LECTURE

Food safety, Legislation and Policy

09:00–09:30	**Safety and quality considerations of insects for food and feed** - *Adrian Charlton, United Kingdom*
09:30–10:50	**ORAL PRESENTATIONS IN PARALLEL SESSIONS**
	Legislation and food safety (room Schouwburg)
09:30-09:50	PROteINSECT- promoting legislation change to help feed the world (Pryor, R. E. and Smith, R.)
09:50-10:10	Use of insects as a protein source in feed and food: Safety and EU legislative aspects (Van der Spiegel, M. and Noordam, M.)
10:10-10:30	Risk assessment of novel proteins in food: Are insect proteins allergenic? (Broekman, H.C.H.P., Knulst, A.C., Den Hartog Jager, C.F., Gaspari, M., De Jong, G.A.H., Houben, G.F. and Verhoeckx, K.C.M.)
10:30-10:50	Microbiological status of edible insects sold as pet feed in Germany (Grabowski, N.Th., Jansen, W. and Klein, G.)
	Food safety (room Kernhem)
09:30-09:50	Inactivation of *Salmonella* spp. and *Ascaris suum* in batch and continuous black soldier fly treatments (Lalander, C.H., Diener, S. and Vinnerås, B.)
09:50-10:10	Evaluation of feed safety aspects in feeding organic layers with fresh house fly larvae (*Musca domestica*) reared in poultry manure (Nordentoft, S., Fischer, C., Hald, B., Enemark, H., Thapa, S. and Bjerrum, L.)
10:10-10:30	Nutrition and heavy metal levels in the mound termite, *Macrotermes bellicosus* (Smeathman) (Isoptera: Termitidae), at three sites under varying land use in Abeokuta, southwestern Nigeria (Idowu, A.B., Ademolu, K.O. and Bamidele, J.A.)
10:30-10:50	Multifaceted aspects of insect pathogenic and commensal bacteria in insect based food (Nielsen-LeRoux, C.)
	Nutrition (room Studio 2)
09:30-09:50	Towards an effective insect supply chain: meeting qualitative requirements and quantitative demands (Vrij, E.M.P. and Peters, M.)
09:50-10:10	Human chitinases' variability and implications for chitin digestion in populations eating insects (Paoletti, M.G., Mostacciuolo, M.L., Battisti, A., Mostacero Leon, J. and Manno, N.)
10:10-10:30	Nutritional and anti-nutritional composition of most preferred ant and termite species used as food by the tribes of Arunachal Pradesh, India (Chakravorty, J.)

10:30-10:50 Ethanol extract of *Bombys batryticatus* induces apoptosis in human hepatoma cell SMMC-7721 via the modulation of Bax/Bcl-2 and P21 expression pathway (Wu, W-P, Wu, J-Y, Zhang, R-F., Feng, J-N and Wang, D.)

PLENARY LECTURES

11:20–11:35 The role of the FAO in assisting countries to develop regulatory frameworks to include insects in the food and feed sectors (Afton Halloran, Paul Vantomme and Christopher Münke) (15 min)

11:35-12:00 Legislation and regulation of insects as food and feed - the EU perspective (European Commission - Health & Consumers Directorate-General - DG SANCO) Sirkku Heinimaa and Wolfgang Trunk

12:00-12:30 Discussion

INSECTS AS FEED: SPECIFIC PRODUCTION SYSTEMS

14:00–14:30 **Black soldier fly farming: The entomology link in kiloton/month (and above) production chains** – *John C. Schneider, USA*

14:30–15:00 **AgriProtein: Building the worlds' largest insect rearing protein farm – a history and vision** - *David Drew, South Africa*

15:30–17:30 **ORAL PRESENTATIONS IN PARALLEL SESSIONS**

Insects as feed - general (room Schouwburg)

15:30-15:50 Current status on use of insects as animal feed (Makkar, H.P.S.)

15:50-16:10 The Insect Biorefinery, an efficient tool for industrial production of insects and derivates (Hubert, A.)

16:10-16:30 The benefits of using insects as fish and animal feed (Miura, T., Ido, A., Ohta, T., Iwai, T., Kusano, K., Kobayashi, S., Kishida, T. and Miura, C.)

16:30-16:50 Case study: Insects as feed (Pieterse, E., Hoffman, L.C. and Drew, D.W.)

16:50-17:10 Industrial fruit fly mass rearing for the application of the Sterile Insect Technique (Abd-Alla A. M. M., Caceres, C., Parker, A.G., and Vreysen, M.J.B.)

17:10-17:30 EnviroFlight, USA: Industrial cultivation of black soldier flies for animal feed (Courtright, G.)

Aquaculture (room Kernhem)

15:30-15:50 Insect meal: a promising source of nutrients in the diet of Atlantic salmon (*Salmo salar*) (Lock, E.J., Arsiwalla, T. and Waagbø, R.)

15:50-16:10 Use of *Tenebrio molitor* larvae meal in diets for gilthead sea bream *Sparus aurata* juveniles (Piccolo, G., Marono, S., Gasco, L., Iannaccone, F., Bovera, F. and Nizza, A.)

16:10-16:30 Mealworm (*Tenebrio molitor*) as a potential ingredient in practical diets for rainbow trout (*Oncorhynchus mykiss*) (Gasco, L., Belforti, M., Rotolo L., Lussiana, C., Parisi G., Terova G., Roncarati A. and Gai, F.)

16:30-16:50 Substitution of fish meal by *Tenebrio molitor* meal in the diet of *Dicentrarchus labrax* juveniles (Gasco, L., Gai, F., Piccolo, G., Rotolo, L., Lussiana, C., Molla, P. and Chatzifotis, S.)

16:50-17:10 Insects are a sustainable alternative to fishmeal in aquaculture feed. Past and future (Henry, M. and Fountoulaki, E.)

17:10-17:30 Mass production system of housefly (*Musca domestica*) for waste reutilization and as feed for chickens and shrimps (Chen, J., Zhao, G. and Han, R.)

Black soldier fly and Housefly as feed (room Studio 2)

15:30-15:50 Nutrient digestibility of *Hermetia illucens* and *Tenebrio molitor* meal in broiler chickens (Schiavone, A., De Marco, M., Rotolo, L., Belforti, M., Martinez Mirò, S., Madrid Sanchez, J., Hernandez Ruiperez, F., Bianchi, C., Sterpone, L., Malfatto, V., Katz, H., Zoccarato, I., Gai, F. and Gasco, L.)

15:50-16:10 Parameters affecting larval development in the mass rearing of *Musca domestica* (Diptera: Muscidae) (Pastor, B., Martínez-Sánchez, A. and Rojo, S.)

16:10-16:30	Evaluation and improvement of a house fly larvae production system in Mali (Koné, N., Nacambo, S. and Kenis, M.)
16:30-16:50	Efficiency and scalability in producing feed from manure using the common housefly (Fischer, C.H., Heckmann, L.H.L., Nordentoft, S., Hald, B. and Bjerrum, L.)
16:50-17:10	Utilization of *Hermetia illucens* larvae for the production of food and feed (Katz, H., Rumpold, B., Katz, P., Fröhling, A. and Schlüter, O.)
17:10-17:30	Cactus as feedstock to produce protein from *Hermetia illucens* in South Africa (Tarrisse, A.)
17:30-17:50	Black soldier fly–Microbes Union: Efficient waste recycling agent and valuable renewable resource (Zheng, L.Y., Zhang, J.B., Li, Q. and Yu, Z.N.)

18:30 **Conference dinner**

Friday, 16 May

NUTRITION, PROCESSING, CONSUMER ATTITUDES AND GASTRONOMY

PLENARY LECTURE

09:00 – 09:30 **The last and critical step in promoting insects as food: Getting people to eat them** - *Paul Rozin, USA*

09:30–12:40 **ORAL PRESENTATIONS IN PARALLEL SESSIONS**

Introducing insects as food (room Schouwburg)

09:30-09:50	Welcoming the world to our table: Hospitality and edible insects (Looy, H. and Wood, J.R.)
09:50-10:10	Taste First: Deliciousness as an argument for entomophagy (Reade, B., Evans, J. and Bom Frøst, M.)
10:10-10:30	The role of design in introducing insects to the UK diet (Dasan, A.)
11:00-11:20	Willingness to pay for new food products from insect protein: Initial evidence from a choice experiment study in Kenya (Alemu, M.H. and Olsen, S.B.)
11:20-11:40	Longitudinal changes in acceptance of edible insects by students at Montana State University (Dunkel, F.V. and Stokhof de Jong, S.)
11:40-12:00	Introducing Entomophagy to America through children's education and culinary events (Ceadel, M.)
12:00-12:20	Can mass-production of insects contribute to alleviating malnutrition in developing countries? (Roos, N.)
12:20-12:40	Sustainable critters or delicious fritters? Consumer perceptions of edible insects in the Netherlands and Thailand (Tan, H.S.G., Tinchan, P., Steenbekkers, L.P.A., Lakemond, C.M.M. and Fischer, A.R.H.)
12:40-13:00	Effect of edible termite-based complementary foods on growth and micronutrient status of 6-15 month old Kenyan infants – a randomised trial (Owino, V.O., Omollo, S.A., Konyole, S.O., Kinyuru, J.N., Owuor, B., Skau, J., Roos, N., Michaelsen, K.; Friis, H. and Estambale, B.B.)

Developing a sustainable business of Crickets for food in Africa; TNO's Flying Food project (room Kernhem)

09:30-09:50	The Flying Food project on crickets in Africa, general introduction (Van Deventer, H., Gianotten, N., De Graaf, M., Kamukama, D., Mancheron, H. and Vrij, M.)
09:50-10:10	Rearing of crickets in Kenya and Uganda (Gianotten, N.)
10:10-10:30	Processing and new insect based products (Van Deventer, D. and Vrij, M.)
11:00-11:20	Market development and business case (Kamukama, D. and Mancheron, H.)
11:20-11:40	Triple loop monitoring and learning approach of Flying Food (De Graaf, M.)
11:40-12:00	Cricket Farming, Reproduction and Economic Potential for Small Farmers (Fuah, A.M., Siregar, H.C.H. and Siregar R.S.)

12:00-12:20 Nutritional assessment of the rare edible monster crickets and soldier termites consumed in the South Eastern districts of Zimbabwe (Musundire, R.)

12:20-12:40 Chemical profiling in the edible stink bug, *Encosternum delegorguei* consumed in South-Eastern districts of Zimbabwe (Musundire R., Cheseto X. and Torto B.)

Edible insects and nutrition (room Studio 2)

09:30-09:50 Mealworms: Alternate source of lipids (Danthine, S., Blecker, C., Paul, A., Caparros Medigo, R., Haubruge, E., Taofic, A., Lognay, G., Fauconnier, M-L., Frédérich, M. and Francis, F.)

09:50-10:10 Lipid extraction of four insect species: Effect of extraction method and potential use as food ingredient (Tzompa-Sosa, D.A., Yi, L., Van Valenberg, H.J.F., Van Boekel, M.A.J.S. and Lakemond, C.M.M.)

10:10-10:30 Proteomics Mass Spectrometry to Discover Changes in Protein Composition: Analyzing gut protein content and protein digestibility (America, A.H.P., Cordewener, J.H.G. and Van der Meer, I.M.)

11:00-11:20 Blood profile and nutrient status of Macaca fascicularis as animal model fed with pupa meal (Astuti, D.A., Sajuthi, D., Irma H.S. and T.B. Clarkson)

11:20-11:40 Insect biochemistry: The assessment of nutritional factors by metabolomics (Snart, C.J.P., Kapranas, A., Hardy, I.C.W. and Barrett, D.A.)

11:40-12:00 Preliminary chemical analysis of extracts from Encosternum delegorguei using Gas Chromatography Mass Spectroscopy (Zvidzai, C.J.)

12:00-12:20 Nutrient composition of four species of winged termites consumed in Western Kenya (Kinyuru, J.N.; Konyole, S.O., Roos, N., Onyango, C.A., Owino, V.O., Owuor, B., Estambale, B.B. and Kenji, G.M.)

12:20-12:40 Extraction and characterization of proteins from five insect species (Yi, L., Lakemond, C.M.M., Sagis, L.M.C., Van Huis, A. and Van Boekel, M.A.J.S.)

12:40-13:00 Traditional processing of selected edible insects of Zimbabwe (Manditsera, F. A. and Zvidzai C. J.)

ENVIRONMENTAL ISSUES

14:00–14:30 **Conversion of organic wastes into insect biomass and added value products: an integrated approach towards sustainability** - *Santos Rojo, Spain*

14:30–15:00 **Generic Life Cycle Assessment of proteins from insects** – *Bart Muys, Belgium*

15:30–16:50 **ORAL PRESENTATIONS IN PARALLEL SESSIONS**

Entomophagy (room Schouwburg)

15:30-15:50 Consumers' associations with insects in the context of food consumption: comparisons from acceptors to disgusted (Cunha, L. M., Moura, A.P. and Costa-Lima, R.)

15:50-16:10 Moving beyond the Bizarre Foods concept and tapping the "foodie" culture to promote entomophagy (Why, A. and Ricci, J.)

16:10-16:30 Business models based on insect inclusiveness (Klewer, M. and Real, F.)

16:30-16:50 Roadmap towards a flowering global insect industry (Peters, M. and Veldkamp, T.)

Environment (room Kernhem)

15:30-15:50 Can greenhouse gas emissions be reduced by inclusion of waste-fed larvae in livestock feed? (Zanten, H.H.E. van, Van Holsteijn, F.H., Oonincx, D.G.A.B., Mollenhorst, H., Bikker, P., Meerburg, B.G. and De Boer, I.J.M.)

15:50-16:10 Third Millennium Farming: utilizing city bio-wastes in a strategy for high-yield urban farming (Dzamba, J.)

16:10-16:30 Conversion of food waste directly to sustainable feed ingredients for animals and plants (Marchant, P.B., Vickerson, A. and Radley, R.)

16:30-16:50 Environmental sustainability of insect production (Oonincx, D.G.A.B.)

Promoting entomophagy (room Studio 2)

15:30-15:50	Open Source: Why we need open knowledge sharing to help insects feed the world (Imrie-Situnayake, D.)
15:50-16:10	Global awareness starts locally: the "Buggy Buffet" model to enhance conversation and adoption (Grant, J.F. and Follum, R.A.)
16:10-16:30	The hockey stick pattern in the acceptance of edible insects in The Netherlands (Dicke, M., Van Huis, A., Peters, M. and Van Gurp, H.)
16:30-16:50	Consumer acceptance of insect-based meat substitutes (Caparros Megido, R., Gierts, C., Blecker, C., Brostaux, Y., Danthine, S., Paul, A., Haubruge, É., Alabi, T. and Francis, F.)
	CLOSURE OF THE CONFERENCE
17:00–17:30	**Way forward to bring insects in the human food chain** – *Paul Vantomme (FAO HQ), Italy*
17:30–18:00	**Conclusions and recommendations**

OVERVIEW OF POSTERS

1. Exploring entomophagy in northern Benin: Practices, perceptions and possibilities (Riggi, L.G., Verspoor, R.L. Veronesi, M., MacFarlane, C., S. and Tchibozo, S.)
2. How can museums contribute for food provision and security in Africa – a stakeholder's approach (De Prins, J., Mergen, P. and Vantomme, P.)
3. Study on proteolysis of *Palembus dermestoides* (Fairmaire) and antioxidant activity of the hydrolysates (Yan, S., Chu, Z. and Meng Z.)
4. Neither wild nor farmed: What can we learn from insect 'semi-domestication'? (Payne, C.L.R. and Nonaka, K.)
5. Influences of different light sources on the life history of the Black soldier fly (Zhang, J.B., Huang, L., Zheng, L.Y. and Yu, Z.N.)
6. Life cycle of three *Hermetia illucens* L. strains and their conversion effect on manure (Zhang, J.B., Zhou, F., Zheng, L.Y. and Yu, Z.N.)
7. Research of co-conversion of livestock and poultry manure by black soldier fly and micro-organisms (Zhang, J.B., Cao, L., Zheng L.Y. and Yu, Z.N.)
8. Kitchen waste converted by black soldier fly and partly substituting soymeal in chicken feed (Zhang, J.B., Zheng, L.Y., Liu, X.L. and Yu, Z.N.)
9. Fishmeal substituted by production of chicken manure conversion with microorganisms and black soldier fly (Zhang, J.B., Zheng, L.Y., Jin, P., Zhang, D.N. and Yu, Z.N.)
10. Discovery of new anti-microbial peptides in black soldier fly and their function (Elhag, O.A.O., Zheng, L.Y., Zhou, D.Z., Yu, Z.N. and Zhang J.B.)
11. Edible insects of Western and Central Africa online (Mergen, P., Tchibozo, S., Theeten, F., De Prins J., Van de Voorde, J.)
12. Positive effects of dietary housefly (*Musca domestica*) pupa for fish and mammal (Ido, A., Ohta, T., Iwai, T., Kishida, S.T., Miura, C. and Miura, T.)
13. Belgian grasshoppers: A nutritious food source (Paul, A., Frédérich, M., Blecker, C., Haubruge, E., Francis, F., Caparros Medigo, R., Uyttenbroeck, R., Taofic, A., Heuskin, S., Lognay, G. and Danthine, S.)
14. Biowastes to Bioenergy (Li, W., Zheng, L.Y., Zhang, J.B., Yu, Z.N. and Li, Q.)
15. Effects of egg associated bacteria on the development of black soldier fly (Zheng, L.Y., Zhang, J.B., Li, Q. and Yu, Z.N.)
16. Optimization of cricket breeding production system for human food in Ratanakiri province (Cambodia) (Caparros Megido, R., Alabi, T.; Nieus, C.; Blecker, C.; Danthine, S., Paul, A., Haubruge, É. and Francis, F.)
17. Situation and perspective of entomophagy in Kinshasa (Nsevolo, P., Caparros Megido, R., Blecker, C., Danthine, S., Paul, A., Haubruge, É., Alabi, T. and Francis, F.)

18. Wild edible Arthropods of tapia woodlands (*Uapaca bojeri*) in Madagascar (Barsics, F., Caparros Megido, R., Malaisse F., Razafimanantsoa, T.M., Minet, J., Lognay, G., Wathelet, B., Haubruge, E., Francis, F. and Verheggen, F.J.)
19. Impact of insect species and preparation ways on composition and digestibility for feed and food (Crahay, B., Beckers, Y., Danthine, S., Blecker, C., Paul, A., Caparros, R., Taofic, A., Haubruge, E. and Francis, F.)
20. Effect of sanitation treatment on the microbiological quality and nutritional value of edible insects (Alabi, T., Fievez, T., Jonas, M., Caparros, R., Blecker, C., Danthine, S., Paul, A., Haubruge, E. and Francis, F.)
21. The sustainability in agribusiness case research centre: opportunities at insects to feed the world conference (Braga, F.S., Omta, S.W.F. and Fortuin, F.)
22. Human consumption and nutrient compostion of adult stage of *Zonocerus Variegatus* (Idowu, T. and K. Ademolu)
23. Purification and characterisation of soluble proteins based on expanded bed adsorption (EBA) chromatography for food application (Kristjansson, M., Eybye, K.L., Miquel Becker, E. and Hansen, M.B.)
24. Micro encapsulation as a means of protecting functional proteins and oils (Nielsen, A.L., Burnaes, K.L. and Isager, P.)
25. Entomophagy and capitalism (Müller, A.)
26. Comparison of honeybee pupae composition from healthy and parasitized brood by *Varroa* (Jonas, A., Benjamin, O., Martinez, J-JI.)
27. *Hermetia* as a transformer of organic waste streams for aquaculture feed (Smárason, B.Ö., Knobloch, S., Björnsdóttir, R., Davíðsdóttir, B., Árnason, J.)
28. Cholesterol and edible insects (Adámková, A., Borkovcová, M., Kouřimská, L., Mlček, J. and Bednářová, M.)
29. Entomophagy in the Czech Republic (Borkovcová, M., Bednářová, M., Adámková, A., Mlček, J. and Kouřimská, L.)
30. Breeding flies in Ghana: Implications of scaling up from pilot trials to commercial production scale (Devic, E., Anankware, J.P., Murray, F. and Little D.C.)
31. Exploring insect wastes as a fertiliser: A preliminary study (Pelissetti, S., Belforti, M., Gaudino, S., Gasco, L., Katz, H. and Grignani C.)
32. Honey, pollen and propolis production of *Trigona laeviceps* (Siregar, H.G.H., Fuah, A.M. and Septiani, A.)
33. Growth performance of common catfish (*Ameiurus melas* Raf.) fingerlings fed insect meal diets (Roncarati, A., Gasco, L., Parisi, G. and Terova, G.)
34. Insects as feed and food: A comparison of domestication potential of some species (Pieterse, E., Hopley, D. and Drew, D.W.)
35. Insect rearing optimisation of *Hermetia illucens* on different organics waste streams (De Bakker, R., Staats, W. and Borghuis, A.)

53. Effect of replacing wheat bran feed with *Flammulina velutipes* cultivation media wastes on the growth of mealworm (*Tenebrio molitor*) (Tae-ho Chung, Ju-min Kim, Je-hyun Lee, Chul Park, Gi-wook Shin, Seong-Hyun Kim and Namjung Kim)
54. Developmental characteristic of *Tenebrio molitor* (Coleoptera: Tenebrionidae) at different temperatures and photoperiods (Kim, N., Kim, S., Kim, S., Choi, J., Lee, S. and Go, H.)

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Setting the table for a hotter, flatter, more crowded earth: Insects on the menu?

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The Earth's population is expected to exceed well over 9 billion by 2050, and we will need to meet humanity’s need for food, feed, fuel, fiber, and shelter, with a minimal ecological footprint. The “9 Billion Problem” has implications for how we grow and view food now and in the future.

Insects have served as a food source for humanity since the first bipedal human ancestor came down from the trees and started walking the Savannahs. Interestingly, however, today, insect eating is rare in the western world, but remains a significant source of food for people in other cultures. According to the FAO, 1,900 species of insects are consumed by more than 2 billion people in more than 80 countries across Asia, Africa, and the Americas.

There are many advantages to insects as food. Insects contain more protein and are lower in fat then traditional meats, along with having a better feed efficiency rate. Insects save a substantial amount of energy and natural resources by their high metabolic rates. Because insects require less space and food, the ecological footprint of insects as food is smaller than that of traditional livestock. Finally, their reproduction rate is significantly higher, making them much easier to raise.

The United States Department of Agriculture’s National Institute of Food and Agriculture (NIFA) focuses on research, education and outreach that aligns with the grand global challenges, including food security and food safety, nutrition, sustainable energy, water and climate change. Going forward, the question is should agencies such as NIFA need to re-evaluate priorities to address the use of insects as a potential food source? Additionally, in relation to insects as human food, we need to understand a number of issues, such as biology of species that can be consumed, biotic and abiotic constraints to insect livestock production, health and environmental risks, food safety and regulatory implications, human behavior and attitudes to consumption of insects, production challenges, and infrastructure needs.

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Anthropo-entomophagy in Latin America: An overview of the importance of edible insects to local communities

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Insects and the products elaborated and/or eliminated by them are used as food source by three thousand traditional societies in over 120 countries. The evolution of anthropo-entomophagy has been achieved in many ways, from the point of view of collection, fixing, marketing and consumption, and for the insects' organoleptic qualities [1]. However, westerners' attitudes of repugnance due to the consumption of edible insects cause that a considerable amount of animal protein becomes unavailable to those individuals who suffer from protein deficiencies [2]. Brazil, Colombia, Venezuela, Ecuador, Peru, as well as Mexico due to its sociocultural origin, stand out as the Latin countries that have the habit of consuming insects by presenting both a biological and ethnic diversity. Edible species are eaten as immature (eggs, larvae, pupae, and nymphs) and in some cases also as adults. They are ingested whole or partially, as well as the products they produce, such as honey, propolis, pollen, and wax [3]. Many insect species are consumed not only as food but also as medicine, and this provides a relevant contribution to the phenomenon of zootherapy, as well as opening new prospects for the economic and cultural valorization of animals traditionally regarded as useless [3]. The ingestion of a varied of edible species contributes to the nutrition of indigenous, traditional peoples, as well as those individuals who live in urban areas that use this kind of food resource, in accordance with their abundance during several seasons of the year when they are available. Some field studies corroborate that although the tradition of eating insects has faced several changes, it has been maintained for a long time thanks to intergenerational knowledge [4]. However, the aversion to the edible insects is the reason why a considerable amount of animal protein becomes unavailable since the phenomenon is regarded as "primitive peoples practice". If the rich biosociodiversity found in Latin American countries is taken into account, then it can be said that the phenomenon of anthropo-entomophagy has been underestimated. Considering the nutritional qualities that insects have, they should be considered as renewable resources available for sustainable exploitation aiming at reducing the problem of malnutrition and hunger in many parts of the world [5].

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Ethno-entomophagy in Asia and the Pacific: historical perspectives and future directions

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Western cultures currently struggle to have insects accepted as a human food. This barrier is either absent or not as high in many parts of the Asia Pacific region because entomophagy is (or was until recent times) a part of their diets. The Asia Pacific region is comprised of many different cultural groups. The degree to which they embraced entomophagy (as food and/or medicine) has been determined by dietary needs, availability of insects, and their environments.

Edible insects are sourced by three main strategies: wild harvesting, semi-domestication of insects in the wild, and farming. The degree to which each of these contributes varies regionally. While entomophagy has decreased in westernised societies, the demand for edible insects has apparently increased in parts of Asia in association with increased standards of living.

Wild harvesting is still the main source of edible insects in much of the region. While some insects collected in the wild are plant pests, others occupy different trophic levels and provide important ecosystem services. The increased in demand for edible insects puts pressure on the source populations of insects because new technologies are now used to collect insects and to store them safely for longer periods, facilitating the collection of greater amounts of insects. This, in combination with either loss of natural habitats or changes to the environment, puts even more pressure on natural insect populations.

Semi-domestication of some edible insects has resulted in higher populations of edible insects with less detrimental environmental effects. This includes managing insect food plants to increase insect production or broader habitat manipulation such as the use of fire. Insect farming may have started with silk worms in Asia, and small insect farms contribute to the local economies in parts of Thailand and Laos. One of the dangers of farming edible insects is to follow the global trend in food usage – to become dependent upon a relatively small number of food plant or animal species. This is a worrying trend, and the establishment of small farms breeding a diversity of insect species should be encouraged. This will be a major challenge if small insect farms move to level of large insect factories.

These issues will be discussed in relation to the Asia Pacific region in the light of currently available information. Future directions for adoption of insects as both human food and as animal feed will be considered.

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Everyday entomophagy in rural Laos: Understanding the heterogeneity of insect consumption in dairy life

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Entomophagy is part of daily life in Laos. Previous research has shown that at least 7 orders and 30 species of insects are consumed on the Vientiane plain alone (Nonaka 2008). However, particularly in the case of dragonflies, stinkbugs, dragonflies and cicadas, this may be an underestimate. The majority of edible insects consumed in Laos are harvested from a diverse range of natural habitats. These habitats, and the insects that are consumed, differ throughout the country.

We conducted a year-long dietary survey during November 2008 – October 2009. Inhabitants (N=60) of three villages (A, B and C) situated in different ecological zones (A: Northern mountainous region; B: Central plains; C: Southern plains) and dependent on different modes of subsistence (A: slash-and-burn agriculture; B and C: paddy-field rice farming) recorded their daily dietary intake. We also conducted observational surveys and interviews in each village.

Results show that entomophagy is most common in village A, with monthly consumption of edible insects reaching an average of 7.9 occurrences per month, in comparison to 6.6 and 4.8 occurrences respectively for villages B and C. Lower rates of insect consumption in villages B and C may be due to a relatively higher abundance of aquatic resources; Fish were consumed an average of 7.4, 22.7 and 15.9 times per month in villages A, B and C respectively. The contribution of edible insects to overall dietary intake is not high. This is even the case for crickets, which are eaten in large quantities when available (e.g. a single family will consume an average of 91 crickets in one meal). However, insects are a valued food item and are sold at high prices compared to other edible goods. The practice of collecting edible insects for commercial purposes is currently increasing in suburban areas.

Overall, wild-harvested edible insects are an important food item in Laos, with both cultural and commercial significance. Their use is intimately connected to local land use practices and seasonal fluctuations. Understanding these patterns will be crucial to ensuring a sustainable harvest in future years.

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Semi-cultivating edible insects: A historical perspective and future prospects

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One key issue in realizing the potential of edible insects in improving food security, sustainable food production, and biodiversity conservation, is assuring an adequate supply of the edible insect resource in a sustainable way. This can be achieved by semi-cultivating and farming edible insects. These activities increase the availability, productivity, and predictability of edible insects. Throughout history humans have semi-cultivated edible insects. This includes eggs of aquatic true bugs (Hemiptera: Neopomorpha) in Mexico; palm weevil larvae (e.g., *Rhynchophorus* spp.) in the Amazon Basin, tropical Africa, and New Guinea; and arboreal, foliage consuming caterpillars (Lepidoptera) in sub-Saharan Africa. Research is and has been carried out to semi-cultivate and farm other edible insects and to optimize existing techniques, e.g.: bamboo worm (*Omphisa fuscidentalis*), Mopane worm (*Imbrasia belina*), termite (Isoptera), palm weevil larvae (e.g. *Rhynchophorus palmarum* and *R. ferrugineus*), cricket (*Acheta domesticus*), and the Asian weaver ant (*Oecophylla smaragdina*). The prospect of semi-cultivating weaver ants is highlighted. Weaver ants are one of the most popular edible insects in Southeast Asia, and they are promoted as a biological pest control agent. It has been suggested that weaver ants can be used to control pest insects while serving as a direct source of human food. To accomplish this, work needs to be done on the use and management of weaver ant colonies. Relevant issues include the location of the queen and the resilience of the colony to using it as human food. Analogous to wasp and bee keeping, the development of artificial nests for weaver ants can boost the use of *O. smaragdina* both as a biological pest control agent and as a direct source of human food. This can speed up our understanding of the colony, and provide insights on how to manage it. The potential benefits of semi-cultivating weaver ants are: a reduction in the environmental costs and financial inputs associated with non-biological pest control methods; an increase in the agricultural productivity of plantations both in terms of tree crops and ants and their brood; and a sustainable diversification of agricultural produce, e.g., by designing agroforestry practices with *O. smaragdina* host trees.

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Harvesting and nutrition value of edible wasps in southwest China

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Chinese people have had the custom of eating wasp larvae and pupae for a long time [1], especially in the southwest China, where local ethnic minority like these food very much. There are more than 120 species insects of superfamily Vespoidea in this region [2], among them, the recorded edible species were up to 16 [3-5], although the actual edible species maybe over 20. The common edible species of consumption in Yunnan Province and Guizhou Province are *Vespa velutinia auraria, V. tropica ducalis, V. analis nigrans, V. variabilis, V. sorror, V. basalis, V. magnifica, V. mandarinia mandarinia, V. bicolor, Provespa barthelemyi, V. orientalis*, *V. binghami*, *V. minuta arisana*, *V. vulgarit*, *Polistes sagittarius*, and *P. sulcatus*. Wasps are common edible insects, and have the largest number of deals among edible insects in local open markets. Generally, the wasp goods appear in markets from late August to December. In recent years, the price of the insects was 10 ~ 75 dollar/kilogram. Local people accumulated knowledge on wasp kinds, collecting and cooking methods in a long time living practical activities. Local wasps "hunters" use some food, such as bees, beef as bait to attract flying wasps for eating, then caught wasp and tied a small red rope or feather on wasp’s body, flied the wasp with symbol again and traced it till found its comb. Usually, when they found the nest, collectors always carry the whole nest back carefully and hang it to a tree near their housing. On market-day, they could open nest shells and collect larvae and pupae to sell. The main nutritional components of 13 species of common wasps have been analysed. The larvae and pupae of wasps are nutrient-rich and abundant in protein and amino acids. Crude protein content is 38.95 ~ 61.78%, average content is 52.07%. Heavy metals As, Hg, Pb, Cd and Cr are detected, but the contents not beyond Chinese food limited standard of heavy metals. The data suggested that wasp larvae and pupae could be used as good food or protein resources for human. However, attention is necessary when collecting wasps for adults may sting and contain apitoxin. Moreover, the utilization of wasps almost completely dependent on natural resources, protection and sustainable exploitation of this kind of insects should be considered.

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The Amazonic strategy to utilize edible insects can be extended?

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For Amazon, the largest forested area of the planet, the theory that most invertebrates consumed are ecologically linked to tree leaves and litter was demonstrated [1,2] as an example of sustainable use of biodiversity linked to the most renewable portion of the system. The increasing interest for insects as source of proteins, fats and nutrients in Western society pose the serious imperative to base the foodweb of the key species we will target as new minilivestock, in a frame of sustainability.

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Prospects and constraints for the use of insects as human food and animal feed in West Africa

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Insects have long been used as human food and animal feed in West Africa. However, compared to Central and Southern Africa, only few species are reported as being traditionally consumed by humans, the most common ones being grasshoppers and termites. This is probably partly due to a lack of specific studies in West Africa in the past, and recent investigations focusing on specific regions showed that more species are consumed than previously reported. However, it cannot be denied that, in general, entomophagy is less widely practiced in West Africa than in other regions of Sub-Saharan Africa. In many cases, the same insects are consumed locally by some ethnic groups but their consumption can be considered totally disgusting by others. A good example is the shea caterpillar, *Cirina forda*, which, in Burkina Faso, is considered a delicacy in the South-West but neglected in other regions. Caterpillars can now be conserved in sterile packages and methods are presently being developed to transform the caterpillars into enriched protein powder or sauce that can be used as food supplement, in particular for pregnant women, babies and young children, and thereby combat malnutrition. The main issue is to obtain sufficient caterpillars to sustain a commercially viable production system. Options include mass collection of naturally occurring caterpillars, environmental manipulation for caterpillar enhancements, including host tree cultivation, or caterpillar rearing on artificial medium.

The insects most commonly used to feed animals in West Africa are termites. Throughout the region, termites are collected in the bush to feed poultry. Chippings of termite mounds are collected and given to poultry on-farm, particularly to chicks. Termites are not equally available in all regions and seasons, and in many cases collectors have to walk long distances to find sufficient amounts of termites for the farm’s consumption. Simple methods have been developed to increase the number of termites available on farm, using for example fibrous and humidified waste or crop residues placed in pots or baskets, which are then inverted and placed on small termite nests. However, termites cannot be easily mass reared and, thus, their use will be restricted to individual farmers. In contrast, house flies and other fly species are easy to rear and maggots can be produced in large quantities, as shown by recently developed industrial production systems in other parts of the world. While similar industrial maggot-meal production systems could also be developed in West Africa for large-scale meat and fish producers, smallholder farmers and rural communities could adopt small-scale production systems on farm or at the community level, e.g. by naturally exposing of organic waste substrate. For the moment this technique is used mainly at pilot farms or research stations although, in some regions, farmers are increasingly adopting the technique.

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Entomophagy in contemporary Japan: Imported insects compensate for a decline in wild harvesting

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Japan is unique in its status as a developed country with a history of traditional entomophagy [1]. Research undertaken during the twentieth century found that 118 species were recognised as edible [2], and insects were used as food in communities in all prefectures [1]. However, Japan has undergone major cultural, environmental and economic changes in recent decades. In order to evaluate entomophagy prevalence and wild harvesting activity in contemporary Japan, I conducted a questionnaire survey (N=220) in the Chubu (central) region during 2013. To gain insight into commercial trends and consumer attitudes, I interviewed buyers and sellers of insects in both rural and urban areas.

Grasshoppers and wasp larvae are the most commonly consumed insects. Individuals aged 0-39 are significantly less likely to have collected edible insects than individuals aged 40+ (Grasshoppers: Chi-squared, c=16.16 p=5.8E-05; Wasp larvae: Chi-squared, c=3.93, p=0.047). Generational differences appear to be due to both a decline in insect availability due to pesticide use, and changing cultural attitudes towards insects. However, interviews with sellers suggest that the commercial edible insect industry has seen an increase in demand in recent years. People who do eat insects in Japan buy them at high prices and consider them a delicacy. Edible insects are imported annually from China, South Korea and New Zealand.

In conclusion, wild harvesting of insects is still present in some rural areas in Japan, but this practice is seeing a marked decline among younger generations. Meanwhile, edible insects remain a commercially viable product. Further research should focus on the factors affecting the changing attitudes of consumers towards edible insects in Japan, and the effects of agricultural practices on edible insect prevalence in rural areas.

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The other food: the status of entomophagy in Botswana

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In Botswana, mopane worm is culturally accepted as food by people of different age groups from different regions and districts. However there are several other insect species that are anecdotally known to be edible in Botswana. To verify this, a study was conducted by means a questionnaire and discussions among Batswana of different age groups from different districts to obtain the names of insect that are known to be edible among Batswana. The study also investigated methods of collection, processing, precooking preparation, cooking methods, storage and recipes. A total of 26 insect species that were reportedly used as food by people from six district of Botswana were identified. The Chi-square analysis showed that people's knowledge of edible insects differed with districts and age groups. Older people were more familiar with uncommon edible insect compared to the younger generation. Except the mopane worm, the majority of the people interviewed, especially the young, had not eaten any one insect species mentioned despite knowing that they were edible. This shows that apart from the use of mopane worm, entomophagy as practice among Batswana is declining. However, in the light of current decline in food production in Africa especially on the arid regions of Botswana, insects used as food may contribute protein and calories to many peoples' diets. A shift from traditional harvesting to mass production of insects has a potential to provide animal protein to humans through direct consumption or when used as livestock feed, and can reduce malnutrition.

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Innovations to convert locusts invasions into a protein pulsed resource accessible to local population?

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Madagascar has a long history with the migratory locusts. The first written mention on the migratory locust dates back to 1617, and the studies of its invasion began in the nineteenth century [3]. The social representation of *L. migratoria* is dominated by the devastation that it caused to the agriculture and the threat it represents regarding food availability and food security. Indeed, several regions are affected each year by this catastrophic plagues of locusts, mainly the southern part, the big west and the north but also the central regions of the Island with numerous damages on the culture of subsistence, in particular the rice production, being the basic food diet of the population (10 to 40 percent of the rice production in 2012 damaged in 17 of 22 regions of the country [2]), but also at the level of the livestock grazing and the other cultures as the corn and the truck farming. Besides, locust is also strongly present in the Malagasy culture. It is seen as a food resource [1], and which must be shared in difficult times. In a context where the challenges in terms of food security have changed the scientific representation of insects, we propose the approach of the locust invasion as a pulsed resource protein, actually available in Madagascar. Once this approach is adopted, the question is how to convert the locust invasions to an accessible resource to the local population as an alternative to meat. To answer this question, this article begins by outlining the findings that indicate the feasibility of this conversion. It highlights that locusts are subjected to an allocation and a mobilization of resources. A policy of curative measure and prevention of the locusts' plagues was undertaken at the national level since the end of 1990s via a National Program of fight against *L. migratoria* invasion (PNLA), with important budgetary allowances. This initiative is supported by international bodies as the Food and Agriculture Organization (FAO) and the African Development Bank (BAD), which collaborate with the Malagasy state in particular on technical and financial aspects. Other organization, as the French Research Centre for agriculture development (CIRAD) was involved on scientific expertise (identification of risk areas) used for monitoring and control strategies.

Next, the paper highlights the impact that can have the establishment of an observatory dedicated to this conversion. The observatory by gathering and transmitting data, as well as knowledge, collected from existing permanent monitoring provides the basic elements for designing and managing technological and organizational innovations for the development of a value chain for either human consumption or animal feed. The main objective is he quantification for technological innovation perspectives firstly, (for examples development of giants traps, storage, and processing), and secondly on the social acceptability of insect based foodstuff innovation (insect flour).

Finally, the paper contributes to the understanding of the organization of innovative supply chain, and the interaction of stakeholders (between public and private) to implement the innovation, and further, the economic and social impact for territory development.

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Entomophagous insects of Kanyakumari District, India

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Insects are known for their proteins, minerals, and high amounts of essential amino acids. Countries around the world including South Africa, Angola, China, Zaire, Thailand, Mexico, New Zealand, Korea, Japan, Australia, USA and India, are known to practice entomophagy. In India, Kanyakumari District which is a biodiversity hotspot, with its long range of mountains in the Western Ghats, has a rich and diverse insect fauna, used in varied forms for edible, medicinal, industrial and cultural purposes. Entomophagy has been known to be practiced among the “Kanikars”, a tribal community spanning across the mountainous regions of this district.

Although edible insects are readily available as important protein sources, socio-cultural reluctance impede entomophagy. In Kanyakumari District, there are a large number of edible insect species which need to be propagated for their use as food. As people in rural areas suffer from undernutrition, alternative nutritional food sources need to be suggested for which information need to be provided on the edible insects present in the district. Hence, this study was conducted to investigate, identify and document the diverse edible insect fauna of the district. A total of 45 insect species belonging to 11 orders were recorded as food items. Maximum number of edible species were recorded under the order Coleoptera and the least number was found in Odonata and Diptera. Of the various insects, termite species were the most preferred, followed by honeybee and silkworm larvae. As entomophagy is found to be scarce in this region, this paper aims at propagating entomophagy practices on a large scale in Kanyakumari District, to overcome the nutritional insufficiencies prevailing among the resident rural population.

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Exploiting pest insects species *Sphenarium purpurascens* for human consumption: ecological, social, and economic repercussions

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A large number of insect species considered to be pests are exploited in non-standardized ways for human consumption, mainly in Africa and Latin America. Although the grasshopper, *Sphenarium purpurascens*, generates one of the most devastating plagues in the central area of Mexico, it produces hundreds of tons per year for human consumption. These species are excellent candidates for exploitation, not only because of their abundance but also because of their ecological, economical and human health benefits. Here, we developed a sustainable exploitation strategy that produces a considerable biomass while minimizing damage to cultural fields, changing the chemical control method to mechanical method. First, we calculated the biomass that may be extracted in each life history stage by demographic analyses of the species. Then, we modeled the current and potential distribution of the grasshoppers through Maxent. Finally, we analyzed the repercussions that this type of sustainable exploitation could have. Our results demonstrate that plague insects have a great potential to be exploited as food sources for human populations. We calculated a population density of 10-55 individuals of *S. purpurascens* per square meter in about 1’050,000 hectares of Mexican agrosystems. The estimated biomass of this insect averaged 350 000 tons per year, generating a gross income of $3.75x10^8$ million U.S. dollars. The number of people who could be fed with this biomass, as well as the reduction in insecticide used to fight this plague-species, is significant. Mechanical control methods have no toxic effects on human populations and/or other species inside and outside of the agrosystems unlike chemical control methods. Besides the ecological and human health benefits that this alternative method may provide economical profit can also be obtained. Based on the biomass of S*. purpurascens* that could be generated in one year in Mexico, it can be shown that insects are excellent candidates to form part of the diet of any human population. Promoting this type of practice could greatly impact on the health of millions of people globally and on the environment, reducing CO_2 and methane emissions, land clearing and use of pesticides.

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Small-scale production of edible insects for enhanced food security and rural livelihoods: experience from Thailand and Laos

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Southeast Asia, particularly the Greater Mekong Subregion, is a major centre for the human consumption of edible insects. More than 200 species of insects have been documented as being consumed in Thailand. In the Lao People's Democratic Republic, more than 80 percent of the population regularly eats insects.

Traditionally, insects for human consumption have been collected from the wild. In the past, most insects were collected for non-commercial home consumption, but insects are now increasingly sold in local markets and to dealers as a source of cash income. The timing of insect harvesting from wild habitats depends on specific species behaviour and life cycles, with some available only seasonally (e.g., weaver ant, *Oecophylla smaragdina*) while others are collected throughout the year (e.g., various species of grasshoppers). A wide variety of collection practices and local knowledge are employed, including the use of nets, baskets, bamboo sticks, glue, cutting and digging tools and light traps, or simply picked by hand.

With the exception of silkworm pupae (raised in conjunction with silk production), rearing of edible insects in Thailand and Lao PDR was rare until about 15 years ago. Since then, farming of edible insects, especially crickets (initially local species including *Gryllus bimaculatus*, *Teleogryllus testaceus* and *T. occipitalis*, but now mostly introduced species of *Acheta domesticus* and some *Gryllus bimaculatus*), has expanded rapidly in Thailand, with approximately 20,000 registered insect farmers. Cricket farming is concentrated in northeast Thailand, while farming of palm weevils (*Rhynchophorus ferrugineus*) is common in southern Thailand. The Food and Agriculture Organization of the United Nations (FAO) has facilitated the transfer of insect farming technology from Thailand to Laos in support of a fledgling insect farming sector in that country. Small-scale insect farming requires relatively little investment and barriers to entry are few, with lack of knowledge of farming techniques and marketing opportunities among the main constraints.

Demand for edible insects is very strong in many parts of Southeast Asia, particularly in Thailand. Insects are clearly a "food of choice" rather than necessity, underscored by the fact that retail prices for insects are typically two to four times the price of chicken, pork or fish. Profits from insect farming are typically more lucrative than for other types of traditional farming and many farmers have shifted their farming operations to concentrate on edible insects. Marketing channels vary, including traditional local markets, cooperative sales, wholesalers, food vendors and other retailers, specialty markets, internet marketing, and sales in supermarkets. Creative new product development and marketing initiatives are flourishing, particularly in Thailand.

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Insect diseases: what are they and how to avoid them?

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Insects suffer from infectious diseases, which may be lethal or in other ways significantly reduce host fitness. Most studied groups of microbial insect pathogens are viruses, bacteria, fungi and microsporidia [1]. Other organismal groups like nematodes and trematodes can also cause serious infections in insects. When working with insects for food and feed, an effort must be made to avoid insect diseases. With the expected rise in production of insects for food and feed, risks from insect diseases should not be neglected. Risks from insect pathogens in cultures of insects can basically be classified into three categories:

1) The insect production can be significantly reduced by increased mortality due to infections
2) The environment can be effected if microorganisms causing epidemics in insects in culture disperse out from production facilities and spread into environment
3) Insects can vector diseases, which can directly affect humans or vertebrate livestock.

The presentation will first introduce different important taxa of insect diseases and their biological traits. Then, all three risks will be addressed. Finally, we suggest how insect pathologists [2] can contribute to the further development of insects for food and feed by advising on these diseases and how to avoid them.

1 Vega, FE, Kaya HK 2012 (eds): Insect Pathology. Second edition, Academic Press, Amsterdam,490 pp.
2 Society for Invertebrate Pathology: www.sipweb.org

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GREEiNSECT: a multidisciplinary research project on potentials and barriers for insect-farming for food and feed in Kenya

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Insect farming holds an untapped potential to be developed as an environmental sustainable feed and food production sector supporting 'green' economy at local and potentially global level. In Kenya, entomophagy is traditionally practiced based on collection from wild sources and trade in local markets. This informal food system is limited in contribution to food security and the economy. Technical as well as institutional barriers need to be overcome to support development of a formalized insect rearing sector. Through the GREEiNSECT project [1], Kenya is a case for investigating how to overcome barriers for the development of a new, sustainable 'green' insect rearing sector.

GREEiNSECT is a research consortium of public and private partners aiming to investigate how insect farming through mass-rearing in small- to large-scale production systems in Kenya can be utilized as novel and supplementary feed and food sources. The project is addressing key aspects related to: 1) technological development of emerging production systems of insects (initially crickets and black soldier flies) for feed and food, and investigation of implementable business models; 2) investigating framework for managing the risk of disease related to mass-rearing systems, and international trade/food security standards; 3) estimating consumer acceptance and demand for insect-based products, and modeling and assessing the contribution of insect production systems to green economic growth and nutritional security, as well as the economic/political incentives for the development of an insect-rearing sector; 4) capacity building of Kenyan research institutions; and 5) development of a Kenya-based knowledge platform involving public and private sectors. International partners from SE Asia will contribute to knowledge transfer through their experience from a more developed edible insect sector in Thailand and neighboring countries. International knowledge dissemination will be support through FAO, Rome.

The project is coordinated from University of Copenhagen, Denmark, in partnership with three universities in Kenya, two private entrepreneurs and four international partners. The project will support seven Kenyan and Danish PhD students. GREEiNSECT is supported by Danida, The Ministry of Foreign Affairs, Denmark, for the period 2014-2017.

1 www.greeinsect.ku.dk

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PROteINSECT- do European citizens accept the use of insects for animal feed and human food?

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Global media channels have increasingly brought to European citizens the concept of eating insects themselves [1]. Recent coverage across trade and specialist news channels has also revealed the increasing interest in breeding and processing insects for use in animal feed [2], [3].

However, the media bringing the prospect of eating insects to European citizens, and the use of processed insect protein in the feed of animals they will subsequently eat does not necessarily mean that Europe is ready to make this change to the daily diet, or buy the products that are subsequently made available fed on insect protein.

Whilst industry is endeavouring to develop processes to make insect protein production viable, and policy makers consider the need for legislation change, it may take more than a few celebrity chefs developing ingenious recipes with insects to influence the average European citizen's daily food choices.

Currently, we do not know the answer. Innovation is worthless without acceptance and adoption.

To help understand what European citizens do think about the use of insects for feed and food, the EC funded project PROteINSECT is conducting a benchmark survey (ends 31 March) [4] which is being promoted via its website [5], through social media channels including bloggers, and via appropriate e-zines and websites.

PROteINSECT has also been tracking and analysing online media coverage of the topics of insects as feed and food, analysing content and tone.

The results of both PROteINSECT's benchmark survey and up-to-date Media Tracking Report will be available to share with delegates at the *Insects to Feed the World* Conference.

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3 http://www.undercurrentnews.com/2013/10/10/insect-meal-a-new-player-in-aquaculture-feed/ Insect meal, a new player in aquaculture feed

4 http://svy.mk/1d5Sabh

5 www.proteinsect.eu

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WINFOOD PROJECT: development and evaluation of Amaranth grain based complementary foods enriched with termites and fish

Kinyuru, J.N.[1], Konyole, S.O.[2], Onyango-Omolo, S.A.[2], Owino, V.O.[4], Owuor, B.O.[5], Estambale, B.B.[2] and Roos, N.[3]

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Availability of affordable, nutrient dense complementary foods is a major challenge to infant and young child feeding in developing countries. The aim of the Winfood study was to develop nutrient dense, acceptable, safe and affordable complementary foods to combat infant and young children malnutrition in Kenya. The ingredients were selected following a survey on traditional foods with public potential for complementary feeding [1] in western Kenya. The nutrient composition of the ingredients was carried out using standard methods [2] before development of complementary foods. Two complementary foods, Winfood classic {germinated amaranth grain (*Amaranthus cruentus)* [71%], maize (*Zea mays*) [10.4%], edible termites (*Macrotermes subhylanus)*[10%], *dagaa* fish (*Rastrineobola argentea*) [3%], soybean oil [0.6%], sugar [5%]} and Winfood lite {amaranth grain [82.5%], maize [10.2%], vitamin and mineral pre-mix (IS 723 and IS 730) [1.8%]} were formulated and processed by extrusion cooking. Nutrient composition, stability and cost of production of the foods were determined using standard methods. Winfood classic contained 423.6 kcal/100g energy, 19.1 g/100g protein, 12.3 g/100g fat, 12.2 mg/100g iron, 6.3 mg/100g zinc while Winfood Lite contained 407.2 kcal/100g energy,14.6 g/100g protein 9.0 g/100g fat, 12.5 mg/100g iron and 5.5 mg/100g zinc. Peroxide value was 0.3 meq/kg and 0.0 meq/kg in Winfood classic and lite respectively and not afflatoxin detected after 6 months of shelf storage at room temperature. Production cost of the foods was 4 USD/Kg and 2 USD/Kg for Winfood classic and lite respectively. The two foods were acceptable with no adverse effects among infants, young children and caregivers [3]. Winfood classic represented a food that could be easily produced in a small scale household setting while Winfood lite represented a food that could be commercialised. Therefore, the ingredients have the potential to be utilized in processing affordable, safe complementary foods with adequate nutrient density either at household or commercial level.

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Perspectives of insect industry in South Korea: Government policies and R&D strategies

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From ancient times, insects were largely used for sericulture, apiculture and partly as medicines in Korea. Although several insect species are currently employed for sustainable agriculture as natural enemies, pollinators, also for education and as pets, still the insect industries contributing future food, livelihoods for farm family incomes and environmental benefits is not focused for industrializing yet in Korea. The total market size of insect industry in Korea was estimated around $170 million in 2011 and expected to grow up to $300 million in 2015. The number of workers in Korean insect industry is currently reported 622 and is on the increase also. Since the future insect industry could be applied to foods, dietary supplements and medicines, and hygiene enabling disposal of food and animal wastes in Korea, the government has legislated “Act on the support of insect industry” in 2010. In addition, the government has also established “Five-Year-Plan for the Nurturing Insect Industry” in 2011 and is supported by detailed action planning every year.

Up to now, the legally authorized edible insects in Korea are just grasshopper and pupae of the silkworm. The Korean government has recognized future prospects and importance of edible insect industry and is also actively making R&D investment for “Sustainable Green Growth of Edible Insect Industry” by Korean Food Standards Codex (KFSC) registration of edible insects by scientific toxicity verification studies for mealworm (*Tenebrio molitor*), white-spotted flower chafer (*Protaetia brevitarsis*), cricket (Gryllidae sp.) and larvae of Korean horn beetle (*Allomyrina dichotoma*). In this way, Korean government plans to construct “Insect Industrialization Supporting Center” for contributing local economy. These centers would support the research and development of insects for food, feed, medicines, pollinator, natural enemy.

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Silkworms to resolve the world's food crisis - the most acceptable insect as food and feed

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Silkworms are well-known insects as human food around the world for centuries. All the four major types of silkworms exploited for textile fibre are also associated with entomophagy for meeting the local demands as an enriched nutritious diet for majority of rural tribes in Asian and African countries. Sericulture practiced in over 60 countries for its more valuable silk –of production of over 152868 mt/yr -with little focus for its by product-pupa. Effectively used for various purposes including human food, *Bombyx mori,* the mulberry silkworm is extensively reared indoors. Over 900000 mt of mulberry silkworm pupa /year as by-product, has become an indispensable part of animal and fish feed as a rich source for protein, lipids and minerals. Presently limited to animal feed and other needs, silkworm pupa with its rich-highly superior grade protein, lipid and vitamin sources in a 'balanced mini pack' is under-utilized for various non-food and feed purposes, with very little benefits being transferred to the cocoon reelers and cocoon growers.

Economic analysis of large scale production and its utility of silkworm pupa of all types of silkworms presently exploited (both mulberry and non- mulberry) in the world gives a clear edge over other insects because controlled rearing conditions, feeding on well nourished food plants with its high nutritive value for badly needed nourishment of large population. Silkworms are the best and most economic insect for resolving human food needs and an answer to resolving malnutrition for a select group of populations and can be exploited in the immediate future. Reviewing the silkworm insect protein and fat extraction and its industrialization efforts around the world, especially in China and Thailand the need for further exploitation to human needs is propagated. With a detailed peep into Indian sericulture and entomophagy practice prevailing, the change of focus to human food and feed needs are discussed. With specific attention on the eri silkworm pupa production and utilization practices around the world, the paper advocates the active spreading of eri silkworm rearing around the world.. Showcasing the pilot initiatives done on effective use of silkworms, suggestions are put forth for consideration of the world entomophagy researchers and planners with need for investing more resources and directing on policies and specific guidelines on silkworm production.

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Ideal edible insect: High value, safety food and innovative products with complete value chain of eri silkworm (*Samia ricini* D.) in Thailand

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Concerning on food tightness and malnutrition of the world in the near future, especially protein source, edible insect has much advantage more than several protein sources. Wild silkmoths especially eri silkworm (*Samia ricini* D.), the only domesticated wild silkworm, represents as safety rich sources of protein and very practical in rearing process e.g., easily to culture using native wisdom, wide range of food plants; particularly the cassava (*Manihot esculanta*) which planted in the largest area in the northeast, high protein content (~ 66 %) and good taste with highly accepted preference. In the present, this wild silkmoth studies are focused on research especially in the northeastern region, where insect are consumed as indigenous foods as a way of life for a time being. Research on eri silkworm in particular has been carried on for a long time in complete value chain with zero-waste by Research Group of Wild Silkmoths, Khon Kaen University, Thailand. The output comprises various eri disciplines i.e., at least 12 eri food menus were registered as petty patents; No. 2394, 2395, 2396, 2397, 2398, 2399, 2664, 2677, 5741, 5742, 5743 and 5744. These menus were diversified eri food products with highly acceptable preference of entomophagy in Thailand. Moreover, 10 textile products were subjected to Thai Community Standard Industry and eri yarn production by machines with 9 intellectual properties (Thai petty patent; No. 2075, 2821, 3820, 3982, 4149, 6288, 6408, 6698, 7759). In addition, waste of eri silkworm rearing, dropping and cocoon reeling waste water as a medium for biological control agent production have been also conducted. Pupa's chitosan could induce plant disease resistance. The protein from the eri waste water was applied in the cosmetics leading to petty patent registration (No. 7590, 7591, 7592, 7593). Furthermore, this protein shows anti-bacterial and antioxidant properties. The development for fibroin exploitation is also included. Besides, new food plants (e.g. kesseru, *Heteropanax fragrans*), improvement for high temperature tolerant/big (Jumbo) fresh cocoon variety are achieved and using biotechnological methods for variety characterization are also ongoing studied. Currently, eri silkworm in the country is industrialized progressively in different levels. Eri pupa has been sold popularly as fresh and innovative processed foods. The eri textile products are marketed not only as handicraft and eco-friendly products but also as factory products. However, eri yarn has been developed as industrial spun silk and spun silk fabric including costume in Thailand. Hence, eri silkworm has potential to be carried out as high value products, not only from fabric but also from cultivation of *Cordyceps militaris* (2,000-3,000 US$/kg). Consequently, the value added-high value of eri products could generate farmer's income and alternative business towards sustainable economy as a whole.

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Pury, a fine powder made from silkworm pupae. As an alternate of nutritious food for human nutrition

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Silkworm pupae is an inside part of cocoon as a waste from yarn silk production which is commonly through away causing pollution. The purpose of study is to develop alternate of nutritious basic food source for human nutrition made from silkworm pupae waste in the reeling industry called *Pury*. It has a well-balanced amount of protein and essential amino acids, fat included PUFA, carbohydrate, vitamins and minerals [1]. Through a simple processing, the dry product of *Pury* fine powder can be used as a basic formula of complementary food and variety of snacks such as crackers, sticks, sponge cake, nugget and flakes and has made great contribution to reduce pupae waste. Intervention program used *Pury* as complementary food in Teluknaga, Tangerang-Indonesia showed that a positive improvement on nutritional status determined by Z-score (W/H) among infants [2].

1 Astuti T, and Kusharto CM, (2009) Using *Pury* fine powder as an alternative food. Pergizi Pangan, 4(1).
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Insects: Potential of stable isotope tools for optimizing insect production management

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Food oracles have highlighted the future move towards high protein diets and the emergence of insects as potential protein sources; this in combination with a projected doubling in global demand for protein and lack of suitable land for agricultural expansion, has led to a renewed focus on the use of insects in the human food chain.

Although insects provide an important dietary supplement in many cultures and societies specifically in times of famine and food insecurity, the “Yuk” factor generally precludes their consumption in Western cultures. This may be why there is little scientific research on the nutritional benefits of insects. In addition knowledge about insect mass rearing or insect farming is generally confined to specialist markets, researchers and pest management practitioners.

In the context of a research program on the mass rearing of sterile insects for pest-population suppression, we developed a number of novel stable isotope methods to assess the impact of rearing diet on insect quality and insect growth rates. In addition an innovative technique for screening insect fatty acid profiles and following their transfer was established.

Deficient intake of omega-3 and omega-6 fatty acids may play a role in sub-optimal nutrition of people in landlocked developing countries, insect consumption whether direct or secondary could overcome these nutritional deficits. Evidence from a number of studies on the fatty acid composition of the insects suggests some insect species are indeed high in the longer chain fatty acids. Simplifications of technologies to measure fatty acid composition means that it is now possible to measure fatty acid profiles rapidly and on small sample sizes directly without complex preparation procedures. Logistically it allows us to study the flows and production of fatty acids in a wide range of insects easily. Understanding the role, synthesis and routing of fatty acids in both insect and secondary consumers could contribute to promoting appropriate development interventions and will certainly play a role in insect production management.

These methods in addition to stable isotope tracing techniques to follow the fate of insect protein could be extremely useful in the emerging field of insect farming.

Results from these and other studies will be presented providing a simple roadmap of how stable-isotopes and pyrolysis GC-MS could be used in optimizing future protein production.

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High potential for mass rearing katydid (*Ruspolia differens*) and palm weevil (*Rhynchophorus phoenicis*) for food in the Lake Victoria basin

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Edible insects provide an important food source in Africa, but their potential to improve livelihoods and environmental conservation is yet to be fully exploited. In 2011, the inter University Council for East Africa approved financial support for a 3-year project on edible insects in the Lake Victoria basin (LVB). This project aims at enhancing the use of edible insects in the LVB, with particular attention to increasing household food security, health, nutrition and incomes of local communities on one hand, and contributing to climate change adaptation on the other. Specifically, the project is focusing on the following: (I) documenting indigenous knowledge, perceptions, preference and practices about edible insects and adaptation to climate change; (II) assessment of the effects of land use and seasonality on the distribution and abundance of selected edible insects, (III) determining nutritive values of edible insect species, (IV) exploring possibilities of rearing edible insect species with high economic potential, (V) Analysis of market opportunities, market players and value chain of edible insect, and (VI) developing novel edible insect products. The project has been implemented in Burundi, Rwanda and Uganda. Indigenous knowledge and market studies from this project have indicated *Ruspolia differens* (katydid), termite alates and palm weevil (*Rhynchophorus phoenicis*) as the most consumed insects in LVB with high economic potential. This paper presents studies conducted to explore the possibility of rearing *Ruspolia differens* and Palm weevil (*Rhynchophorus phoenicis*). *Ruspolia differens* and *R. phoenicis* are being reared in a laboratory at Makerere University with various feed types at room temperature (22 – 27 °C). *Ruspolia differens* collected from the wild during swarming laid fertile eggs that has produced three generations in the lab so far. On average, the eggs take about 4 weeks to hatch and nymphs developed full wings at 50 days after hatching. All nymphs are green at hatching, but some change colour after the first instar. Palm weevil larvae were reared to adults on palm logs and sugarcane stems. Our studies have demonstrated a high potential for mass rearing *R. differens* and *R. phoenicis* under natural temperature conditions in Uganda. However, further studies on the biology of these species are necessary to develop protocols for mass rearing of these species with the aim of eventually rolling out the knowledge and skills to the private sector to supply farmers with eggs, immature or mature stages of the insects for mass production.

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Edible mealworm species: the effect of diets composed of organic side stream material

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Proteins derived from edible insects provide an interesting alternative for protein sources derived from conventional livestock. Insects, being poikilotherms, do not use metabolic energy to maintain a constant body temperature as homeotherms do and can therefore invest more energy in growth. Furthermore, farming of insects (mini-livestock) requires less water and space than production of conventional livestock.

Sustainability of insect production could be increased by growing the insects on diets composed of side streams from the agro-industry. Little is known on how diet composition influences insect nutritional composition.

Three species of edible tenebrionid beetle larvae, better known as mealworms, are currently being produced by several commercial breeders in The Netherlands: the Yellow mealworm (*Tenebrio molitor* L.), the Giant mealworm (*Zophobas atratus* Fab.) and the Lesser mealworm (*Alphitobius diaperinus* Panzer). In this study, the food utilisation of these three species on diets composed of five different side streams was determined. The side stream materials were mixed such as to obtain four different diets that differed from each other with respect to protein and starch content. In a first experiment, larval development rate was determined as well as pupal and adult beetle weight. In a separate experiment, larvae were allowed to grow on diets for a set amount of time and feed conversion efficiency as well as nutritional composition was determined. The different diets strongly influenced larval development rate, as well as efficiency of biomass conversion.

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The rearing and utilization of cockroach in Yunnan, China

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Periplaneta Americana L. is one kind of common insects found in room and kitchen. The cockroach usually was refered as medical and stored products pest as its body carries some harmful microorganism and can contaminate food and other goods [1]. But *Periplaneta Americana* L. has been recorded as medicinal insect since more than one thousand years ago. Chinese scientists have research the insect for many years and found some special medical functions, such as antibacterial, anti-virus, anti-cancer and immunoregulation [2]. Several pharmaceutical enterprises have used the cockroach as raw material to produce medicines for treatment of skin infection, hepatitis, liver cancer and cardiovascular disease in China [3-4]. The pharmaceutical utilization has promoted the development of the cockroach rearing. There are some small and medium scale insect rearing farms where cockroach be reared at artificial condition in Yunnan, southwestern of China. The cockroach farming become one of means to earn income for local people. The rearing method and skill were developed relatively advance. The cockroach could develop well and finish all living stages in the condition that animal feed was be applied as the feed, keep dark and humidity by supplying water. The cockroach could been produced in large quantity every year due to the rearing technological advance. Besides the pharmaceutical utilization, the insect could been used for other purpose. Gradually, local people begin to eat the nymph. Now more and more people accept the cockroach as edible insect. That means the availability of insects influences the receptivity of insects as food. The nutritious content analyze has showed that the crude protein of nymph, female and male adults are 60.2%, 61.9% and 67.2% relatively. The food safety evaluation also confirmed the cockroach is non-poisonous for human and animal. Researchers have studied the possibility of the cockroach as poultry feed and found it is good for chicken living and laying eggs. The protein, amino acids, oil and chitin could extracted from the cockroach, and been used as food and feed addition, health care food materials. At present, as rearing technology improvement, the cockroach could been reared in mass scale and applied in food and feed. But the nutritional value, food safety still need to study further. The environmental security in rearing also need to take in to consideration.

1 Bernton, HS. and Brown, H (1964) Insect allergy—Preliminary studies of the cockroach. Journal of Allergy, 35(6): 506.
2 He, ZC, Peng, F, Song, LY, Wong, XY, Hu, MH, *et al.* (2007) Review on investigations related to chemical constituents and biological activities of *Periplaneta americana.* China Journal of Chinese Materia Mediaca, 32(21): 2326.
3 Du, YM, Chen, HS, Li, SN, Li, Z., Li, XB, *et al.* (2006) The hepatic pharmacological effects of Ganlong capsules in vivo. Lishizhen medicine and materia mediaca research, 17(8): 1369.
4 Wu, JX, Niu, RX, Huang, XQ, Tian, KL, Dong, CL (2006) Effect of xinmailong on metabolism of oxygen free radicals and content of lipofuscin in brain and hepatic tissues. Chinese Journal of Clinical Rehabilitation, 10(31): 188.

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Two rearing substrates on *Tenebrio molitor* meal composition: issues on aquaculture and biodiesel production

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Insect meals are rich in proteins and lipids [1] and could represent a good source of nutrients in animal production. One issue related to the use of insects in aquaculture is their fatty acids composition, usually poor in n3, rich in n6 and lacking in long chain fatty acids as arachidonic acid (AA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) [2].

The aim of this trial was to evaluate the effect of two different rearing substrates on *Tenebrio molitor* (TM) larvae proximate composition, and fatty acids profile, in order to assess their possible use as fishmeal substitute. As the lipids richness of insect meals could be a critical point during the feeds formulation but could be exploited for other purposes (i.e. biodiesel) [3], we also evaluated the efficiency of fat extraction from TM meals using different solvents and the oleic acid (C18:1 n9) content for biodiesel production.

The insects were reared using two diets (A and B) differing in fatty acids composition: linoleic (C18:2 n6) and α-linolenic (C:18:3 n3) acids content in diet A was about the half of the one in diet B (29.5% vs 58.3% and 2.2% vs 4.1% respectively). The trial lasted 73 days and environmental parameters were checked daily (T°: 25°C, relative humidity: 70%). At the end of the rearing period, insects fed the same diet were grinded and obtained meals were sampled (n = 4) for proximate composition as well as for fatty acids analyses. The efficiency of fat extraction was determined using Soxhlet extractor with three different solvents: diethyl ether, petroleum ether, and ethyl acetate.

Proximate composition of TM larvae meals appeared not influenced by diets, and in agreement with compositions reported in literature [1]. The ether extract content was about 32%. Statistical differences were found for TM fatty acid composition in particular for linoleic acid (20.46% *vs* 28.59%), and α-linolenic acid (0.57% *vs* 1.07%) for insects fed diets A and B respectively. with the highest value for the n3/n6 ratio in larvae fed diet B.

Oleic acid content of TM meals reported considerable differences due to rearing substrate (50.37% vs 44.30% for diets A and B respectively) with an important implication when fat is used for biodiesel production [4]. The fat extraction efficiency was not affected by the solvent used.

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2 Barroso, F.G., de Haro, C., Sánchez-Muros, M.-J., Venegas, E., Martínez-Sánchez, A., et al. (2014) The potential of various insect species for use as food for fish. Aquaculture, 422-423, pp. 193-201.
3 Veldkamp, T. ; van Duinkerken, G. ; van Huis, A. ; Lakemond, C. M. M. ; Ottevanger, E. et al (2012). Insects as a sustainable feed ingredient in pig and poultry diets - a feasibility study. Rapport 638 - Wageningen Livestock Research
4 Knothe, G. (2005) Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters. Fuel Processing Technology, 86 (10), pp. 1059-1070.
5 The authors thank gratefully to Gaobeidian Shannong Biology CO., LTD (Gaobeidian, Hebei province, China) for providing Tenebrio molitor meal

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An aquatic worm production concept for the valorisation of food by-products

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A novel tubular worm reactor concept [1] was adapted to produce a high quality animal feed source by converting safe industrial food by-products into worm biomass. A freshwater worm *Lumbriculus variegatus* (common name: blackworm) has been selected for this purpose. This species is capable to reduce and concentrate semi solids like food residues or bacterial sludge and recover its nutrients. Its simple life cycle and high stress tolerance makes this worm suitable for controlled application. The worm's macronutrient composition also makes it a promising aquaculture feed source. With a gross nutritional value similar to diets such as brine shrimp and trout chow it matches fish nutrition guidelines with respect to proteins and essential amino acids [2].The goal is to develop an eco-effective worm tubular reactor for the production of worms. A renewed prototype was designed, tested and optimized for the valorisation of food by-products. The key element in this prototype is the use of a carrier material which acts as a separation layer between the worm-feed compartment and the water column. In this design, worm feed particles, worms and worm faeces can be separated and collected. The challenge is to control the conditions for sustainable growth and efficient biomass production. To determine the performance of the worm tubular reactor, mass flows for carbon and nitrogen were determined in combination with worm growth performance. Experiments with different reactor designs will result in various criteria for worm feed selection and reactor design. The operational success of the worm production will mainly depend on the production costs which are directly related with the food recovery and speed of production realized per area of reactor. The commercial success will largely depend on the acceptance of blackworms as a safe feed for cultured animals and the legalization of food waste products for worm feed applications.

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2 Mount, DR, et al., Use of the oligochaete, *Lumbriculus variegatus*, as a prey organism for toxicant exposure of fish through the diet. Environmental Toxicology and Chemistry, (2006) **25**(10): p. 2760-2767.

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African edible-insects: inventory, diversity, commonalities and contribution to food and nutritional security

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Food, feed and nutritional insecurity is one of the most serious challenges that many Africa countries continue to grapple with. Strengthening the agricultural sector is essential as it contributes to the livelihoods of vast majority of Africans. Utilization of insects as food and feed has the potential for improving food and nutritional security and reducing poverty among vulnerable people in Africa. Since most edible insects are harvested in the wild, their large-scale farming should potentially offer important new insect-based agro-enterprises for rural youth and women providing them much needed income. An inventory of edible insects compiled by *icipe* showed that more than 500 species of insects are eaten across 40 African countries surpassing the earlier reported figure of 250 (Jongema, 2012). Among the various African countries, the Democratic Republic of Congo leads in the consumption of insects with more than 150 insect species consumed. The insects consumed by the African communities commonly belong to the Orders of Coleoptera, Lepidoptera, Orthoptera, Hemiptera and Isoptera. Besides, insect species such as the black soldier flies, crickets, houseflies, mealworm and others can be used as protein supplement and replacement for expensive fishmeal and soybean in feeds for poultry and fish production. Some of these insects are also very efficient at bioconverting organic wastes (Diener et al. 2009). Insects and insect-derived products are also widely used for medicinal purposes in many parts of the world including Africa (Costa-Neto, 2005; Srivastava et al., 2009). However, to ensure continuous availability, conservation and utilization of these insects, there is the need to develop and build capacity in mass rearing techniques, an area that ICIPE's Animal Rearing and Quarantine Unit and its Insect for Food, Feed and other Uses Program has adequate skill and expertise to offer training to institutions in Africa and beyond, entrepreneurs, farmers, and others that are interested in insect-based agribusiness. In addition to building capacity in mass rearing, R&D is required on nutritional composition, post harvest, socioeconomics and food safety issues including awareness creation on the nutritional and health benefits of consuming insects. Research must also inform policy and create enabling environment for standards and legislation relevant to the use of insect as food and feed.

1 Costa-Neto, EM (2005) Entomotherapy, or the medicinal use of insects. Journal of Ethnobiology 25: 93–114
2 Diener, S, Zurbrugg, C and Tockner, K (2009) Conversion of organic material by black soldier fly larvae: establishing optimal feeding rates. Waste Management Research 27: 603 – 610.
3 Jongema, Y (2012) List of edible insects of the world (April 4, 2012) Available online at: http://www.wageningenur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences/Laboratory-of-Entomology/Edible-insects/Worldwide-species-list.htm.
4 Srivastava, SK, Babu, N and Pandey, H (2009) Traditional insect bioprospecting-As human food and medicine. Indian Journal of Traditional Knowledge 8: 485-494.

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Safety and quality considerations of insects for animal feed

Charlton, A.J[1], Booth, A.[2], Cook, N.[1], Bruggeman, G.[3], Dickinson, M.[1], Fitches, E.[1], MacDonald, S.[1], Neal, H.[2], Robinson, K.[1], Romero, R.[1], Sissins, J.[2] and Wakefield, M.[1].

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There is an urgent need to increase the supply of protein from sustainable sources and the use of insects as animal feed provides a potential alternative to imported protein crops. However, the safety and quality of feed protein from insects and subsequently the meat and fish fed on such a diet, needs to be assessed.

Increasing demand for food, particularly meat, fish and eggs, has led to an urgent need for new supplies of protein from sustainable sources. Invertebrates contribute to the natural diet of wild fish and monogastric livestock across the world and offer the potential to be used effectively as an alternative to animal and soya based proteins in animal feed. With a change in meat consumption habits towards pork and chicken and to an increase of fish in the diet, insects and insect protein could provide a low-cost and sustainable source of high-protein feed. Insects thrive on waste products from various sources, they efficiently convert nitrogen from agricultural waste into valuable protein whilst requiring fewer valuable resources such as land and water per unit protein than protein crops [1]. Farms processing insects for feed are likely to become a realistic prospect and projects, such as the EU funded PRO*te*INSECT, have already set up pilot scale production facilities to investigate the exploitation of insects as a source of animal feed.

However, the potential for insect bioaccumulation of toxins and pathogens present in waste streams has yet to be explored to the standards required to fulfil regulatory requirements for the use of insects as food or feed, raising significant concerns about the safe use of insects in the European food chain. The persistence of chemical residues, such as antibiotics and pesticides through the food chain is of particular concern where for example manure or anaerobic digestate is used as feedstock. The use of food waste generates concerns over microbiological safety and the bioaccumulation of, for example, heavy metals and mycotoxins. Industrial toxins such as dioxins may also be important depending on the insect rearing processes that are being used.

Food security is a global challenge and insect farming offers the potential to provide a sustainable source of protein for animal feed. This presentation will investigate the safety issues associated with insects raised on waste biomass and their potential for subsequent incorporation into animal feed.

1 Van Huis, A (2013). Potential of insects as food and feed in assuring food security. Annual Review of Entomology 58: 563-583

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PROteINSECT- promoting legislation change to help feed the world

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Insects are increasingly being recognised as an excellent alternative source of protein for use in animal feed [1]. However, current EU legislation represents a major challenge to the development of large-scale production processes for inclusion in animal feed and ultimately for human consumption. This is an area that PROteINSECT is funded to help overcome.

The EC funded PROteINSECT project (www.proteinsect.eu) has mapped existing EU legislation in order to identify the necessary changes that must be made. At present, the inclusion of insect-derived protein in animal feed is prohibited with the exception of feed intended for aquaculture [2]. Additionally, insects produced for processed animal protein (PAP) are classified as 'farmed animals' under EU law [3]. This means that it is not possible to rear insects on organic waste materials such as manure or catering waste, despite this being desirable from both an economic and environmental point of view.

One of the key objectives of PROteINSECT is to drive changes in legislation to encourage and support the use of insect protein in animal feed. This will be achieved by engaging key stakeholders and providing evidence to demonstrate that insects represent a safe, sustainable and economic source of protein. Ultimately, this work will lead to the creation of a White Paper to be presented before the European Parliament, ensuring that regulatory issues are brought to the political arena.

Encouragingly, there is evidence that this topic is already on the agendas of the appropriate European authorities and significant legislative advances have been made in recent months. For example, the European Commission has recently drafted amendments to current regulation that will permit processed animal protein derived from insects to be fed to non-ruminant farm animals. It is vital that such positive action continues so that a clear and permissive regulatory framework can be established in Europe.

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2 Commission regulation (EU) No 56/2013. Amendment to regulation for the prevention, control and eradication of certain transmissible spongiform encephalopathies. Regulation (EC) No 1069/2009. Animal By-Products Regulation.

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Use of insects as a protein source in feed and food: Safety and EU legislative aspects

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Introduction: Insects are expected to enter the European feed and food market as replacers for animal-derived proteins. Technical and processing properties are being investigated. Feed and food business operators that wish to put insects on the European Union (EU) market are responsible for the safety of the food and feed product, and should comply with EU and national legislation. Knowledge on potential safety hazards associated with the use of novel proteins in feed and food applications is scarce however. This may have implications for the possibilities to use insects as a protein source in feed and food.

Purpose: The aim of this study was to investigate the possibilities and bottlenecks of bringing insects as protein source on the feed and food market by evaluating the range of potential hazards, possible control measures, and EU legislative requirements.

Methods: A literature review was performed to obtain insights into the range of potential hazards present or introduced during the production of insects for use as feed or food. The potential to control hazards has been studied as well as the safety requirements and unclearities in EU legislation.

Results: Potential hazards may include a range of contaminants, like heavy metals, mycotoxins, pesticide residues, as well as pathogens. Although some safety aspects of novel proteins are intrinsic to the product, many potential hazards can be controlled by production methods and by production and processing conditions. Feed and food business operators should comply with EU legislation like general legislation for food and feed production, food and feed hygiene legislation, novel food legislation, feed legislation, and specific legislation for insects. Some unclearities in EU legislation were found for insects as novel protein source.

Significance: Based on the obtained results, recommendations were given to control the production process of insects as protein source and to adjust and clarify the European legislation.

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Risk assessment of novel proteins in food: Are insect proteins allergenic?

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Due to the imminent growth of the world population, shortage of protein sources for human consumption will arise in the near future. Alternative and sustainable protein sources like insects are now being explored for the production of food and feed. Before novel products can be launched on the market, the assessment of food safety is vital. One of the key aspects of food safety is the risk of the development of food allergy. Food allergies specifically have a significant impact on the quality of life of allergic patients and their daily functioning, and they may even be life-threatening.

TNO together with partners developed a risk assessment strategy to assess the allergenicity of novel proteins, in accordance to the European Food Safety Authority (EFSA) guidelines to assess the safety of genetically modified organisms. Using this strategy we assessed the safety of yellow mealworm (*Tenebrio molitor* L.) proteins for use as human consumption. Next to *in vitro* tests also a human study was performed.

Based on the first results it can be concluded that house dust mite and crustacean allergic patients may be at risk when consuming food containing mealworm proteins. For these patients it is important that products containing mealworm proteins are correctly labelled.

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Microbiological status of edible insects sold as pet feed in Germany

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In Germany, obtaining edible insects produced under food quality standards is difficult. Instead, entomophagists often rely on feed insects from pet shops. This pilot study asserts the microbiological quality of typical feed insects in Germany, which in other countries also have a tradition of being consumed by humans. For that, edible insects (*Locusta migratoria, Acheta domesticus, Gryllus [G.] assimilis, G. bimaculatus, Tenebrio molitor, Zophobas morio, Pachnoda marginata, Galleria melonella,* and *Chilecomadia moorei*) were purchased from two pet shops in Northern Germany. Samples included pooled animals encountered alive (n = 27) and dead (n = 4) at the time of purchase, as well as the substrate (earth, feed, faeces and egg carton sections; n = 10). All samples were analysed according to modified ISO methods for total aerobic bacterial count, *Enterobacteriaceae*, *Staphylococcaceae*, yeasts and moulds, *Bacillus* spp., *Listeria monocytogenes*, and *Salmonella* spp. Bacterial counts were expressed in common logarithms of cfu/mg sample ($lg_{cfu/mg}$).

Results varied according to species and life status. Data is summarized in Tab. 1. Eventually, results were negative or exceeded the dilution steps, accounting for varying sample sizes. Within parameter, differences were not statistically significant, probably due to sample sizes. So, data suggests that bacterial counts of the substrate were generally in the same range as those of living insects. Dead insects yielded less *Enterobacteriaceae* but more *Bacillus* spp. as well as yeasts and moulds, with total anaerobic bacterial counts exceeding eventually 8.477 $lg_{cfu/mg}$. The results ranged above common benchmark and threshold values for other foodstuffs, e.g. meat, fish or crustaceans.

Tab. 1: Bacterial counts [$lg_{cfu/mg}$] of edible insect packages

	Living insects			Dead insects			Substrate		
	x	sd	n	x	sd	n	x	sd	n
Total bacterial count	7.041	0.434	25	7.366	0.518	2	6.696	1.060	10
Enterobacteriaceae	6.710	0.639	26	6.438	0.915	3	6.965	0.821	7
Staphylococcaceae	4.843	1.336	23	5.910	0.377	2	5.852	1.014	7
Yeasts and moulds	4.554	1.044	27	5.296	0.169	2	4.222	0.704	10
Bacilli	6.775	0.568	22	6.929	0.776	3	7.055	0.739	9

x = arithmetic mean, sd = standard deviation, n = sample size

All samples were free of *Salmonella* spp. and *Listeria monocytogenes*. The samples yielded a series of opportunistic pathogens, i.e. coagulase-negative staphylococci, *Proteus* spp., *Serratia liquefaciens*, *Enterobacter cloacae*, *Pantoea* spp., *Morganella morganii*, *Geotrichum* spp., *Trichosporon* spp., *Candida albicans* and *C. krusei*.
In conclusion, edible insects sold as pet feed do contain a marked micro flora which may be derived from the substrate they are sold with. Classical zoonotic pathogens were absent. Thus, reducing the bacterial counts in the insects' production environment is prone to improve the microbiological quality of edible insects. Meanwhile, thorough washing and heating remains necessary to reduce the risk of acquiring any food-borne disease.

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Inactivation of *Salmonella* spp. and *Ascaris suum* in batch and continuous black soldier fly treatments

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The black soldier fly (BSF), *Hermetia illucens,* is an efficient organism to be used in organic waste management [3]. The prepupae can be used as animal feed as it is high in fat (30%) and protein (40%) [4]. In its final larval stage it leaves the feed material to find a dry and dark site for pupation and is due to this migratory habit self-harvesting [2]. The fly larvae composting introduces a shift in the value-chain by redirecting the nutrient flow by shortcutting the field for feed production. One major concern in this system is the hygiene of the produced compost and of the generated prepupae. The inactivation of *Salmonella* Typhimurium. and *Ascaris suum* ova was monitored in BSF treatments operated in batch and continuous feeding systems as well as in prepupae generated in the batch system. It was found that salmonella was reduced 7 $\log_{10}$ in eight days in the batch system [1], while the concentration of *Salmonella* Typhimurium was below the detection limit (varied between 1000 and 0.2 CFU g^{-1}) in the outflow material in the continuous system having a hydraulic retention time of two weeks (inflow concentration: 6-7 $\log_{10}$ CFU g^{-1}) (unpublished data). The concentration of *Salmonella* spp. detected in the prepupal gut was <0.5 CFU g^{-1} [1]. *Ascaris suum* eggs did not appear to be destroyed nor inactivated in neither the batch treatment nor the continuous BSF system. *Ascaris suum* eggs were also found inside the gut of prepupae, viability not confirmed. However, no development of the eggs were observed during the treatment, indicating non favorable conditions and thereby a potential for inactivation during post treatment storage only (unpublished data). Until confirmed it is recommended to post-treat the compost if it is to be used as fertiliser in crop production, in particular if the crops are consumed raw. It is further recommended to process the prepupae (by heat treatment) prior to animal feeding.

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Evaluation of feed safety aspects in feeding organic layers with fresh house fly larvae *(Musca domestica)* reared in poultry manure

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In the production of organic table eggs it is difficult to provide feed that accomplish all needs for the hens. Especially essential amino acids are in deficits and this may lead to reduced productivity, and in worst case elicit feather pecking and cannibalism in the flock. The addition of fish meal in the feed has been used to avoid these problems. As fish meal may be a limited resource in the future due to overfishing, a more sustainable protein source is needed. Thus, the BioConVal project has investigated the possibility of using larvae of the common house fly (*Musca domestica*) as poultry feed to address some of these issues. The larvae is natural feed for all poultry and contains large amounts of high value protein. Furthermore, feeding fresh larvae may stimulate the hens toward a more natural behavior when kept in large flocks.

House fly larvae may be cultured on waste resources such as animal manure. However this is a very complex matrix that may contain pathogenic bacteria, parasites and chemical or biological toxins. Especially pathogenic microorganisms are of great concern as feeding contaminated larvae to hens may cause animal disease or if transmitted to table eggs may cause human disease. Although adult house flies are known to carry plenty of pathogens, this seems to be different for the larvae. In fact research from BioConVal has shown that larval stages of *M. domestica* may actually feed and degrade various Enterobacterial species in the manure.

In the context of using fly larvae as fresh feed, we have conducted laboratory assays to evaluate microbial (*Salmonella* Enteritidis, *E. coli Campylobacter jejuni*), parasitological (*Coccidia* ssp, *Ascaridia galli*) and toxicological risks (dioxin, PCB). Results from this work will be presented at the conference.

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Nutrition and heavy metal levels in the mound termite, *Macrotermes bellicosus* (Smeathman) (Isoptera: Termitidae), at three sites under varying land use in Abeokuta, southwestern Nigeria

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The consumption of insects, especially termites, has over the years gained attention. This study aims at evaluating the nutritional and heavy metal levels in workers, soldiers and primary reproductives of *Macrotermes bellicosus* (Smeathman) collected from farmland, a dump site and an industrial estate in Abeokuta, southwestern Nigeria. Proximate analysis was done using standard methods, vitamins were analysed spectrophotometrically while minerals and heavy metal analyses were done using an atomic absorption spectrophotometer. The soldiers and worker termites recorded higher values of ash, crude fibre, crude protein and carbohydrate contents than reproductive termites (queen and king). The reproductives recorded higher fat content than workers and soldiers. The highest ash (2.27 ± 0.02 %), crude fibre (1.04 ± 0.02 %), crude protein (20.96 ± 0.01 %) and carbohydrate contents (3.65 ±0.01 %) were recorded for workers and soldiers collected from the industrial estate.

The reproductives from farmland recorded the highest average vitamin contents, 16.96 ± 0.01 mg/g of vitamin A, 2.74 ± 0.01 mg/g of vitamin B and 7.15 ± 0.02 mg/100 g of vitamin C. The lowest vitamin A and B contents recorded for soldiers from the dump site were 15.12±0.01 mg/g and 2.09±0.01 mg/g, respectively, while soldiers from the industrial estate had the lowest (4.51 ± 0.01 mg/100 g) vitamin C content. Castes from the industrial estate had the highest amount of Cu^{2+} (0.076±0.001 mg/l) while the highest values of Cr^{2+} 0.226±0.001 mg/l and 0.223±0.003 mg/l were recorded for workers from farmland and the dumpsite, respectively. Lead Pb^{2+} was only detected in the soldier castes.

From the results, it can be concluded that termites are rich in crude protein and have a very low tendency to accumulate heavy metals from the soil.

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Multifaceted aspects of insect pathogenic and commensal bacteria in insect based food

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Like other organisms insects are associated with bacteria as commensals, symbionts or as pathogens. It seems obvious that aspects related to the role and impact of these microbes in insect based food, from rearing, during processing to storage and finally in the host, need to be explored at various levels. In the Micalis Institute (www.micalis.fr) we are working with several topics related to microbial food safety. Both to elucidate bacterial pathogenesis in insects, for instance with *Bacillus thuringiensis*, bacteria as probiotics and bacteria in food conservation; the latter two are mainly belonging to species of lactic acid bacteria. Then although one of the interesting points with insects are the presumed low risk of transfer of pathogens from insect to vertebrates, there is a need for investigating the microbiota associated with the chosen insect's sources to evaluate benefice and risk. My presentation or poster will mainly highlight such aspects but will also raise ideas related to the potential of bacterial entomo-pathogens as enzyme sources for industrial biotransformation of insect based products. The aim of the presentation and hopefully the discussion is to set up research topics related to insect based food safety in order to include them in new collaborative projects.

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Towards an effective insect supply chain: meeting qualitative requirements and quantitative demands

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If we look at the insect supply chain as a locomotive with carriages that has to start rolling, the wheels will only start to turn if all are separate carriages in the chain are in place. Each supply chain partner is important and will need to be qualified to meet the quantity demands as well as the quality requirements of the end supplier and customer. Demands for raw materials in the animal feed industry go as high as millions of Tons per year. The chain starts with the insect feed supplier than goes through insect rearing on to the insect processing businesses and in the end the customer.

The insect industry is not industrialized yet. Mechanisation, automation and "Good Manufacturing Practices" are the next steps to be introduced to increase insect yields and quality. When providing new raw materials for industrial use a constant volume and quality is required. Customers must be able to rely on suppliers. For a starting industry, confidence between suppliers and customers has to develop. But this is a time consuming process. How to accelerate this process? A good start is to talk "the language" of your customer. This can be done by using the same analyses as your customer, the same quality systems and the same standards for quality and safety.

Being a new industry brings the possibility to start right from the beginning. Lessons learned in other industries should be used in developing an economic and healthy insect business. Quality standards can be copied from other industries like the animal feed industry and the food industry. When fresh insect products are produced quality measures from the meat industry can be used and in the case of dried products, quality standards of the animal feed industry are at hand.
The rearing of insects must be seen as a production process. This process can be unravelled into unit operations with control points.

It is vital for a business to provide product related safety data sheets (e.g.MSDS/ PDS/SDS) as well as technical related data sheets (TDS). The product related data sheets consider the hazards related to the use of the product, while the technical data sheet has its focus on performance, function and usage of the product.

Each supply chain partner needs to realise that their company is always responsible for the product that it puts in the market.

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Human chitinases' variability and implications for chitin digestion in populations eating insects

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Chitin is an insoluble polymer constituting a relevant part of edible insects, crustaceans and fungi, and humans have two chitinolytic specific enzymes [1]. Particularly Acidic Mammalian Chitinase (AMCase) is active at pH 2, exerts a digestive function in mammals, and is active in human gastric secretions [2].

We recently investigated the presence of genetic adaptation to chitin digestion in Amazonian and Andean ethnic Amerindians highly exposed to chitin by insects and crustaceans consumption. The AMCase variable loci (exon4) genotypified in our sample presented the wild-type form, which is known to encode for a protein with low enzymatic activity at pH 2 [3]. Meta analysis on human genetic variability showed that the gain-of-function form (with double activity at stomach and lung level) is an ancestral condition partially conserved only in Africans (30%).

We feel that human populations don't invest in highly polimerized chitin digestion but possibly in softening cuticles. However, chitin ingestion is known to influence gut-microbiota in mammals and humans – with a disinflammatory effect on human gastric mucosa – [4], and further studies should investigate gut-microbia diversity and functionality in populations practicing entomophagy.

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Nutritional and anti-nutritional composition of most preferred ant and termite species used as food by the tribes of Arunachal Pradesh, India

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Among the ethnic people of Arunachal Pradesh, NE India, entomophagy is a traditional and culturally accepted practice. The interest in the use of insects as food in this state has been expressed in our earlier reports and revealed 102 edible insect species [1, 2]. Among these, *Oecophylla smaragdina* (Hymenoptera: Formicidae) and *Odontotermes* sp. (Isoptera: Odontotermitidae), are in the list of preferred species. This study was undertaken to provide scientific data on nutritional and anti-nutritional composition of these two species. The samples were collected from Papumpare district of Arunachal Pradesh. Standard methods were followed to determine the nutritional anti-nutritional composition.

O. smaragdina and *Odontotermes* sp. contained 55.28 and 33.67% protein, 14.99 and 50.93% fat, 19.84 and 6.30% fiber, 2.59 and 3.01% ash and 7.30 and 6.09% carbohydrate respectively. The protein of both the species is composed of 18 amino acids, including all of the essential ones, which except for methionine, satisfy the recommended level(score> 100) suggested by FAO/WHO/UNU (2007). In *O. smaragdina,* proportion of MUFA (51.55%) was dominant followed by SFA (40.26%) and PUFA (8.19%) whereas, SFA (52.89%) was predominant in *Odontotermes sp*. followed by MUFA (44.52%) and PUFA (2.59%). *Odontotermes* contained more palmitic (38.32%) and stearic acids (12.74%) than *O. smaragdina* Of the UFA, oleic acid (49.96%) as MUFA and linoleic (7.13%) and linolenic acid (0.23%) as PUFA were present in higher amounts in *O.smaragdina* compared to *Odontotermes sp*. Fe, Zn and Cu were the most abundant minerals in both the species. Ca, Mg, Na and K were present in substantial amounts. On the basis of our analyses *O. smaragdina* found to be a better choice for nutrient content compared to *Odontotermes sp*. Respective values for anti-nutrients, phytic acid and tannin content (mg/100g) *O. smaragdina* (171.0 and 496.67) and *Odontotermes* sp. (141.23 and 615.0) was much lower compared to some common foods of plant origin. Consumption of these two insects can be recommended as a means to combat the problem of malnutrition among the less privileged inhabitants of Arunachal Pradesh and the world at large and this can be a good choice as a replacement of vertebrate animal food products.

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Ethanol extract of *Bombys batryticatus* induces apoptosis in human hepatoma cell SMMC-7721 via the modulation of Bax/Bcl-2 and P21 expression pathway

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Bombyx batryticatus is the dried larva of *Bombyx mori L.* (silkworm) infected by *Beauveria bassiana* (Bals.) Vuill. It is a traditional Chinese medicine in the treatment of different illnesses such as dispel flatulence, relieve fever, dissolve phlegm and reduce spasms. The present study aimed to evaluate the effects of *Bombys batryticatus* ethanol extract (BBE) on the viability and apoptosis of SMMC-7721 and to investigate its molecular mechanism in SMMC-7721 cells. Anticancer activity and toxicological mechanisms of BBE against SMMC-7721 cells was studied by MTT assay, morphological assessment, DNA fragmentation assay, flow cytometry analysis, western blot analysis and real time polymerase chain reaction. BBE inhibited the growth and induced the apoptosis of SMMC-7721 cells. MTT assay indicated the cytotoxicity of BBE on SMMC-7721 cells was correlated with treatment time and concentration. The value of IC_{50} at 30 h was determined to be 0.1812 mg/mL. The microscopy results showed that SMMC-7721 cells were severely distorted, grew slowly and some cells became round in shape when treated with 0.6 mg/mL BBE for 24 h. Annexin-V/propidium iodide double-staining assay identified early and late apoptosis morphology of SMMC-7721 cells when treated by BBE through laser confocal fluorescence microscopy. Flow cytometry revealed a dramatic increase in the number of apoptotic after BBE treatment. DNA ladder results revealed a trend towards increased DNA fragmentation when SMMC-7721 cells were treated with BBE at indicated concentration for 18 h. The proapoptotic activity of BBE was attributed to its ability to modulate the expression of *Bax*, *Bcl-2* and *P21* genes. The expression profiles of *Bax* and *P21* at protein and mRNA level are dramatically increased whereas the synthesis of *Bcl-2* is decreased and the ratio of *Bax/Bcl-2* increased when cells are treated with BBE for 18 h. These results presented in this paper suggested that BBE-induced apoptosis on SMMC-7721 cell was achieved by its ability to modulate the high expression of Bax/Bcl-2 and P21 at protein and mRNA level. This finding reveals an interesting correlation between gene regulation and BBE-induced apoptosis, and provides a molecular basis for the development of naturally insect product.

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The role of the FAO in assisting countries to develop regulatory frameworks to include insects in food and feed sectors

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High population growth in low and middle-income countries coupled with an increasing demand for animal protein is placing immense pressure on regional, national and global food systems. In order to feed the world the importance of diversifying food sources, especially protein, for human and animal consumption is paramount. Insects have been identified as one of many suitable alternatives/candidates to supplement other animal-based proteins, in addition to new/existing plant-based protein sources, in order to improve nutrition and food security, as well as to meet the growing demand for food. While some countries have encouraged research into edible insects as food and feed as a step towards a green economy, as well as nutritious food source, legislation governing this activity still legs significantly behind. There are few regulatory frameworks that explicitly refer to insects as food or feed at national, regional and global levels. Moreover, there is a considerable amount of ambiguity in the language of laws, regulations and decrees governing the origin, quality, labeling and procedures in the food and feed chains. A major barrier to the growth of the edible insect sector is the lack of precise and insect-inclusive legislation, standards, labeling and other regulatory instruments (legally binding or otherwise) governing the production, trade and use of insects in the food and feed chains. The purpose of this study is to identify and compile relevant legislation from countries, where applicable, and attempt to give an annotated overview of the current regulations at global, national and regional perspectives. Moreover, this discussion paper aims to shed light on the current legal climate that influences insects as feed and food, and may provide guidance to those stakeholders involved in the development and/or improvement of legislation.

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Legislation and regulation of insects as food and feed - the EU perspective

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As a fundamental principle of the European Union's (EU) food safety system, the food and feed business operators are responsible to ensure that the food and feed placed on the market is safe with respect to animals and consumers. Food and feed business operators placing on the market insects or derived products as food or feed in the EU need to comply with a set of requirements developed to ensure both animal and public health and inform , consumers adequately about the properties of the food and feed placed on the EU market. These rules also ensure the free movement of food and feed within the EU to allow citizens and businesses to make the most of the advantages of the single market, which promote mobility, competitiveness and innovation without compromising on safety. The presentation will describe the legal framework regarding the production and consumption of insects as feed and as food, with its challenges and opportunities.

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Black soldier fly farming: The entomology link in kiloton/month (and above) production chains

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The black soldier fly [*Hermetia illucens* (Diptera: Stratiomyidae)] (BSF) is currently the object of considerable, world-wide interest as a candidate for producing bulk agricultural commodities, i.e., industrial-scale insect farming. Produced in sufficient quantities, BSF could become an important source of protein for feeds and lipid for biofuels. BSF has several desirable characteristics for this purpose: saprophagy, communal feeding habit, rapid growth rate, non-pest status, efficient digestion, high protein and lipid content, and low incidence of disease and other mortality factors.

Farming BSF for production of agricultural commodities will share several important characteristics with confined animal feeding operations (CAFOs), intensive systems of livestock production, e.g., poultry and swine. Compared to less spatially intensive systems, BSF CAFOs, like all CAFOs, will suffer the disadvantages of increased risk of local environmental damage due to eutrophic pollutants and increased risk of disease and associated losses due to crowding of the "livestock". However, BSF CAFOs will also enjoy the advantage of increased production efficiencies with the increased levels of mechanization possible.

The most successful BSF CAFO design will have the best combination of clever engineering informed by an intimate knowledge of BSF biology. The greater one's knowledge of BSF biology, the more efficient can be the BSF CAFO designed. Some examples of the importance of knowledge of BSF biology can be drawn from published patents: prepupal behavior [1] and mating and oviposition behavior [2].

We have followed the "engineering informed by entomology" strategy over the last three years in developing a BSF rearing system for which a US Provisional Application for patent has been filed by Mississippi State University. Based on our experience, including initial testing on a commercial catfish farm in Mississippi, we estimate that production of one kiloton of larvae per month will require $\leq$ 0.1 ha floor space for eggs and ca. 2.0 ha floor space for larvae. As envisioned, this ca. 2.1 ha facility would achieve the following production rates: ca. 85 kg_{dry} protein/m^2/yr, 55 kg lipid/m^2/yr, and 570 kg_{dry} feeding waste/m^2/yr. Assuming 1.0 €/kg_{dry} protein, 0.2 €/kg lipid and 0.01 €/kg_{dry} feeding waste, the gross value of these products would be ca. 100 €/m^2/yr. The net profitability of this system is unclear because of uncertain capital and production costs.

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AgriProtein: Building the worlds' largest insect rearing protein farm – a history and vision

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You need look no further than your local supermarket to understand the state of our seas. The frozen section contains baby hake and sole petite. This is not because they are easier to catch or tastier but simply because we have eaten their parents. You don't need to be a farmer or fisheries scientist to understand that eating your breeding stock is a disaster. From the grand banks to the Sea of Galilee we are closing our fisheries – only after we have broken them.

Whilst we take for granted the imperative to recycle waste paper, glass, aluminium and steel, we have yet to take on board the recycling of waste nutrients. It takes as much of our worlds natural resources, for example, to make the bits of a chicken we do eat as the bits we don't eat. These and many other nutrient rich 'waste' products are discarded every day.

AgriProtein is leading the nutrient recycling industry, using existing waste products to feed fly eggs as they grow into larvae. These larvae are then harvested and dried into MagMeal - a natural and high-quality protein source for aquaculture and industrial animal farming operations. MagMeal is a sustainable substitute for fishmeal and for every tonne produced, allows 5 tonnes of fish to remain in the oceans, and creates an environmental cost saving of $2,500.

Since 2009 to 2014, AgriProtein has been on a mounting curve of research and development and production scale. Understanding the economic benefits of different species, their ideal yields on different feed sources and their end protein content and amino acid profiles.

AgriProtein has industrialised the production of this natural food source of these animals - larvae. As well as the larvae, an animal oil, MagOil, is extracted, and soil conditioning residue completes the waste derived product portfolio. Using high-recycled protein sources such as MagMeal we have every possibility of making aquaculture and industrial agriculture sustainable while saving our fragile seas – one fish at a time. Let's get busy repairing the future.

Each year from inception to 2014 AgriProtein has built larger facilities, tested greater volumes and has just closed financing for its first full scale factory, (on-line 2015), which will process 110 tonnes of waste and produce 20 tonnes of maggots per day.

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Current status on use of insects as animal feed

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A substantial increase in future consumption of animal products will demand enormous resources, the feed being the most challenging because of the ongoing climatic changes, food-feed-fuel competition and limited availability of natural resources. The costs of conventional feed resources such as soymeal and fishmeal are very high and increasing at a high rate; and moreover their availability in the future will be limited. Insect rearing could be a part of the solutions. Here we present the available information on the nutritional quality of black soldier fly larvae, the house fly maggots, mealworm, locusts-grasshoppers-crickets, and silkworm meal and their use as a substitute of soymeal and fishmeal in the diets of poultry, pigs, fish species and ruminants. The crude protein content of these insects ranges from 42 to 63% and the lipid content is also high (up to 36% oil), which could possibly be extracted and used for various applications including biodiesel production. Unsaturated fatty acid concentrations are high in housefly maggot meal, mealworm and house cricket (60-70%), while their concentrations in black soldier fly larvae are lowest (19-37%). The palatability of these feeds to animals is good and they can replace 25 to 100% of soymeal or fishmeal depending on the animal species. Except silkworm meal other insect meals are deficient in lysine and methionine and their supplementation in the diet can enhance the performance of the animals and replacement rate of conventional protein-rich feedstuffs in the diets. Most insect meals are deficient in calcium and its supplementation in the diet is also required, especially for growing animals and laying hens. The field of mass rearing of insects and their use as livestock feed currently is in infancy and further work is required. This paper also identifies future areas of research. The information synthesized will open new avenues for a large scale use of insect products as animal feed.

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The Insect Biorefinery, an efficient tool for industrial production of insects and derivates

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Ynsect is a French company established in 2011 operating in the fields of environment, biotechnology and feed industry. Its main activities are insects' biodegradation of organic residues and their transformation into nutrients for animal feed (proteins, lipids) and non-feed products (chitin and derivatives, peptides, fertilizers).

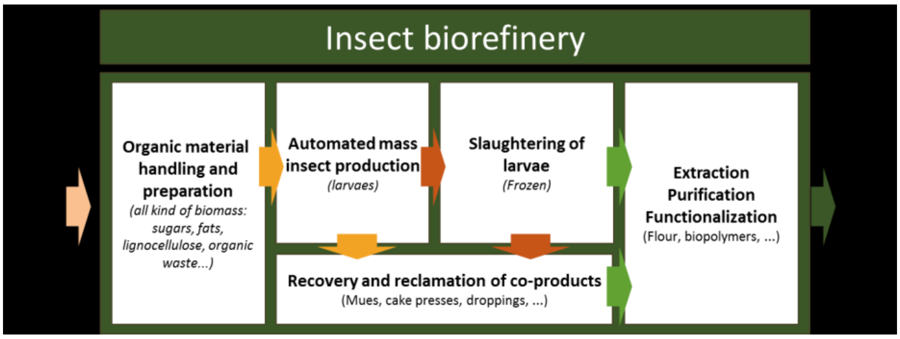
Ynsect strategy lies entirely on sustainable development principles: the technology allows upstream a better use of local biomass and downstream the promotion of more efficient agro-food systems: as Europe is 75% dependent on protein importation, local production of protein could improve feed and food environmental balances and create local jobs.

The vision of Ynsect is to use the extraordinary biodiversity of insects, and the variety of their diets, to develop a wide range of technologies for effective recovery from all types of biomass residues available in any territory.

Ynsect's activity is part of a new industry creation called insect biotechnologies, which are using physiological, biochemical and behavioral properties of insects as new sources of value.

Ynsect designs and operates biomass valorization units called "Entoraffinerie™", meaning insect biorefineries, with reference to biorefineries using microorganisms as bioreactors. These plants include insect rearing units as bioreactors and a downstream processing unit for separation and purification process.
"Entoraffinerie™" are ideal technologies for large scale production of insect and then of insect feed and food ingredients. Other products from this technology have applications in pharmaceutical, nutraceutical, cosmetics, fertilizers and green chemistry.

This presentation will present the state of art of insect production in different parts of the world, and focus on insect biorefinery concept and its tremendous capacities of production and abilities to valorize each part of insects, and its application to *Tenebrio molitor* species.



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The benefits of using insects as fish and animal feed

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Due to deficiency in edible biomass caused by world population explosion, humans need new animal protein resources. Insects have a great potential to be a food source. They have drawn attention as unutilized natural resource in world population explosion to be a key to resolve food problem. Deficiency in edible biomass is also a big problem in aquaculture, as well as food for human. Although the original purpose of this study is to examine the possibility of using housefly (*Musca domestica*) as a substitute for fishmeal, we found positive effects of housefly pupa and other insects instead; namely the feed containing housefly pupa was strongly preferred by some fish species, promote fish growth and tolerance for fish disease with immunostimulation, and reduces low density lipoprotein (LDL) cholesterol in fish and mammal. Among these benefits of pupa, we focused on the immunostimulatory effects and analyzed their mechanisms.

To understand the mechanisms of immunostimulatory effects of pupa, we attempt to purify the substance that stimulates an immune response from melon fly (*Bactrocera cucurbitae*), which shows high immunostimulatory effect among diptera. As a result of biochemical analysis, we succeeded to isolate this substance as acidic polysaccharide and named it “dipterose”. Dipterose was composed of 9 monosaccharides including L-rhamnose, and its molecular weight was 1.01×10^6. Using mammalian macrophage cell line, RAW264, functional molecular mechanisms for immunostimulation of dipterose were observed. In leucocyte, dipterose is recognized by Toll-like receptors and induce various cytokines and/or nitric monoxide (NO) production through the expression of inducible NO synthase (iNOS). Immunostimulatory substances like dipterose exist not only in fly, but also in other insects. At present, we had investigated ten species of insects, and silkworm (*Bombyx mori*), wild silkmoth (*Antheraea yamamai*), *Opisthoplatia* sp., cockroach (*Periplaneta* sp.), Black cicada (*Cryptotympana* sp.) included high immunostimulatory substances. Thus, various species of insect have substances with immunostimulatory effects on other animals.

These results indicate that insects have a great potential food source and animal feed. Various benefits of insects as food for fish and mammals, including human, are expected.

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Case Study: Insects as feed

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A review of the research conducted at the Stellenbosch University in collaboration with Agriprotein (Pty) Ltd on the use of different species of dipteran larvae in poultry, aquaculture and ruminant nutrition. Species of larvae include *Musca domestica* (larvae and pupae), *Hermetia illucens* (larvae and pre-pupae) and *Chrysomya chloropyga*(larvae). Comparisons are made on the basis of a broiler based bio-assay of the total chain including the nutritional composition (proximate analysis, mineral analysis and amino acid composition), presence of possible toxicities and allergens, influence on immunological systems, digestibility, production parameters, carcass characteristics, meat quality characteristics and ultimately sensory characteristics of the meat produced. Bio-assay of larvae meal in aquaculture diets are restricted to African catfish and Tilapia where production parameters were assessed while ruminant studies include *in vitro* and *in vivo* studies of *H. illucens* larvae and pre-pupae as well as *C. chloropyga* larvae. Broiler trials were the most comprehensive. From these data it was concluded that the larvae, pre-pupae and pupae of the species under investigation showed no toxicities, had no negative effect on gut histology, were highly digestible and palatable, led to superior production efficiency factors and had no negative influence on meat quality or sensory characteristics of meat. Produced meat had a higher water binding capacity and was juicier than that of controls further the Fe and Zn content that that of soya based diets which indicated that the use of this protein source could add value in the production of functional foods high in bioavailable nutrients commonly lacking. Ruminant studies showed the potential of this protein to act as a bypass protein while aquaculture studies are still underway.

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Industrial fruit fly mass rearing for the application of the Sterile Insect Technique

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Mass rearing of the target pest insect is a key requirement for the industrial production of billions of good quality and sexual competitive insects per week for the application of the Sterile Insect Technique (SIT). Over the last fifty years the Joint FAO/IAEA Programme for Nuclear Techniques in Food and Agriculture has been a key driver for the development of new innovative mass rearing systems and processes for some selected key insect pests i.e. the Mediterranean fruit fly, *Ceratitis capitata* [2] and other fruit fly species (*Bactrocera* spp and *Anastrepha* spp.), the New World screwworm fly *Cochliomyia hominivorax* [3], the false codling moth *Thaumatotibia leucotreta* [1], and several tsetse fly species, *Glossina austeni* [4], *G. pallidipes* and *G. palpalis gambiensis*. For each of these insect species mass rearing techniques were established including guidelines to design and equip mass rearing facilities, standard operating procedures and quality control protocols.

There may be potential for adapting these mass rearing techniques for the mass production of other insect species for purposes other than the SIT. The objectives are different but parallel in some respects: SIT rearing aims to produce the best quality (competitive) insects at the lowest cost whereas rearing for food aims to produce the highest yield of quality nutrient for the lowest cost. But beyond this other aspects are similar: cost minimization, energy efficiency, cheap diet, waste diet disposal or reuse, disease control, minimizing labour and so on. Experience has been gained in rearing for SIT over many decades in each of these aspects and much of this experience might be translated to the production of food for humans and livestock.

1 Bloem S, Bloem KA, Fielding LS (1997) Mass-rearing and storing codling moth larvae in diapause: a novel approach to increase production for sterile insect release. J Entomol Soc B C 94: 75-81.

2 Caceres C (2002) Mass rearing of temperature sensitive genetic sexing strains in the Mediterranean fruit fly (*Ceratitis capitata*). Genetica 116: 107-116.

3 Lindquist DA, Abusowa M (1991) The new world screwworm in North Africa. World Animal Review: 2-7.

4 Vreysen MJB, Saleh KM, Ali MY, Abdulla AM, Zhu Z-R et al. (2000) *Glossina austeni* (Diptera: Glossinidae) eradicated on the island of Unguja, Zanzibar, using the sterile insect technique. J Econ Entomol 93: 123-135. DOI:10.1603/0022-0493-93.1.123

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EnviroFlight, USA: Industrial cultivation of black soldier flies for animal feed

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EnviroFlight, USA has successfully commercialized the industrial production of black soldier fly larvae for animal feeds. EnviroFlight's technology operates in temperate climates with temperatures ranging from -20 degrees Celsius in winter to + 42 degrees Celsius in summer. EnviroFlight is currently supplying the feed industry in the USA with BSFL based feed ingredients, formulated aquaculture diets, and commercial fertilizers. EnviroFlight is in the process of large scale expansion in the USA and developing markets for its products and services globally.

The presentation will cover the following elements of EnviroFlight:
Evolution of EnviroFlight from biofuels to commercial feed production

- *Global stressors amplifying the need for insect technologies*
  - *(optional, this adds about 15 minutes to the presentation. Covers population growth, ocean acidification, over fishing, food waste)*
- EnviroFlight's production process
- Aquaculture Feed Trial results
- Commercial Products
- U.S. Regulatory approvals

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Insect meal: a promising source of nutrients in the diet of Atlantic salmon (*Salmo salar*)

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The Norwegian salmon industry has had an annual growth rate of around 5-10% during the last 20 years and is projected to maintain this growth in the next 10 years. Traditionally fish oil and fish meal (FM) have been important ingredients in the diet. However, supplies of fish oil and FM are finite and prices have increased dramatically. In 2006 salmon consumed 15% of the total amount of fish meal (FM) used in aquaculture production [1]. The inclusion of FM has since decreased in compound aquafeeds for salmon from around 30% of the diet (2006) to 15% in 2012. This amount is projected to decrease further and reach 8% in 2020 [1]. Currently, the majority of FM replacement is sourced from vegetable ingredients like soy protein, corn gluten, pea meal and wheat gluten. Vegetable proteins sources are able to replace a substantial part of FM, however have their limitations due to unbalanced amino acid profiles, high fiber content, anti-nutritional factors and competition with use for human consumption. Alternative protein sources, like insect meal (IM), are required to create flexibility in diet formulations, sustain a healthy industry and allow for future growth [2,3].

In the past years intensive efforts have been made to use organic waste streams for large scale production of black soldier fly larvae (*Hermetia illucens*) in The Netherlands. We tested the replacement of FM with two IM types in diets for Atlantic salmon. Different nutrient isolation and processing techniques led to these two IM types. The modern control diet contained 200 g kg^{-1} fish meal (FM100), which was stepwise replaced by insect meal A (IMA) as a 25% (A25), 50% (A50) or 100% (A100) FM replacement or insect meal B (IMB) as a 25% (B25) or 100% (B100) FM replacement. Diets were analyzed for nutrient composition and contaminants. A25, A50 and A100 performed equally well as the FM100 group. The feed intake decreased moderately with increasing IMA inclusion however FCR decreased resulting in an equal net growth of the fish. Histology did not show any differences between any of the dietary groups and sensory testing of fillets did not reveal any significant differences between groups. The favourable AA profile and the high medium-chain fatty acid content make IM a promising ingredient for use in diets for Atlantic salmon. The method of nutrient isolation and processing of the IM has an important impact on the performance of the product.

1 Tacon, AGJ and Metian, M (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future perspectives. Aquaculture, **285**, 146-158.
2 Hardy, RW (2010) Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal. Aquac. Res., **41**, 770-776.
3 Van Huis, A (2013) Potential of insects as food and feed in assuring food security. Annu. Rev. Entomol., **58**, 563-583.

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Use of *Tenebrio molitor* larvae meal in diets for gilthead sea bream *Sparus aurata* juveniles

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Fish meals are currently the main ingredients in the diets for carnivorous fish species, due to their high protein requirements [1]. However, there are serious doubts about the economic, biological and ecological sustainability of their use in aquaculture. A class of alternative protein sources could be represented by insect meals, and in particular by insect larvae meals that for their chemical composition, more closely match the nutritional requirements of fish species [2]. Tenebrio molitor (mealworm beetle), is a coleopter belonging to the family Tenebrionidae.

The aim of the study was to evaluate the effect of the inclusion of Tenebrio molitor larvae meal (TM) in practical diets for gilthead sea bream (Sparus aurata) juveniles on growth and feed efficiency. The trial was carried out in an indoor water recirculating system using 207 gilthead sea bream (45 g average initial body weight) randomly distributed in 9 fiberglass tanks. Three isoenergetic and isoproteic diets (Total lipid 19%; crude protein 44%; Gross energy, 23 MJ kg–1) were formulated: a control diet (FM), in which 999" fish meal was the sole protein source; TM25 and TM 50 diets in which 25% and 50% of fish meal protein was replaced by Tenebrio molitor larvae meal. Each diet was experimentally tested in triplicate.

Fish were daily hand-fed twice a day (9:00 and 16:00) to visual satiety. The water temperature ranged between 21-23 °C. The trial lasted 60 days and at the end fish were group weighted.

For each experimental group, weight gain (WG), daily intake rate (DIR), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were determined. The whole body composition of 6 pooled fish per replicate group were analysed for proximate composition.

The results showed that up to 25%, the inclusion of TM meal in diet did not lead to adverse effects on WG and final weight, while a slight depression was observed for PER and FCR. TM 50 induced growth reduction and less favourable outcomes for SGR, FCR and PER. The whole body proximate composition analysis did not show any differences between treatments.

These results showed that the substitution of fish meal protein in diets for gilthead sea bream juveniles is feasible up to 25% without adverse effects on growth performance and whole body proximate composition.

1 FAO (2014) Food and Agriculture Organization of the United Nations- Fishery Statistics: http://wwwfao.org/fishery/statistics
2 Barroso, FG, De Haro, C, Sánchez-Muros, MJ, Venegas, E, Martínez-Sánchez, A et al. (2014) The potential of various insect species for use as food for fish. Aquaculture 422–423: 193–201.

The authors thank gratefully to Gaobeidian Shannong Biology CO., LTD (Gaobeidian, Hebei province, China) for providing Tenebrio molitor meal

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Mealworm (*Tenebrio molitor*) as a potential ingredient in practical diets for rainbow trout (*Oncorhynchus mykiss*)

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The sustainability of the aquaculture industry greatly depends on the ability to find good replacements for fish meal, characterized by the same nutritional quality, cost and market availability, and easily manageable for the requested uses [1]. Nowadays there has been a growing interest in animal protein sources from insects. Recent experimental trials showed the possibility to use insect meal as alternative source of protein and fat in aquafeeds for cultured fish, without negative effects on growth performances [2-3]. Among insect meals, mealworm (*Tenebrio molitor*) (MW) is a good candidate as raw material for fish nutrition due to its high protein and lipid content. The aim of this research was to evaluate MW as a potential substitute for fish meal in rainbow trout diets. The MW was characterized on the basis of proximate analyses, fatty acid profile and amino acid composition and then two experimental diets were formulated to be isonitrogenous (crude protein 45%) and isoenergetic (21.5 MJ kg^{-1} dry matter) with increasing levels of MW (25%, and 50%, respectively) tested against a control diet without MW (MW0). A feeding trial was performed on quadruplicate groups of 30 rainbow trout (mean initial weight: 115.9 g) fed experimental diets for 75 days. At the end of the trial, the growth performance traits were determined and viscera and hepatosomatic indexes were calculated on nine fish per each treatment. Moreover, dorsal muscle tissues were sampled and analyzed for their proximate composition. Statistical differences did not appear for any of the growth performance traits considered, while as far as the somatic indexes are concerned, fish fed the 25% and 50% MW diets showed the lowest hepatosomatic index values (1.80 and 1.62, respectively). Fish proximate composition did not show any statistical difference among treatments. In conclusion, the main result of this study is that the MW can be used at an inclusion level of up to 50% without a growth performance reduction in rainbow trout feedstuffs, leading to a saving on fish meal protein.

1 Tacon, AGJ, Hasan, MR, Metian, M (2011) Demand and Supply of feed ingredients for farmed fish and crustaceans: Trends and Prospects. Technical Paper No 564, Food and Agriculture Organization of the United Nations, Rome, Italy.
2 St-Hilaire, S, Sheppard, C, Tomberlin, JK, Irving, S, Newton, L, *et al.* (2007) Fly prepupae as a feedstuff for rainbow trout, *Oncorhynchus mykiss.* Journal of the World Aquaculture Society, 38 (1), 59-67.
3 Barroso, FG, De Haro, C, Sánchez-Muros, MJ, Venegas, E, Martínez-Sánchez, A, *et al.* (2014) The potential of various insect species for use as food for fish. Aquaculture 422–423: 193-201.

The authors thank gratefully to Gaobeidian Shannong Biology CO., LTD (Gaobeidian, Hebei province, China) for providing Tenebrio molitor meal

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Substitution of fish meal by *Tenebrio molitor* meal in the diet of *Dicentrarchus labrax* juveniles

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The aim of the study was to evaluate the effect of the inclusion of *Tenebrio molitor* meal (TM) - as an alternative protein source in practical diets - on growth and feed efficiency of European Sea Bass (*Dicentrarchus labrax*) juveniles. Three experimental diets were prepared by replacing fish meal by graded levels of TM (TM 0%, TM 25% and TM 50%). All diets were isonitrogenous (CP 54.6% on wet basis) and isocaloric (22 MJ kg^{-1}). Four hundred and fifty sea bass juveniles of 5.23±0.82 g (initial body weight ± sd) were individually weighed and randomly distributed in 9 circular fiber glass tanks (500l) supplied by borehole sea water. The water temperature ranged between 19-20^{o}C. Each diet was assigned to triplicate groups of 50 fish and feed was distributed to apparent satiation by hand, twice a day for 7 days per week. All feed was consumed by fish without feed loss.

At the end of the feeding trial, the performance traits of weight gain, specific growth rate, feed conversion ratio and feed consumption were evaluated. The diets and the whole body composition of ten pooled fish per replicate group were analysed for proximate composition, gross energy and fatty acid composition.

The results showed that up to 25%, the inclusion of TM meal in diet did not lead to adverse effects on weight gain, while at 50% level, TM induced growth reduction and less favourable outcomes for both specific growth rate and feed consumption ratio. Protein efficiency ratio and feed consumption were not affected by the inclusion of TM. The whole body proximate composition analysis did not show any differences between treatments. On the other hand, TM inclusion influenced the fatty acid composition of body lipids. In particular, a decrease in the contents of EPA (from 395.07 to 164.10mg/100 g) and DHA (from 619.88 to 203.26 mg/100 g) were observed with the increase of the inclusion to 50% TM.

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The authors thank gratefully to Gaobeidian Shannong Biology CO., LTD (Gaobeidian, Hebei province, China) for providing Tenebrio molitor meal

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Insects are a sustainable alternative to fishmeal in aquaculture feed. Past and future

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The decline in catches of wild fish at a rate of 0.5% per year is occurring simultaneously with the rapid growth of aquaculture production (FAO, 2010). The paradox of aquaculture using 30% of wild fish catches to produce fishmeal and fish oil to feed farmed fish has encountered the opposition of consumers (Tiu, 2012). In order to replace such decried and expensive ingredients, soya and other terrestrial plants have been introduced in the feed of aquaculture fish (Hardy, 2002). However, the feeding carnivorous fish with plants, the competition for arable land used for human consumption together with the amount of energy and water necessary to produce the protein-rich plants does not make this a sustainable alternative to fishmeal and fish oil. Total replacement of fish meal as the protein component of diets may be problematic because of the high sensitivity of carnivorous species to dietary imbalances, antinutritional factors present within plant meals (Francis et al., 2001) and palatability problems (Papatryphon and Soares, 2001). Total replacement of fish oil using plant and animal oils (Koshio et al., 1994) was also very problematic particularly for carnivorous fish because of their specific dietary requirements for long-chain unsaturated fatty acids. Studies on finishing diets to manipulate the final tissue fatty acid profile and product quality are undertaken (Bell et al., 2004; Morris et al., 2005). Fish feed more efficiently on animal proteins than plant proteins (Boonyaratpalin, 1997) and wild freshwater and even marine fish do feed partly on insects and on their aquatic crustacean cousins. Insects have been used as baits for recreational fishing of both freshwater and sea water species. Therefore, introducing insects in the formulated diet of fish seems a much more sustainable alternative:

Insect larvae can transform low quality organic waste into fertilizer for the next-generation of plant growing, thus providing an excellent recycling method. The cold-blooded insect larvae are very efficient producers of proteins and lipids because they do not consume energy to create body heat like farm animals, which are nowadays the main providers of proteins for human consumption. Their production does not require arable land, nor does it need high amounts of energy or water and it releases smaller quantities of greenhouse gases and ammonia into the environment. They are rich in amino acids, fat, vitamins and minerals. For these reasons, the use of insects in animal feed and aquaculture feed (mainly for freshwater aquaculture fish species) has started in Asian, African and South American countries where regulations authorize their use. In Europe, future regulation is envisaged for fish and chicken as suggested by current studies such as PROteINSECT.

The present abstract will describe the use of insects (larvae and adults) in aquaculture feed for freshwater and marine fish. It will attempt to cover the hurdles and advantages of using insects in fish feed, the scientific advances on the subject and emphasize its potential use for the future.

1 Bell, JG, Henderson, RJ, Tocher, DR, Sargent, JR (2004) Replacement of dietary fish oil with increasing levels of linseed oil: modification of flesh fatty acid compositions in Atlantic salmon (*Salmo salar*) using a fish oil finishing diet. Lipids 39, 223-232.
2 Boonyaratpalin, M, (1997) Nutrient requirements of marine food fish cultured in Southeast Asia. Aquaculture 151, 283-313.
3 Francis, G, Makkar, HPS, Becker, K (2001) Antinutritional factors present in plant-derived alternate fish feeding ingredients and their effects in fish. Aquaculture 199, 197-227.
4 Hardy, RW (2002) Rainbow trout, *Oncorhynchus mykiss*, in: Webster, C.D., Lim, C.E. (Eds.), Nutrient requirements and feeding of finfish for aquaculture. The Haworth Press, Binghamton, New York, USA, pp. 184-202.
5 Koshio, S, Ackman, RG, Lall, SP (1994) Effects of oxidized herring and canola oils in diets on growth, survival, and flavor of Atlantic salmon, *Salmo salar*. J. Agric. Food Chem. 42, 1164-1169.
6 Morris, PC, Haughton, P, Black, A, Hide, G, Gallimore, P, Handley, J (2005) Full-fat soya for rainbow trout (*Oncorhynchus mykiss*) in freshwater: effects on performance, composition and flesh fatty acid profile in absence of hind gut enteritis. Aquaculture 248, 147-161.
7 Papatryphon, E, Soares, JH (2001) Optimizing the levels of feeding stimulants for use in high-fish meal and plant feedstuff-based diets for striped bass, *Morone saxatilis*. Aquaculture 202, 279-288.

8 Tiu, LG (2012). Enhancing sustainability of freshwater prawn production in Ohio. Ohio State University South Centers Newsletter 11, 4. BACK TO overview oral presentations. BACK TO overview posters

Mass production system of housefly (*Musca domestica*) for waste reutilization and as feed for chickens and shrimps

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Chicken production in China produces millions of tons of manure waste to pollute the environment. In other words, the industry imports 70% of the consumed animal proteins for chicken feed production. How to solve this problem is an issue for the government and the industry. Reutilization of the manure waste into valuable insect protein by housefly is considered to be a potential way. Large-scale housefly production system by using chicken manure is established in China to provide fresh maggots for feeding chickens and shrimps. The system contains several improvements of the rearing process: (1) pretreatment of the manure by heat, and addition of useful bacteria to improve the maggot yields; (2) efficient maggot separation from the manure by low oxygen; (3) clean processing; (4) automation design for manure treatment and maggot rearing. The fresh maggots were used to feed the chickens and shrimps for improving the favor and disease tolerance of the test animals. The cost estimate of the fresh maggots is comparable to the industrial chicken and shrimp feed from the market.

The work is supported by EU Project "Enabling the exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition" (PROteINSECT, Grant agreement no: 312084), and National program of Science and Technology (2012BAD14B16).

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Nutrient digestibility of *Hermetia illucens* and *Tenebrio molitor* meal in broiler chickens

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Poultry meat is a market increasing all over the world thanks to the absence of cultural or religious obstacles. One of the factors that most influence the costs of broiler production is the price of protein source. Invertebrates are a raw material included in the Feed Register Material of the EU and, for this reason, they could represent a material for feed manufacturing. In this regard many studies have already been performed, especially by teams from developing countries to find unconventional protein sources such as maggot [1], house fly pupae [2], silkworm [3] meal.

Thirty 1-d-old male broiler chickens (Ross 708) were raised in floor pens until the age of 19 d and fed a diet formulated to meet their requirements. From the age of 19 d, birds were kept individually in 2-floor cages. At the age of 25 days a basal diet (BD) was administered for the adaptation period lasting 5 d. Two assay diets were developed by substituting 250 g/kg (w/w) of the basal diet with the *Hermetia illucens* (HD) or *Tenebrio molitor* (TD) meal. The apparent digestibility (AD) trial was performed using the total excreta collection method. Digestibility was evaluated from 31 to 34 d. Feeds and excreta were analyzed for dry matter, organic matter, total fat, crude protein [4], and gross energy (IKA C7000, Staufen, Germany).
The nutrient digestibility data were analysed using the one-way analysis of variance, with cage as the experimental unit. Differences were considered to be significant at $P<0.05$ and significant differences between means were separated by the Tukey's least significant difference test.

The AD of dry matter and organic matter showed the same trend and resulted higher for the basal diet than the two tested diets ($P\leq0.001$) (BD=69.2 and 71.5%; HD=64.3 and 68.2% and TD=64.6 and 67.2% respectively). The highest AD of total lipids was found in HD group (97.8%), the lowest in TD group (94.0%) and the intermediate value in BD (95.7%) ($P<0.001$). The AD of crude protein and energy showed the same trend and resulted highest in BD (76.9 and 77.1%), intermediate in HD (69.1 and 75.7%) and lowest in TD (66.1 and 74.3%). Results suggest that the two insect meal tested in the present study are suitable as alternative protein source in broiler chicken nutrition.

The authors thank gratefully to Gaobeidian Shannong Biology CO., LTD (Gaobeidian, Hebei province, China) for providing Tenebrio molitor meal.

1 Adeniji, AA (2007) Effect of replacing groundnut cake with maggot meal in the diet of broilers. Int. J. Poultry Sci. 6 (11): 822-825.
2 Hwangbo, J, Hong, EC, Jang, A, Kang, HK, Oh, JS, et al. (2009) Utilization of house fly-maggots, a feed supplement in the production of broiler chickens. J. Environ. Biol., 30, 609-614.
3 Ijaiya, AT, Eko, EO (2009) Effect of replacing dietary fish meal with silkworm (*Anaphe infracta*) caterpillar meal on growth, digestibility and economics of production of starter broiler chickens. Pak. J. Nutr. 8 (6), 845-849.
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Parameters affecting larval development in the mass rearing of *Musca domestica* (Diptera: Muscidae)

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Pig manure is potentially a sustainable substrate to rear housefly larvae. Larval development of *Musca domestica* in pig manure was studied in order to apply this knowledge in a mass rearing facility. Various aspects of larval development were analyzed: optimal environmental conditions, different housefly strains, the feed rate in fresh and pre-treated manure, the optimal initial volume of manure and the chemical characterization of the residue obtained after larval feeding. The best environmental temperature for larvae of housefly was 25 to 27ºC; at these temperatures a reduction of almost 80% of the initial manure weight can be obtained. Environmental humidity was optimal at 50-60%; at higher humidity, an early larval mortality occurred. No differences in percentage of feed rate were found between the three different strains of housefly, although some differences in developmental time were observed, which could improve mass rearing of this species. Feed rate was higher in fresh manure than in pre-treated manure, no differences in the number of pupae obtained were observed between the two types of manure. The optimal initial quantity of manure was considered to be 2 or 3 kg for the highest manure reduction and 4 or 5 kg, as the best to optimize space; the higher number of pupae per kg of substrate were obtained in the 5 kg treatment. Chemical differences were observed between initial manure and the residue obtained after larval development: reduction of organic nitrogen was 2-4% and the maximal reduction of total nitrogen was nearly 40%. This technology permits reducing the final volume of waste and obtaining two valorised sub-products: manure residue which can be used as fertilizer and housefly pupae, which can be commercialized with several uses.

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Evaluation and improvement of a house fly larvae production system in Mali

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House fly maggots have the potential to provide proteins to fish and poultry farming in West Africa, both for smallholder farmers as well as for the industry. Traditionally, house fly (*Musca domestica*) larvae used for animal feed in the region are obtained by exposing attractive substrates for fly oviposition. Mature maggots are collected 3-4 days after oviposition and given, fresh or dried, to poultry or fish. In Mali, a fly production system was set up to assess the efficiency of the system and to improve the different stages of production. In particular, different substrates are presently being tested for their attractiveness and suitability to larval growth: chicken manure, sheep manure with fish offal or with dried blood, etc. All substrates can provide good yield, i.e. up to 2-3 kg per 10kg of dry substrate. However, substrates based on sheep manure provide more reliable yields than poultry manure, which shows stronger variations in quality. The main advantage of the "natural system" compared to a system where fly eggs are produced from adult rearing is its simplicity. It requires less manpower and less investment in rearing facilities. In contrast, the issues are that: (1) the yield depends largely on fly populations nearby and, subsequently, will vary with the season, with higher yields in the rainy season than in the dry season; (2) although the majority of the flies are usually house flies, the harvested maggots often comprise several species of various families; (3) the substrate for oviposition needs to be placed on the ground and cannot be more than 10cm thick, thus, the production of large quantities of maggots requires a very large ground surface; (4) the system may cause nuisance for the neighbourhood. Solutions are provided to overcome some of these problems.

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Efficiency and scalability in producing feed from manure using the common housefly

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BioConVal (BioConversion to Value) is a R&D project carried out amongst Danish R&D institutes and European SMEs. The project aims at developing and demonstrating an integrated system for cultivating pathogen-free fly larvae (*Musca domestica*) in poultry manure locally at farms, and subsequently use them as dietary supplement for the livestock.

The fly larvae are very nutritious and a natural food source for poultry. They have an amino acid composition that is similar to fishmeal, and which is especially rich on the essential amino acids methionine and cysteine. Among laying hens, the lack of methionine may lower the production and may possibly lead to feather pecking and cannibalism, a problem often seen in organic farming. Feeding live larvae could help overcome these problems; and is furthermore expected to increase gut health and animal welfare and behaviour. Thus, BioConVal provides a sustainable approach to meeting EU requirements for organic farms (100% organic feed in the near future).

Fly larvae have an amazing ability to convert fresh manure to compost in a very short time [1]. However, many factors influence the cultivation of high-quality larvae, e.g. the manure temperature, dosage of fly eggs, humidity, hatchability of fly-eggs, as well as efficient retrieval of the larvae [2] prior to being applied as feed [3]. To address these issues, a number of laboratory and pilot scale tests have been carried out to optimize the system. Our experiences from BioConVal will be disseminated in this presentation highlighting efficiency and scalability, which are key to establishing a commercially viable system.

1 Wang, H, Zhang, Z, Czapar, GF, Winkler, MK, Zheng, J (2013) A full-scale house fly (Diptera: Muscidae) larvae bioconversion system for value-added swine manure reduction. Waste Management & Research 31:223-231.
2 Čičková, H, Kozánek, M, Morávek, I, Takác, P (2012) A Behavioral Method for Separation of House Fly (Diptera: Muscidae) Larvae from Processed Pig Manure (2012) Journal of Economic Entomology 105:62-66.
3 Van Huis, A (2013) Potential of insects as food and feed in assuring food security. Annual Review of Entomology 58:563-583.

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Utilization of *Hermetia illucens* larvae for the production of food and feed

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The black soldier fly (*Hermetia illucens*) is a sustainable and resource-efficient alternative protein as well as food and feed source. It can be utilized for the conversion and valorization of organic waste and has a high potential for the application e.g. in the aquaculture as a fish meal replacer [1].

The Hermetia Baruth GmbH produces black soldier fly larvae and pupae on an industrial scale and an overview of the production process is given. It is divided into substrate acquisition and preparation, insect rearing and harvesting process, and the formulation of the final product. Besides the challenge to choose a cost-efficient as well as nutrient-efficient substrate, further optimization of the rearing conditions for the improvement of mating, oviposition and larval as well as pupal development is still researched.

For the application of the live insect, the processed insect and insect – based products as food and feed stuff, legal as well as safety aspects need to be considered. Regarding the microbial safety of products based on insects, different decontamination methods are compared concerning their inactivation and storage stability. Thermal traditional processing methods such as cooking and baking have been compared with non-thermal cold plasma treatment and high hydrostatic pressure treatment on the microbial surface as well as overall activity of mealworm larvae as an example. The applicability of these results on the black soldier fly remains to be determined since the species differ in size, volume and composition.

1 Diener, S, Zurbrügg, C, Tockner, K (2009) Conversion of organic material by black soldier fly larvae: establishing optimal feeding rates. Waste Manag Res 27, 603-610.

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Cactus as feedstock to produce protein from *Hermetia illuscens* in South Africa

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Insect is often misrepresented as a resource of protein, while it is tool to recover nutrients in a usable form from low value waste and animal manure. While only 10% of world land area is arable, humans try to produce food, feed, fiber, fuel from it with conventional crops limited to only 6 main plant species. The real challenge of using insects to feed the world is to base it on a sustainable primary plant producer, which can grow on marginal non-arable land to feed livestock integrating a process of bioconversion using *Hermetia illucens*. The preliminary results provide evidence of the capacity of using drought tolerant Spineless cacti as a sustainable feedstock for the production of: 1- *Hermetia illucens* to sustain small livestock production in Africa (Fish, Guinea fowl) 2- Cattle combined to *Hermetia illucens* to process the manure. Data will be presented to show the capacity of bioconversion combined to fermented spineless cactus on 1km² semi-arid land area based on the work conducted at the Zimbabwean border of South Africa near Musina.

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Black soldier fly–Microbes Union: Efficient waste recycling agent and valuable renewable resource[§]

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[§]The study was supported by Project 31301913 supported by NSFC.

Black soldier fly (BSF), *Hermetia illucens* (L.), has been considered as a sustainable method for reducing decomposing organic material, especially animal manure and plant wastes. Larvae reduce dry matter, bacteria, offensive odor and house fly populations during conversion. Resulted larval and prepupal biomass can be used as feedstuff for livestock and poultry. A great deal of research has been done on BSF, including its rearing method, development traits, waste management and feeding value, etc. However, there has been not much relevant research that took the role of microbes into account which actually is very important and interacts a lot with BSF.

We domesticated a native and new strain of BSF, Wuhan strain, and an improved breeding system has been established in which new egg hatching device is used and artificial lights and attractant microbes are employed to enhance the mating and oviposition. To know better and make better use of BSF, we have done some studies on its microbial ecology. Using 16S rDNA 454 pyrosequencing, we examined bacterial diversity associated with successive life stages of the BSF. Bacteroidetes and Proteobacteria were the most dominant phyla associated with the BSF accounting for two-thirds of the fauna identified. Of the bacteria found associated with the egg stage of development, 15% were shared by first and second generation samples suggesting the possibility of vertical transmission and retention of bacteria through successive developmental stages. Oviposition sites preference (OSP) tests indicated that ovipositional substrates acted as a long distance attractant during oviposition site detection and fresh conspecific eggs had an effect of stimulation on oviposition behaviour. Further OSP tests of sterile eggs showed that egg-associated bacteria were the major source of this aggregation stimulus. Growth study with sterile BSF larvae obtained by egg surface sterilization was conducted, and it is shown that those egg-associated bacteria are also very important to the development of BSF larvae. We have cultured a series of microbial strains, BSF probiotics. Those microbes involved in life activities of BSF and could be used for co-conversion with fly, enhancing the fly growth and waste conversion efficiency. Feeding value and potential utilization for bioenergy of fly biomass were evaluated. We believe a union of BSF and microbes could improve the current artificial breeding system of BSF, enhance the processing capacity of the waste management system, and increase the final insect biomass yields.

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Getting people to eat more insects

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On the one hand, in the developed world, insect consumption is rare, but the technology would be available to efficiently farm them if there were a demand. On the other hand, many cultures in the developing world consume insects and favor them as food, but rarely farm them. Behavioral research on insect consumption in the developed world should reasonably focus on insect acceptance and consumption, whereas in the developing world it should have the dual foci of encouraging both consumption and farming.

The present study focuses on resistance to consuming insects, based on survey responses of approximately 200 American adults and 200 Indian adults. Most subjects are middle class. We developed a measure of insect acceptance, based on three types of questions. A substantial minority of individuals in both countries are reasonably positive about the prospect of consuming insects, and a smaller minority are completely resistant to trying insects in any form as food. In both cultures, the insect group that people are most positive about consuming is ants, and the most negative is cockroaches. In both cultures, the most favored way to consume insects is with insect flour, incorporated into a favored food.

In both samples, a factor analysis of beliefs and attitudes about insects reveals three categories: 1) Beliefs about possible harm (e.g., infection, toxins) resulting from consuming insects, along with disgust or distaste at this prospect; 2) Beliefs about the benefits (nutritional, environmental) of consuming insects; 3) Attitudes about the morality of consuming insects. Indians are more negative about consuming insects than Americans, with the biggest difference being that the Indians are much more likely to say that eating insects is immoral.

What predicts the inclination to accept or at least try foods containing insects? When asked an open-ended question about why they reject insects as food, the majority of respondents in both countries indicate “disgust.” We predicted insect acceptance using both demographic and psychological (scaled) variables. Substantial predictors include: gender (less acceptance in females, especially in the USA), beliefs about the risks of consuming insects, beliefs about the benefits of consuming insects, desire to have new and stimulating experiences (sensation seeking), risk tolerance, food neophobia (resistance to trying new foods) and trait disgust sensitivity. Surprisingly, moral attitudes to killing and eating insects are poor predictors of acceptance.

We discuss implications of these findings, as well as the importance of investigating why, among the many developing cultures that consume and favor insects as food, almost none seriously farm them.

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Welcoming the world to our table: Hospitality and edible insects

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Development of the “edible insects sector” as an element in sustainable global food security, and also as an underutilized economic opportunity, is an exciting and important project. At its core, this work is centered on the human meanings of food. Food choices, production, preparation, presentation and consumption are deeply and uniquely human activities. The global agribusiness and food production systems tend to reduce food and eating to nutrient delivery systems. For example, researchers are attempting to establish production levels of insect cell lines for meat production, and elsewhere a team of students from Guelph University won the $1 million (USD) Hult Prize in social entrepreneurship for their proposed commercial distribution of insect flour. They claim the new product removes the “yuck” factor. Insect flour is for a limited and specialized market, well out of the mainstream of food production and distribution. Will such high profile projects clear the way, or merely reinforce attitudes that food insects are ‘starvation’ or ‘ghetto food’?

While a secure and stable adequate insect-based nutrition supply system contributes to the necessary conditions for human flourishing, success in adopting insects into mainstream diets involves a complex of psycho-social-cultural factors. Food is more than nutrition, calories, vitamins and fiber. It is also central to cultural identity, community formation, and building relationships among friends and strangers. Recognition of these cultural aspects is critical in overcoming the strong psychological barriers to edible insects evident in the West. Insects, for most Western peoples, are not merely an unfamiliar ethnic food. Rather they have come to symbolize negative and dangerous characteristics. Even the thought of consuming food insects evokes a visceral rejection, not only of the animals but of those who consume them. We have investigated how this negativity might be overcome with popular “Bug Banquet” presentations. And we have explored the depth of disgust that has unconsciously influenced the structures and policies of food systems, and remains a significant challenge to public acceptance of edible insects. Appeals to safety, nutrition, novelty, or economic benefit, or attempts to make edible insects more widely available, may be insufficient to break down these barriers. To effectively promote insects as human food we must attend to the ways in which food is an expression of cultural and personal identity. Food insects must become a means of creating and sustaining community, and be seen as an expression of hospitality—welcoming the stranger.

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Moving beyond the *Bizarre Foods* concept and tapping the "foodie" culture to promote entomophagy

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Insects have been consumed for hundreds of years in non-Western cultures, where their value as a renewable and nutritious source of food has been recognized and even revered. The disjunction of Western/First-world countries, and especially the United States, from how its own food resources are produced and the environmental costs they entail, only help to propagate the notion of insects as an exotic novelty food item – not a viable food source.

"Foodies" across the globe, and especially in the West, can be the economic drivers of change in food culture. The expansion of "organic" and "locally-produced" food markets in the United States are evidence of this shift in thinking and food consumption. Tapping into the mind-set of this sector of the economy, could be a viable route towards moving the average consumer into seeing insects as a viable and necessary alternative to eating large quantities of commercially-raised beef, pork, poultry and fish.

However, there is still the "creepy" factor of eating insects to overcome and the introduction of dishes and food products that are made from insects, but don't look like insects is a route that needs to be explored.

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The role of design in introducing insects to the UK diet

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Ento is a design-driven insect foods company in the UK, formed by four graduate designers and engineers from the Royal College of Art and Imperial College London.

For the past 18 months, Ento have been creating well-designed eating experiences and developing appealing recipes with insects, with the aim of establishing entomophagy in mainstream food retailers by 2020. Our roadmap for achieving this consists of carefully designed food products and delightful experiences that gently challenges the Western cultural taboo against insects, and normalises them as a source of food for the public. In this talk, Aran Dasan of Ento Foods Ltd. will talk about the role that design plays in encouraging the consumption of insect-based food in the (sometimes) unwilling West.

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Willingness to pay for new food products from insect protein: Initial evidence from a choice experiment study in Kenya

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In developing countries, climate change and shortage of water pose tremendous challenges on traditional farming which can lead to a failure to meet the rising demand for animal protein. Meanwhile, the population living in this part of the world keeps increasing causing the demand for protein to increase substantively in a foreseeable future. As a result, other sources of protein should be introduced to meet this rising demand, and in this regard, insects can play a significant role in terms of serving as a vital source of protein. As a matter of fact, insects are already being consumed in some parts of the world. However, they are typically harvested in the wild and no formal insect food sector is identified to date. This is partially because their roles in terms of achieving food security are inadequately investigated. Most notably, there exists no scientific evidence in relation to the potential demand for food products originating from insects. In this paper, we will assess the market potential in terms of consumer acceptance of and preference for introducing new insect-based food products in Kenya. Using a discrete choice experiment method based on quantitative interviews with a representative sample of respondents from rural and urban areas, we will estimate consumers' willingness to pay to reveal demand for insect-based food products and reflect the associated marketing opportunities for potential agribusinesses engaged in producing food products using insect proteins. We expect the following results from the choice experiment analysis:

- that individuals are willing to pay for new insect-based food products suggesting the feasibility of establishing small-to-large-scale insect production agribusiness sectors in Kenya,
- that our estimation results from mixed logit models will validate the expectation that respondents are willing to pay more for insects characterized by high nutritional content and high level of food safety standards,
- consumers' preference differs for insect foods provided as *whole insect* and as *paste* with a mixture of other ingredients,
- that the specific types of insects have a big impact on preferences even if all other factors are kept alike,
- that respondents are very sensitive to the type of feed basis (e.g. municipal waste, brewery waste and human feces) used to rear insects,
- and therefore, our findings, generally, demonstrate that there is a considerable demand for food produced from insect proteins, and therefore, policy makers can use results to explore means of promoting edible insect production in Kenya.

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Longitudinal changes in acceptance of edible insects by students at Montana State University

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Western culture attitudes toward the value of edible insects dramatically changed in the US in the past 20 years. Montana is one of few US states whose main revenue is still derived from agriculture or natural resources. Macro-livestock, particularly beef and bison, is a strong part of the business climate in this agriculture state. Simultaneously during these twenty years there was a rapidly growing national and international public education and awareness process emanating from State of Montana's Land Grant University, Montana State University (MSU). We tested the hypothesis that acceptance of edible insects has significantly increased during these two decades among MSU students and now the ramifications are seen in a campus and statewide acceptance of the importance of edible insects among Montana faculty, families of young children, and teachers in preschools, middle schools, and high schools. Acceptance rate of entomology students rose from 35% to 80% 1994-2014. Reasons for acceptance changed from taste to personal nutritional health to environmental sustainability. In 2014, 100 community members, restaurants / catering services in the Bozeman and Big Sky area of Montana were surveyed as were 60 Montana teachers of family and consumer science and instructors in statewide sous-chef training programs. Personal acceptance rate of high school teachers is not as high as students but most were planning to use the "new" food source in their high school curriculum. One hundred percent of restaurants interviewed are interested in putting insects on their menu or already have.

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Introducing Entomophagy to America through children's education and culinary events

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Americans have been notoriously against entomophagy, but the tide is turning; could cricket cowboys be around the corner? With resources thin and the number of hungry growing, innovative startups are gearing up to bring to the people, and the people are loving it.

Little Herds is an Austin-based nonprofit organization educating the public, particularly children, about the environmental and health benefits of eating insects. In the past year Little Herds has served almost 4,000 people insects in Central Texas. Little Herds also serves to support the growth of the entomophagy industry, facilitating important dialogues between regulators, insect farmers, chefs, businesses and the public to encourage the western world to adopt insects into their daily diet. Earlier this year, Little Herds brought together innovative American companies like Chapul, World Entomophagy and Six Foods at the Future Food Salon ATX.

A 20-minute presentation will provide a short overview of our major activities, events to date, and plans for the future. We'll also provide a broad overview of North American edible insect market dynamics and key industry players. The following topics will be covered:

Insect farming for human consumption — Divergent roles of small and large scale farms to supply insects for new and varying consumer preferences.
Edible insects in the culinary world — Which chefs are already cooking with insects and how cultural cuisine will help herald a change.
Insect-based products —The US is leading the way in setting-up businesses that make edible insect-based products: cricket flour, energy bars, chips, cookies and more; who the major players are and what stage of commercialization they are at.
Overcoming the challenges — For greater adoption of edible insects in North America, education and a broad appeal to niche markets will play crucial roles; how we're overcoming the taboo.

The presentation will be supported by two short videos from Little Herds' educational events showing the response to edible insects from children and adults.

See more information at www.littleherds.org

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Can mass-production of insects contribute to alleviating malnutrition in developing countries?

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Worldwide malnutrition is responsible for 45% of preschool child deaths [1]. Animal-source food (meat, milk and fish) are recognized as a key to optimal growth and health of children [2] and have been shown to improve growth, muscle mass and cognitive function in children in food insecure settings. Improved access to nutritious animal-source food can prevent child undernutrition and death. Domestication and mass-production of Insects may be a sustainable, cost effective alternative to traditional livestock products.

Insects are generally perceived to be nutritionally beneficial to humans. However, the nutritional composition is highly variable with species and metamorphic stage, and evidence-based knowledge of nutritional advantages and potential harms – for example allergic risks of high chitin intake - is needed. Generally, the macronutrients composition of insects is as characteristic for meat and fish, with 50-70 % protein of dry weight, but highly variable. Fat contents are found up to 50%. Exoskeleton chitin contributes up to one third of the dry weight. Pioneering investigations of nutritional quality of protein (digestibility scoring) and fat quality are reported, but much remains to be researched to conclude on the general nutritional contribution. Protein digestibility ('PDCAAS' score) has been investigated for silk prepupae and pupae (*Samia ricinii*) and found comparable with fish. For fatty acids, n-3 fatty acids are highly critical to be deficient in diets in developing country [3]. The n-6:n-3 ratio was found to be 3:1 in field cricket (*Teleogryllus testaceus*) and similar in Cambodian spider (*Haplopelma sp*), while the ratio in four East-African termite-species were less advantageous, between 10:1 and 60:1. For cultured insects, the feed source will impact the fat quality similar to findings in fish culture. For minerals and vitamins, reported contents of minerals and vitamins in edible insects across species are highly variable with findings of species with high contents of iron and zinc, nutrients highly critical to be met in diets in developing countries. The bioavailability of minerals in humans remains to be investigated. We recently completed a human intervention study in children in Cambodia receiving a food with 2% edible spider in comparison with other foods [4]. The results were inconclusive with regard to impact of spiders on iron and zinc nutrition and call for studies specifically on arthropods [5].

Domesticated mass-production of insects holds a potential to contribute to improve the dietary quality in food insecure populations and the quality in food products for preventing malnutrition, in settings accepting entomophagy.

1 Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de OM, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, Uauy R (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet; 382:427-51.
2 Michaelsen KF, Hoppe C, Roos N, Kaestel P, Stougaard M, Lauritzen L, Molgaard C, Girma T, Friis H (2009) Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. Food and Nutrition Bulletin; 30:S343-S404.
3 Michaelsen KF, Dewey KG, Perez-Exposito AB, Nurhasan M, Lauritzen L, Roos N (2011) Food sources and intake of n-6 and n-3 fatty acids in low-income countries with emphasis on infants, young children (6-24 months), and pregnant and lactating women. Maternal and Child Nutrition; 7:124-40.
4 Skau JKH, Bunthang T, Chamnan C, Mary C, Unni US, Filteau S, Wieringa F, Dijkhuizen M, Ritz C, Wells J, Berger J, Roos N (2013) Effects of animal-source foods and micronutrient-fortification complementary foods on body composition, linear growth, iron status - the WinFood project in Cambodia. Tropical Medicine & International Health 2013:18:87 (abstract).
5 Skau JKH, Bunthang T, Chamnan C, Wieringa FT, Dijkhuizen MA, Roos N, Ferguson EL (2014) The use of linear programming to determine whether a formulated complementary food product can

ensure adequate nutrients for 6-to 11-month-old Cambodian infants. American Journal of Clinical of Nutrition, 99:130-8.

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Sustainable critters or delicious fritters? Consumer perceptions of edible insects in the Netherlands and Thailand

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[4] Consumer Science & Intelligent Systems, Wageningen UR Food and Biobased Research, Bornse Weilanden 9, 6708 WG, Wageningen, The Netherlands

Insects are considered a promising source of sustainably-produced protein-rich foods. Efforts to promote the consumption of insects in the West have largely focussed on sustainability, but despite strong public interest in sustainability, the arguments presented are insufficient to convert consumers unaccustomed to eating insects. This cross-cultural qualitative study explored the basis of acceptance and rejection of various insects and insect-containing foods amongst Thai consumers, from a culture where insects are part of the cuisine, and Dutch consumers, from where insects are generally not considered food. Eight focus groups were conducted, four in each country, of which two consisted of participants who do not eat insects and two who have eaten insects. Motivations, preferences and decisions were discussed to understand how prior exposure to insects as food influence the way it is perceived and evaluated.

Liking or aversion of insect-containing foods was found to be an interplay of cultural and individual preferences and motivations. Extrinsic motivators such as healthiness and sustainability might arouse interest but do not overcome the psychological barriers to consumption. When presented with images and actual snacks, sensory expectations and perceived appropriateness played a dominant role in the intention to eat. Prior experience influenced whether evaluations were based on actual tasting experiences or on insect- and appearance-related associations. Liking was not only dependent on sensory factors, since a tasty species with tasty accompanying ingredients could be rejected if the combination is not considered appropriate. In some cases insect-containing foods could also be rejected simply because it is not regarded as food. Curiosity could also drive intentions to try, irrespective of actual liking. This study implies that the promotion of insects should not solely focus on communicating its functional benefits but should pay due attention to creating products that suit consumer expectations in their own cultural context.

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Effect of edible termite-based complementary foods on growth and microutrient status of 6-15 month old Kenyan infants – a randomised trial

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Background: The period of transition from breast milk to solid food is highly critical for development of undernutrition in food insecure populations. Complementary foods must meet the requirements of the growing infant. The efficacy to support growth and nutritional status in Kenyan infants receiving a daily portion of either two versions of a locally produced complementary foods based on maize and germinated amaranth grains with or without termites ('WinFoods') was assessed and compared to a standard food aid product ('Corn-Soy-Blend plus (CSB+)).

Methodology: In a randomized controlled design, 428 infants received Winfoods for 9 months from 6-15 months of age. Growth and nutritional status were assessed as weight and length gain, change in fat-free mass (FFM) by a stable isotope methodology, hemoglobin concentration and biochemical iron status parameters. The randomization between the 3 food groups was blinded for the investigators.

Results: There were no significant differences in growth (weight and length gain, and change in FFM) between the infants receiving different foods (A, B and C), with or without termites. Weight relative to WHO standards (weight-for-age (LAZ)) for food was not significantly different at both 6 [-0.2±1.2, -0.3±1.1 and -0.5±1.3, respectively; p=0.07] and 15 months of age [-0.4±1.1, -0.4±1.0 and -0.6±1.1, respectively; p=0.2]. The mean FFM was 6.0±0.8, 5.9±0.8 and 5.9±1.3 kg, respectively; p=0.7 at 6 months of age and 8.2±1.1, 8.3±1.2 and 8.2±1.0 kg, respectively; p=0.7 at 15 months of age. Length relative to WHO standards (Length-for-age (LAZ)) for food C was significantly lower at both 6 [-0.5±1.3, -0.8±1.1 and -0.9±1.3, respectively; p=0.01] and 15 months of age [-1.3±1.1, -1.4±1.1 and -1.6±1.1, respectively; p=0.03]. There were significant differences in Hb among the food groups A, B and C (will be unblinded before presentation) [10.5±1.6, 11.3±1.3 and 11±1.8 g/dl, respectively; p=0.002], transferrin receptor [-0.58±3.7, 1.8±3.1 and 1.1±3.8 mg/kg.bw, respectively; p<0.001] and body iron stores (ferritin) [10.5±1.6, 11.3±1.3 and 11±1.8 g/dl, respectively; p<0.001] at 15 months of age.

Conclusions: We did not detect significant different impact on weight gain, length gain or fat mass from feeding a locally produced complementary food with or without termites compared to a standard plant-based product. However, the foods impacted hemoglobin and iron status differently. The full unblended results will be available for the Insect to Feed the World conference.

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The Flying Food project on crickets in Africa, general introduction

Van Deventer, H.[1], Gianotten, N.[2], De Graaf, M.[3], Kamukama, D.[4], Mancheron, H.[5], Vrij, M[6]

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In many Africa countries there is a need for food that adds nutritional value to the daily diets of people at the Base on the Pyramid. In the daily food intake especially proteins are missing due to the relatively high costs for meat, fish, etc. In many countries the diet is supplemented with insects, caught from the wild and only seasonal available. Great potential is expected from rearing insects, more specific crickets, as a continuous source of high quality food, containing proteins, minerals and vitamins. The challenge to develop a sustainable business of reared crickets in Kenya and Uganda is subject of the Flying Food project, sponsored by the Dutch Ministry of Foreign Affairs within the FDOV program. This innovative project aims the rearing 55 tons of crickets per month by 4000 farmers in Kenya and Uganda, the processing of crickets, cricket based food design and marketing of cricket based food products. Availability and accessibility of nutritious quality food is increased and entrepreneurship and income generation is facilitated through value chain development.

Based on the knowledge of Kenyan, Ugandan and Dutch partners, rearing of crickets is set up at farmer level. Model rearing centres are set up, forming an example and training facility for other farmers. Although crickets can be eaten directly after frying, cooking or roosting, with growing production there is need for conservation to increase shelf life and product development. Many people prefer crickets processed into food products like flour, cakes, samosa's, meatballs, etc. In order to develop a feasible value chain for crickets and cricket derived products, stakeholder co-creation workshops, selection of farmers / entrepreneurs, consumer testing, marketing and consumer campaigns are included in the project. A sustainable value chain will be developed including processing, packaging, distribution and retail. A model for scaling and the installation of learning alliances / entrepreneurial networks will be set up to support farmers and entrepreneurs with technical and business knowledge and to scale to other regions and countries.

Given the innovative character of the project we constantly need to check whether we are doing planned activities right and are doing the right activities to reach the objectives. Therefor an integrated and flexible mechanism for registration, processing and analyses of context, baseline and progress data will be developed. This is not only an important source for reporting but also for common learning.

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Rearing of crickets in Kenya and Uganda

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Based on the knowledge of Kenyan, Ugandans and Dutch partners, within the Flying Food project rearing of crickets is set up at farmer level. Rearing will be optimized towards optimal growth, egg laying, feed conversion, feed quality, rearing containers and housing. Model rearing centres are set up, forming an example and training possibility for other farmers. Finally cricket knowledge centres in Kenya and Uganda will distribute knowledge and experiences with rearing, but also on food production and processing.

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Processing and new insect based products

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Although crickets can be eaten directly after frying, cooking or roosting, with an increasing production at farmer level, the need for conservation will grow. Fresh crickets are very perishable and for trade and consumption at distant places, there is need for conservation of the crickets to increase the shelf life. Many people prefer crickets processed into food products that have to be developed according to local preferences, like blend flour, cakes, samosa's, meatballs, etc. Once the cricket production has increased, the foundation of processing centres at community level is foreseen within the Flying Food project, as starting point for feasible cricket value chains.

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Market development and business case

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In order to develop a feasible value chain for crickets and cricket derived products, stakeholder co-creation workshops, selection of farmers / entrepreneurs, consumer testing and marketing and consumer campaigns are included in the Flying Food project. A sustainable value chain will be developed including processing, packaging, distribution and retail. A Business Model will be elaborated for supporting farmers and entrepreneurs, infrastructure for production and distribution, based on stakeholder identification, local market insights and market analysis. A model for scaling and the installation of learning alliances / entrepreneurial networks will be set up to support both farmers and entrepreneurs with technical and business knowledge. Also, a model for replication will be developed in order to scale to other regions and countrie
s.

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Triple loop monitoring and learning approach of Flying Food

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Given the innovative character of the Flying Food project we constantly need to check whether: a) we are doing planned activities right, b) we are doing the right activities to reach our objectives and c) our theory of change is correct. For this end we count with an integrated and flexible mechanism for registration, processing and analyses of context, baseline and progress data. This is not only an important source for reporting but also for common learning.

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Cricket Farming, Reproduction and Economic Potential for Small Farmers

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Cricket (*Gryllus*) is widely recognised as a very potential insect, commonly kept by village farmers for food and according to Nakagi (1987) cricket can be used as animal feed. In general, crickets has very short life cycle (60-70 days) with 3 weeks of eggs laying period and egg production within the range of 200-1500 eggs/female. The famale have capability to multiple mating with different male so the eggs can be more fertile (Gregory and Howard, 1996). Serial studies including experiments on laboratory and field observation on farming practices of local crickets have been conducted to evaluate farming practices and reproductive performance of 3 local species (*G. mitratus, G. testacius* and *G.sp*) given local feeds (*Manihot esculenta* and *Carica papaya* leaves). Simple analysis was used to assess the economic feasibility for bussines development. Randomized Block Design was used, species as block, feeds as treatment with 10 replications; each replication consisted 1 male and 5 females. Data were analized using Analysis of variance. Variables measured including feed consumption, feed conversion, egg production, hatchability, hatching period and mortality rates. Data of income and expenses were analysed using R/C ratio and demand trend analysis with time series model.

The results revealed that feeds did not significantly affect feed consumption (0.46/g/cricket/day), feed convertion (0.04), dayly egg production (17.87 egg/female), hatching periode (15.14 days), hatchability (80.48%), and mortality (2.97%) in *G. testacius. G. mitratus* fed on *M. esculenta* leaf had lower feed conversion (0.03 vs 0.04) but higher dayly egg production (36.08 vs 27.15 egg/female). Conversely, Gryllus sp. had on C. papaya had higher feed consumtion than *M. esculenta* (1.60 vs 1.56 g/cricket/day). The R/C ratio of was 1.4, indicating a significance provit received by farmers from the small scale cricket enterprises. Market demand for crickets as animal feed increased monthly, this result was supported by Widyaningrum (2001), therefore, it could be as alternative for farmers to improve their income regularly.

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Nakagi, B J., Sunde M L and Defliart G R. 1987. Protein quality of the house criket, *Acheta domesticus*, when fed to broiler chiks. J. Poultry Sci. 66 : 1376-1371.

Widyaningrum, P., Fuah A M, Sihombing D T H. 2000. Productivity of the two types of local cricket *Gryllus testaceus Walk* and *Gryllus miratus Burn* (*Orthopetera: Gryllidae)* are cultivated. J. Biology News 5 (2): 169-175.

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Nutritional assessment of the rare edible monster crickets and soldier termites consumed in the South-Eastern districts of Zimbabwe

Musundire, R.[1*], Zvidzai, C.[1], Chidewe, C.[2], Shonhe, Y.[1], Mawire, P.[1], Manditsera, F. and Masheka, A.

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Consumption of the occasionally occurring *Henicus whelani* and termites *Macrotermes* species is prevalent in South eastern districts of Zimbabwe characterised by frequent droughts and low fertile soils. However, lack of scientific data on nutrient and anti-nutrient composition may limit health benefits associated with consumption of these insects. This study was conducted to investigate nutritional and anti-nutritional components of *H. whelani* and soldier termites. Experiments were conducted with traditionally prepared (cooked) adult insect specimens collected from Bikita and Buhera districts. Proximate composition, anti-nutrient and bio-active component analyses were conducted using standard procedures. Radical scavenging capacity (% di (phenyl)-(2, 4, 6-trinitrophenyl) iminoazanium) (DPPH)) was assessed to test the antioxidant properties of methanol insect extracts. Promixate proportions for various constituents were (*H. whelani*: *Macrotermes* spp.): crude protein (%) (53.58: 37.1), fat (%) (4.33: 23.4), ash (%) (13.43: 2.3), crude fibre (%) (10.64: 3.25). Total phenolics, tannins, alkaloids, cyanogenic glycocides, oxalates, saponins and flavonoids in insects (*H. whelani*: termites) were: (7.77: 9.37 mg/100g), (0.168: 0.02 mg/ 100g), (52.3: 35.8 g/100g), (60: 79 µg/100g), (9.31: 14.08 g/100g), (57: 53.3 g/100g) and (15.50: 15.14 g/100g) respectively. The % DPPH radical scavenging of methanolic extracts for termites was 94% and exceeded or compared equal to controls ascorbic acid (92%), Butylated hydroxyanisole (97%) and Catechin (92%). The % DPPH for *H. whelani* was 42%. This study shows that high nutritional benefits can be derived from consuming *H. whelani* especially potash due to high ash content, protein, fibre and flavonoids. However, relative high levels of cyanogenic glycosides which often cause cyanogenesis and poisoning if consumed by humans needs further investigations. Benefits associated from consumption of *Macrotermes* spp. could be associated with high calorific value and anti-oxidant properties. Further studies are required to evaluate the bio-accessibility nutrients and safety of bio-active compounds in relation to human consumption.

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Chemical profiling in the edible stink bug, *Encosternum delegorguei* consumed in South-Eastern districts of Zimbabwe

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Encosternum delegorguei is a delicacy consumed widely in the northern provinces of South Africa, South-eastern districts of Zimbabwe and with traditional claims of having essential nutrients and medicinal roles [1], [2], [3]. However, very little has been explored to determine the chemical profile of beneficial and harmful bioactive compounds associated with these insects. This study was conducted to identify these bioactive compounds in both raw and traditionally processed insects. Gas chromatography-coupled with mass spectrometry and liquid chromatography coupled with mass spectrometry were used to profile bioactive compounds including flavonoids and essential fatty acids and potential toxins. This presentation will discuss our findings and suggest methods for harvesting and processing of this edible insect to minimize contamination.

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Mealworms: Alternate source of lipids

Danthine, S.[1], Blecker, C.[1], Paul, A.[1], Caparros Medigo, R.[1], Haubruge, E.[1], Taofic, A.[1], Lognay, G.[1], Fauconnier, M-L.[1], Frédérich, M.[2] and Francis, F.[1]

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The aim of present study was to determine the physicochemical properties of the oil obtained from *Tenebrio molitor* larvae (mealworms) and explore its potential as edible oil. Five batches of *Tenebrio molitor* larvae were investigated for their lipid content and physiochemical properties. Three batches were reared in lab (3 different productions) and two were purchased from a local supplier. The lipids were extracted using a cold extraction technique employing 2:1 ratio chloroform/methanol as solvent. The fatty acid profile was determined using gas chromatography and triacylglycerol profile using HPLC. The thermal properties of the lipid extracts were also analyzed using differential scanning calorimetry. All the samples contained high amount of unsaturated fatty acids. The chemical composition and the thermal properties of the samples varied with the source. With this quantity and quality of lipid content, mealworms offer potential as an important source of edible lipids.

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Lipid extraction of four insect species: Effect of extraction method and potential use as food ingredient

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Interest of the western countries towards insects as food had increased in the last 10 years. Protein isolation has been the mayor focus of the studies, however lipids are also a main component of insects and are produced during protein isolation (Yi et al., 2013). In this study we investigate the influence of extraction methods on chemical characteristics of insect lipids. We assess its potential as food ingredient by performing a physical characterization. Our study is the first to assess the quality of insect lipids for its use as food ingredient.

Lipids from *Tenebrio molitor, Alphitobius diaperinus*, *Acheta domesticus* and *Blaptica dubia,* reared in the Netherlands, were extracted by two industrial extraction processes (aqueous & Soxhlet) and one laboratory method (Folch). Chemical characterization in terms of fatty acid composition (GC-FID), triacylglycerol profile (GC-FID) and lipid classes (TLC) was performed on all the extracted lipids. Physical characterization in terms of thermal behaviour (DSC), colour (Hunterlab spectrophotometry) and volatile profile (SPME-GC-MS) were performed on lipids from aqueous extraction.

The major findings on chemical characterization were: 1) *T. molitor* had the highest lipid content; 2) the highest yield was obtained using Folch extraction, and the lowest yield using the aqueous method; 3) ω-3 fatty acids, which are related to health benefits (Calder, 2006), were most abundant in lipids from aqueous extraction, while ω-6 fatty acids were most abundant in Folch extractions, except for *B. dubia*; 4) lipids from Folch and Soxhlet extractions contained free fatty acids and partial glycerides, which were absent in aqueous extractions. 5) triacylglycerol distribution is similar among insect species, which enriched in ECN 50-54 and depleted in ECN 36-38.

The major findings on physical characterization were:1) Upon crystallization, lipids extracts contained several crystals, with crystallization points below -5°C. The lowest crystallization point (-49°C) corresponded to a fraction of *B. dubia,*. The crystals were clearly separated, which opens the possibility for lipid fractionation. 2) All four lipid extracts tend to have a bright yellowish colour, which is desirable in edible lipids. 3) The volatile compounds found in all four insect lipids corresponded to grassy, sweet, buttery, sour aromas, known as pleasant aromas. Valeric acid, with an unpleasant and penetrating aroma, was present only in *B. dubia.*

In conclusion, aqueous extractions gave the lowest lipid yield but provided a lipid extract low in ω-6/ω-3 ratio and with less polar lipids than Soxhlet and Folch extractions This characteristics are desirable in edible lipids. Insects lipids have melting points below -5°C and could be further fractionated. They have a pleasant yellow colour and their aroma could be characterized as pleasant, except for *B. dubia*. This is the first time that the triacylglycerol profile of insect lipids is reported. It is also the first time that C18:1 and C18:2 are reported as separated isomers and that trans isomers of C16:1 and C18:1 are reported in insect lipids.

1 Calder, PC (2006) n-3 polyunsaturated fatty acids, inflammation, and inflammatory diseases. Am J Clin Nutr 83(6):1505s-1519s.
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Proteomics Mass Spectrometry to Discover Changes in Protein Composition: Analyzing gut protein content and protein digestibility

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Proteomics is the current state-of-art procedure for highly detailed characterization of complex protein mixtures. High resolution mass spectrometry is used to identify and quantify the peptide composition from mixtures of more than a thousand proteins [1,2]. This technology can be used to provide detailed insight in physiological response of plants or animals, but also for monitoring purity and stability of proteins in a (industrial) processing workflow.

Amongst others, we have applied proteomics analysis to:

- Identify changes in digestive system in the gut of insects (Helicoverpa) as response to trypsin inhibitors in feed plants [3]
- Identify changes in the gut of fish (salmon, trout and turbot) in response to feed [4,5]
- Characterize the defense responses of plant-pathogen interaction [6,7]

Analyzing the gut content of fish fed on different feed stocks provided insight in the digestibility of the feedstock, in combination with changes in the secreted digestive enzymes.

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Blood profile and nutrient status of *Macaca fascicularis* as animal model fed with pupa meal

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Macaca fascicularis has been known as an animal model for human research purpose. Utilization of fresh egg yolk as source of cholesterol and soya meal as source of protein has been developed to make an atheroslerosis animal model of *Macaca fascicularis* with cholesterol status around 430 mg/dl. Problem with soya meal, as source of protein, will give confounded effect to hypercholesterolemia due to content of isoflavone which has phytoestrogen properties and affected to the hormonal profile. Pupae meal is waste of silkworm, has 43% protein and 27% fat content, which can be used as an alternative source of protein and fat to substitute of soya. This research was conducted to evaluate blood profile and nutrient status by replace soya meal with pupae meal in atherosclerosis diet. Twelve *Macaca fascicularis* have been used as animal model, divided into two groups and given 12 months diet treatment. Diet 1 contained soya meal and diet 2 contained pupa meal, as source of protein. Parameter measured were nutrient consumption and absorption, and blood profiles. Result showed that there were no significant different of protein, fat and carbohydrate intake and its absorption in both diets. Plasma triglycerides, HDL-cholesterol, WBC, RBC, haemoglobine and PCV were same, while cholesterol were high (> 400 mg/dl) in both diets. It is concluded that pupa meal can substitute soya as protein source in atherogenic diet for *Macaca fascicularis,* without any problem with nutrient and hematological status, but still resulted high plasma cholesterol.

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Insect biochemistry: The assessment of nutritional factors by metabolomics

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This talk assesses the ability of metabolomic techniques to generate applicable nutritional data for the assessment of insect tissues. Further focus is placed on the potential of metabolomic approaches to act as a screening mechanism to ensure the quality and safety of potential food products.

Modern approaches to food production require a high degree of quality control, supplemented by appropriate regulatory procedures, in order to generate confidence in the nutritional value of a product. In response to recent concerns about the highly specific nature of previous analytical assessments, wide scale assessments of nutritional factors utilising untargeted methodologies focusing on gene and protein expression are gradually being adopted [1]. Alongside these proteomic and transcriptomic approaches, metabolomics - the study of a metabolite set within an organism or tissue - has been utilised to detail the biochemical composition of numerous insect tissues [2, 3, 4]. These metabolomic analyses can draw direct parallels between an organism's metabolome and its phenotypic state, providing detailed information regarding the composition of individual tissue metabolites not available in more targeted approaches [5].

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Preliminary bioactive compounds analysis of extracts from *Encosternum delegorguei* using Gas Chromatography Mass Spectroscopy

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This investigation was focused on the quantitative analysis of methanol extract of *E. delegorguei* through GCMS using a plasma-ionization detector (PID), quartz capillary column ZB-5 (polydimethylsyloxane, 5 % of phenyl groups). A figure of 18 bioactive compounds were identified and produced which were C_2-C_{13} aliphatic hydrocarbons, aldehydes, furanones, aromatic, oxo-alkenals, esters, ketones, lactones and ethers. The compounds were namely: 2-hexenal, 1-methylbutyl formate, 3-methyl-3-heptanol, octenal, 2,4-dimethyl-3-heptanol, 1,1-diethoxy butane, tridecane, 6-trideceny-4-ne, 4,6-nonadien-8-yn-3-ol, 4,5-dimethyl-1,3-dioxolane-2-cyclohecyl, 3-heptanol, 2-hexenal diethyl acetal, 3-ethoxy pentane, 1,1-dimethoxy heptanes, 2-heptanol acetate, 2-methyl-4-pentanal, 5-ethyl-2-furanone and 2-butoxy pentane. Of these compounds, there were four major compounds found namely; 2-hexenal, 3-methyl-3-heptanol, 3-heptanol and tridecane.

FT-IR studies showed that chitin had the characteristic absorption bands at 1551, 1655 cm^{-1} and in the vicinity of 3262 and 3099 cm^{-1} and corresponded to the stretching vibrations νC=O and νNH(-NHCOCH$_3$), respectively. The presence of the absorption band at 1376 cm^{-1} corresponded to the bending vibration δ_sCH(-CH$_2$ -) of chitin. The elemental analysis produced the following percentages of chitin elemental constituents of carbon 46.11 $\pm$ 0.055; hydrogen 6.63 $\pm$ 0.002; nitrogen 7.06 $\pm$ 0.077; with a C/N ratio = (46.11/12)/(7.06/14) =7.62.

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Extraction and characterization of proteins from five insect species

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Insects are now seriously considered as an alternative and additional source of protein in developed countries in view of an increasing world population and the environmental problems caused by conventional cattle [1].
In many countries of South America and Africa, edible insects are habitually used as animal protein food for human consumption. However, people in the western world on average have a strong bias against insects as food, which will hamper them to eat insects, especially when the insects are offered in a recognizable form (including egg, larvae, pupae or adult). However, it is also possible to extract proteins from insects for further use in food products. In view of consumer acceptance, this is particularly relevant for countries with no habit of consuming insects, such as Europe and North America [2].
Very little information from a food science point of view is available on characteristics and functionality of extracted insect proteins. The aim of this study is to extract proteins from insects, namely the Yellow mealworm (*Tenebrio molitor*), the Super mealworm (*Zophobas morio*), the Lesser mealworm (*Alphitobius diaperinus*), crickets (*Acheta domesticus*) and cockroach (*Blaptica dubia*), in order to characterize the obtained protein fractions and to establish their functional properties.
It was found that the crude protein content of five insect species studied ranged from 19 - 22 % Dumas. Essential amino acid levels in all insect species were comparable with soybean proteins, but lower than for casein determined by reversed phase C18 HPLC.
The extraction procedure is shown in Fig. 1. Firstly, fresh insects were frozen by liquid nitrogen. After adding demineralized water and blending, the insect suspension obtained was sieved and a suspension and a residue were collected. After centrifugation, three fractions were obtained from the filtrate: supernatant, pellet, and fat.
At 3 % (w/v), supernatant fractions did not form stable foams and gels at pH 3, 5, 7, and 10, except for gelation for *A. domesticus* at pH 7. At 30 % w/v, gels at pH 7 and pH 10 were formed, but not at pH 3 and pH 5. After aqueous extraction, supernatant, pellet, and residue fractions contained 17 – 23 %, 33 – 39 %, 31 – 47 % of total protein, respectively. The storage modulus G' is a measure for the elastic energy stored reversibly in a gel during deformation, and characterizes its stiffness. The value for G' determined using a stress-controlled rheometer in the linear response regime of *A. domesticus* supernatant gels was around 2500 Pa, which was almost 1.5 times stronger than that of *B. dubia* (around 1600 Pa), 6 times stronger than that of *Z. morio* (around 390 Pa), and 25 times stronger than that of *T. molitor* (around 100 Pa) and *A. diaperinus* (around 140 Pa).
In conclusion, the insect species studied have potential to be used in foods due to: 1) absolute protein levels; 2) protein quality; 3) ability of forming gels[3].

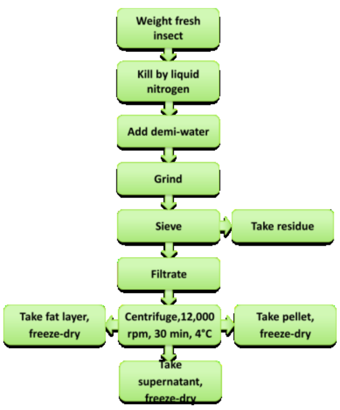

Fig. 1: Protein extraction procedure

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Nutrient composition of four species of winged termites consumed in Western Kenya

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The objective of this study was to gain knowledge on the nutrient composition of *Macrotermes subhylanus, Pseudacanthotermes militaris, Macrotermes bellicosus and Pseudacanthotermes spiniger* termite species consumed in Western Kenya. Proximate, iron, zinc, calcium and fatty acid composition were analyzed in order to ascertain their potential in food-based strategies to improve nutritional health. The fat content was 44.82 – 47.31 g/100g, protein 33.51 - 39.74 g/100g, available carbohydrate 0.72 - 8.73 g /100g, iron 53.33 - 115.97 mg/100g and zinc 7.10 -12.86 mg/100g. The level of unsaturated fatty acids was 50.54 – 67.83 %, while n-6:n-3 ratio ranged between 5.80:1.00 to 57.70:1.00 signifying potential nutritional and public health significance. The termites may be exploited in provision of high quality diets especially in the developing countries which have been plagued by iron and zinc deficiencies as well as poor supply of dietary polyunsaturated fatty acid sources.

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Traditional processing of selected edible insects of Zimbabwe

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Zimbabweans consume several indigenous edible insects that are more than 40 species [1]. Among the commonly cited ones include the *Encosternum delegorguei* Spinola (Shona name; harurwa), *Henicus whellani* (majenya), *Eulopida mashona* (mandere) and *Brachytrupes membranaceus* (makurwe). These edible insects are used as relish in conjunction with a thick maize porridge. This report gives an overview of the traditional processing techniques of the selected insects based on oral evidence. *Majenya* and *makurwe* are dug from underground and their preparation involve squeezing out the gut contents using fingers followed by either thorough washing and then boiling them or roasting on fire followed by adding oil and salt to season them. This process has been reported to increase the palatability of the insects and for long term storage, sun drying can be done. Limited cases of food allergy and intolerance have been reported from consumption of *makurwe*, *harurwa* and *majenya*. *Harurwa* and *mandere* are harvested from trees using traditional skills. *Harurwa* should be prepared by gradually killing them with warm water and stirring them until their colour changes. Flaming can be done to burn off volatiles from the insects. Failure to do so results in very bitter insects which cannot be used as relish. This maybe due to some adverse chemical reactions from the insects that produces the unpalatable compounds. In case of *mandere*, the preparation varies from one household to another. It generally involves boiling several times which is believed to reduce cases of incidental poisoning. Indigenous insects have the potential to contribute to the food and nutritional security; however there is a need to optimise the processing methods for production for safe and nutritious food material.

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Conversion of organic wastes into insect biomass and added value products: an integrated approach towards sustainability

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Intensive animal farming refers to the industrialized production of terrestrial livestock (cattle, pigs, poultry, etc.) and aquaculture. This activity is widespread in developed countries and with agri-food industry around the world generates, thousands of tons of organic wastes as manure and different by-products. In fact roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tonnes — gets lost or wasted [1]. Also organic households waste is an important problem, as example only in UK this is estimated about 7 million tonnes of food every year, around one third of the total purchased [2].

Organic wastes and by-products usually generate environmental problems because the high volume yearly generated and potential microbial development, water and soil contamination etc. Strategies for its valorisation and minimize environmental impact would be their use for high value-added activities related with intensive production of insect biomass. In this contribution an overview of the research related with intensive insect farming of saprophagous insect species (mainly flies) on manure and other organic wastes and by-products is presented.

An integrated approach towards sustainability of wastes bioconversion based on larval insect development is necessary. If an accurate selection of insect species and strains is adopted (including a deep knowledge of key biological parameters), main bottlenecks of true intensive farming of insects as minilivestock will be developed. Paradoxically, insects associated with manure and organic wastes are annoying and even affect negatively livestock production, but could play a key role for sustainable valorisation of organic waste streams as high add value products [3].

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Generic life cycle assessment of proteins from insects

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Global population growth combined with dietary shifts towards higher proportions of meat and fish is predicted to boost the pressure on land and marine resources and greenhouse gas emissions [1]. Feed production and animal husbandry account by far for most of the environmental impacts related to food consumption [2]. In order to reduce the environmental impacts of feed production, insects are recently considered as sustainable substitutes [3]. Reared on organic waste streams, they provide valuable proteins suitable for fish and monogastric livestock production. While this concept suggests great application potential [4], the actual environmental impact of insect-derived protein feeds remains widely unexplored [5].
Most of the insect rearing systems are still at pilot scale or in early stage of commercial development. In order to provide an initial estimation of the environmental impact of different scaled up insect production systems, we applied the life cycle framework on generic, ex-ante modeled product scenarios. To build generic Life Cycle Inventories we surveyed different insect rearing systems in Spain and China and analyzed biophysical and economic in- and output data to detect generally applicable system realities. These determining input-output relations were used as fixed data points to build generic production functions for different unit processes. To parameterize the generic product systems with regional data and assess their environmental impact, we used professional LCA software (SimaPro®, Pré, the Netherlands). This way we are able to compare the environmental impacts and performance driving factors of different insect rearing techniques, varied in their deployed fly species, substrates and technological setups as well as their accommodating environment. To facilitate a comparison on equal footing, the environmental impact assessments were calculated for one kg of the final, fresh insect product.

Preliminary results show following relevant patterns:

- To facilitate optimal year-round temperature regimes, insect production in subtropical (China) and Mediterranean climates requires considerable heating efforts (5 to 7 month/year). Related energy consumption increases the environmental load of the production output. When analysing the related unit processes, production of fly eggs accounts for most of the energy related impacts, whereas inputs of water, sugar and milk powder, significant in their mass flow, are almost negligible in their environmental ramifications.
- The impact of rearing substrates is strongly depending on their trade value in a socio-economic environment. If alternative substrate treatments, other than insect rearing, are established and form part of a local value chain, the waste streams become of value and thus bear some of the environmental impact of their originating production processes, depending on the chosen allocation procedure.
- Insect production, in particular adult reproduction and harvesting process, are very labour intensive and require further automation.

In conclusion we observe that the performance of current insect rearing techniques is subject to its hosting environment. Tropical climates, with favourable year round high temperatures and high air humidity seem most suitable. To lessen the environmental load per unit process output in other climates, the current production systems need to become less labour and energy intensive. It is therefore recommended to invest in an increase of heating efficiency and implement measures that allow for further process automation. When compared with fish meal and soy, insect-derived feeds cause relatively high environmental impacts, due to their yet low efficiencies. To facilitate a more rational and meaningful comparison of insect-based and conventional protein feeds, we identified further research needs concerning emission patterns of larvae rearing, ileal digestibility of insect-derived feeds (comparison on equal footing), and evaluation of the economic value of insect-derived feeds and of the service of manure treatment in different geographical regions.

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Consumers' associations with insects in the context of food consumption: comparisons from acceptors to disgusted

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Many traditional societies have used or still use insects as a protein source, while westernized societies are reluctant to use insects, despite being the major consumers of animal proteins [1]. Edible insects are highly nutritious with high fat, protein and mineral contents depending on the species and thus represent a noteworthy alternative food and feed source. Nevertheless, consumer acceptance needs to be established [2]. The aim of this work was identify consumers' understanding of insects and their incorporation into diet and to evaluate consumer acceptance of insects as food or feed. Consumers were asked to complete a questionnaire comprising three open-ended questions about insects, insects and diet and edible insects; to evaluate their perceived acceptance of the consumption of food incorporating insects, and of fish, poultry, pork and beef from animals fed with insect-based feed formulae, using a seven-point scale, going from 1-tottally reject, to 7-totally accept. The elicited terms were translated into English, coded and grouped into categories. Acceptance scores were compared using non-parametric tests. Consumers were segmented, through Clustering Analysis following their acceptance scores. Clusters were compared, regarding their associations with insects in the context of food consumption, using Correspondence Analysis. 138 consumers were interviewed, 70% females, aged mean of 37.3±12.3years, 48% without higher education. Acceptance scores yielded four cluster of consumers: C1-"disgusted" (n=32), presenting a mean acceptability of 1.5±0.1; C2-"rejecters" (n=56), presenting an mean acceptability of 3.5±0.1; C3-"feed acceptors" (n=20), presenting an mean acceptability of 5.4±0.1, although with a rejection of insects as food (3.0±0.2); and C4-"acceptors" (n=30) presenting a mean acceptability of 6.1±0.1. C1 consumers mainly associated "insects" and "insects and diet" with strong negative emotions and feelings of disgust, repugnancy, horror and fear. Conversely, C4 consumers associated "insects" directly with insect characteristics and with non-insects, such as spiders; associated "insects and diet" with food and diet, geography and culture -mainly from Asian countries-, and insect characteristics; they also refer beetles as edible insects.

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Taste First: Deliciousness as an argument for entomophagy

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If it were simply a matter of sustainability, nutrition, and edibility, insects would already be a part of the Western diet. Many require fewer resources to rear and have a lower environmental impact than conventional livestock [1] They are highly nutritious [2], and are celebrated for their high gastronomic value in much of the world. The main barriers to their consumption in the West are psychological, particularly disgust and a lack of knowledge of their potential hedonic value [3] The Western palate simply does not know how delicious insects can be.

Our research explores and expresses the latent culinary value of different types of insect. The exploration of good flavour is a critical part of building the necessary context for encouraging Western people to accept insects as food.

Focus is given to our field work, currently being conducted across six continents, to investigate the culinary context of insect consumption within traditional cuisines. Our studies look into how, when, where, why, and by whom different species are consumed. We identify methods for processing and culinary elaboration, investigating both the adaptation of diets and perceptions of gastronomic, nutritional and ecological acceptability. Attention is also given to our culinary research. Through developing recipes and applications at the frontier of gastronomy our work has a percolating effect, catalysing the implementation of acceptable food production practices at different scales and within differing end consumer markets. Acceptable food production is based on food security and sustainability, a key to which is preserving and cultivating bio-cultural diversity.[4,5] Insects are often indicators of biodiversity in both managed and wild ecosystems, therefore we can also view insects as indicators of sustainable diets. This culinary work can both contribute to the diversification of the Western diet, and also help preserve the bio-cultural diversity of indigenous and traditional diets around the world. We will share some examples of our culinary work at the conference.

We are investigating insects and other neglected and underutilized edible resources to develop our relationship with the organisms that comprise our biome and upon which we rely. By diversifying our food sources, sustainability can emerge through the pursuit of deliciousness in an ecological context – promoting good flavour, food and nutritional security under one unified strategy.

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Business models based on insect inclusiveness

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Rising global demand for food, water scarcity and climate change are among the global challenges humanity is facing today, and insects clearly represent an opportunity to address those challenges effectively.

There are business concepts, as the Bioeconomy, which address global challenges from a holistic perspective centered on a technological paradigm shift, including genetic modifications of organisms [1]. In contrast to those artificial solutions, the inclusion of insects' “know-how” and their intrinsic features will help to face those challenges from a natural perspective instead [2]. Insects also provide inspiring technical solutions based on natural designs, an approach that Biomimicry uses [3].

Insect rearing or semi-cultivation systems represent the basic step in helping with the global challenges. However, in a more developed stage, they also can be used to enhance current industrial processes, or even to develop closed-loop systems of production by allowing the combination of different business models altogether. The idea is that insects can maximize the value creation of a large variety of business models, using them as raw materials or nutrients, by reducing water and energy consumption, or as a by-products.

This proposal forms the basis for a PhD research. It has the aim to present a framework for the strategic development of individual business models (BM) and combinations of them, all powered by insect inclusiveness. Three dimensions are promising:

1. as a business model itself for new market niches or as a standalone product (BM^1),
2. as a key element to improve an existing business model (BM^2) by, both, eliminating bottlenecks or improving activities within the value chain, or
3. as a connector element to strengthen different business models (BM^3), promoting novel cooperation constellations among economic sectors as a way to diversify risk.

In the eyes of the authors, this framework will systematically detect economic opportunities so that it makes the promotion of insects in strategic industries economically attractive and scalable. That way, insects will play an important role to confront global challenges and create a more sustainable future, where resources are used in the most efficient way, and different business models will operate synergistically.

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Roadmap towards a flowering global insect industry

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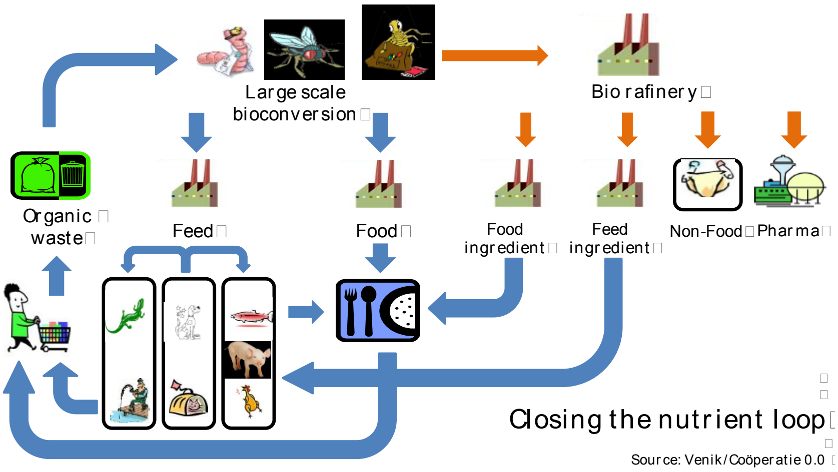
FAO (2013) reported on the future prospects of edible insects for feed and food security. Despite the fact that the insect production industry and supply chain are small and immature, however the future looks promising.

It is clear the future demands an increasing need for nutritious food. To cover the need for more proteins, insects arise on one side. On the other side there is an obvious environmental impact of the existing meat production system. Water and soil pollution, emission of greenhouse gasses, major land-use for feed production and depletion of natural sources like fish meal is a serious concern to us all; while immense organic waste streams find it's way to be destructed.



The industry design of the insect supply chain is circular (fig. 1), it promises a major source of ingredients for feed and food. In a system that is based on the upgrading and re-use of organic waste; organic waste will gain a higher economic value when it can be used in de insect industry. In this circular design economic development will benefit from natural solutions present in the ecological system. Insects farmed on organic waste will have a low environmental impact and do not leave a large surplus after rearing. The introduction of insect products can significantly contribute to the exponentially growing demand for sufficient, affordable and sustainable proteins in several efficient ways.

New opportunities arise
1. Insects as bio-converter
2. Viable and sustainable alternative designs for a new agricultural sector
3. Opportunity for innovative modern entrepreneurs

Major challenges for the foundation of a flowering and viable industry are:
1. Scaling
2. Increase market and consumer acceptance
3. Tackle legislative frameworks on a national and international level
4. New cooperative and funding models are developed

As soon as the supply chain is starting to function and there is a market pull created, the insect industry will make a major contribution to the growing demand for more sustainable, cost-effective, high-quality protein in the feed and pet food industry.

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Can greenhouse gas emissions be reduced by inclusion of waste-fed larvae in livestock feed?

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Attention for insects as food for humans and feed for livestock is increasing. The livestock sector requires for alternative protein sources, because of the expected increase in demand for animal products. Insects have a high protein content and, therefore, can contribute to this goal. Moreover, use of insects may reduce the environmental impact of livestock production as insects have the potential to turn organic waste streams, such as manure or food waste, into high quality insect-based feed products. Such insect-based feed products may replace conventional feed ingredients with a high environmental impact, like fishmeal, fish oil and soybean meal. To our knowledge no studies explored the potential to reduce the environmental impact of livestock production by including insects in livestock feed. The aim of this study was to explore the potential reduction in greenhouse gas emissions from inclusion of larvae of the common housefly fed on food waste in diets for piglets. We, therefore, compared the greenhouse gas emissions of piglet diets with and without larvae. Data were based on a business model to produce 20 ton dried larvae meal per day. The model, based on experimental studies, is developed by four companies in the Netherlands: an animal nutrition company, two waste processing companies and an insect rearing company. The larvae are fed on a substrate of poultry manure and food waste. After harvesting the larvae, the remaining substrate is used for anaerobic digestion, thus replacing fossil fuels and artificial fertiliser. Larvae meal is included in a diet of piglets and mostly replacing fishmeal and soybean meal. Furthermore, we accounted for the current use - anaerobic digestion- of food waste. The reduction in biogas and digestate was replaced by fossil fuels and artificial fertiliser. Preliminary results showed that the piglet feed with larvae has a GWP between 0.63 kg CO_2-eq and 0.85 kg CO_2-eq per kg of feed. The piglet feed without larvae has a GWP of 0.67 kg CO_2-eq per kg. The uncertainty in the GWP estimate of the larvae originates from lacking knowledge around three important aspects. We have limited insight in the potential of the remaining substrate as fertiliser; the use of energy for larvae production; and greenhouse gas emissions from the substrate (i.e. a mix of manure and food waste) during larvae cultivation. To conclude, inclusion of waste fed larvae in diets of piglets has the potential to reduce greenhouse gas emissions with 6%. Further research about the environmental impact is needed to supply lacking knowledge required for an accurate estimate of the reduction potential and potential improvement options of the current process.

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Third Millennium Farming: utilizing city bio-wastes in a strategy for high-yield urban farming

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This paper presents an approach to urban agriculture called Third Millennium Farming (3MF) [1]. Previous work has revealed that 3MF food production strategies have a significantly smaller 'foodprint' [2] than current techniques for crop farming and livestock rearing. This paper describes how unique synergies can be created by utilizing city bio-wastes [3] and sunlight to farm micro-crops which can be used as feed for micro-livestock, while through the same process clean city waste water, scrub CO2 from the city air, and produce food for the city's inhabitants.

This paper analyzes examples of existing bio-waste streams on a city, neighborhood and building scale with a discussion of fundamental design guidelines for urban planning, architecture, and engineering that will enable grafting 3MF operations onto the city grid. Based on analyzing existing bio-waste streams, this paper proposes a restructuring of city waste infrastructure to prevent contamination of city bio-wastes by toxic or non-biodegradable substances, so that city bio-wastes can be utilized as organic inputs for 3MF operations. The paper also investigates the feasibility of deploying existing solar technologies such as tracking hybrid solar concentrators [4], solar condensers [5], solar ducts, and smart energy management devices as 3MF energy collection/management systems at urban, neighborhood, and building scales; this is important as 3MF micro-crop operations require sunlight for photosynthesis. Attention is paid to the costs and capabilities of these devices as well as their potential for powering 3MF operations. In addition, several existing projects that utilize smart energy management systems are examined to identify possibilities for linking 3MF farming operations to building/neighborhood/city smart energy management systems for the purpose of reducing overall energy consumption.

Analogous to many industrial ecology initiatives, 3MF is about linking farming operations to city bio-waste streams in an urban context—utilizing micro-crops and micro-livestock as a vector for transforming bio-wastes into food, and thereby decreasing the city's dependence on importing food and disposing of bio-wastes. Urban 3MF operations will enable various environmental savings: offsecting food production related pollution by reducing reliance on existing non-sustainable farming methods, offsetting the need to transport food from abroad into cities, and reducing the amount of industrially-farmed land which can be returned to more naturally resilient states.

Finally, this paper argues that 3MF creates food security by utilizing a renewable resource (bio-wastes), which increases proportionally to population expansion, as opposed to current food production methods which rely on resources which are antagonistically linked to population expansion.

1 3MF is about harnessing the abilities of micro-crops (such as algae and grass) and micro-livestock (insects) to rapidly reproduce, under controlled conditions, to create meat (protein) on a significantly smaller foodprint[2] than current industrial meat farming operations, and to provide humanity with a sustainable, organic, ethical and decentralized source of food.
2 Foodprint is defined as all of the land and resources required to farm all of the food needed by one person for one year.
3 City bio-wastes are any organic waste generated within cities, such as: black water (sewage), grey water (shower, kitchen, and tap water) and compost.
4 Tracking Hybrid Solar Concentrators: a system of reflective concave dishes that focus sunlight to a single point – the collection point. At the collection point the sunlight is converted into electricity by high-density photovoltaic segments at a lower cost than typical low density photovoltaic panels. The surplus heat that is generated at the collection point is harvested through a liquid cooling system that provides thermal gains in the form of heated water (up to 90°C).
5 Solar concentrators: a system of reflective concave dishes that focus sunlight to a collection point. At the collection point, sunlight is transported via solar ducts (limited range) or fiber optic cable into the building – providing sunlight for 3MF micro-crop farms.

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Conversion of food waste directly to sustainable feed ingredients for animals and plants

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Enterra provides a solution to two major, global problems – wasted food and a growing demand for affordable and sustainable food for animals and plants. Enterra's proprietary process transforms clean, recycled food waste – collected from food producers, grocery stores, food distributors and other traceable sources – yielding high-quality animal protein and oils that can be used to feed fish, chickens and pets as well as a natural fertilizer product ideal for plant propagation with natural pesticide activity… we call it **Renewable Food for Animals and Plants™**.

Enterra is a Vancouver-based company that has developed technology that can increase global nutrient supply, while simultaneously reducing the growing pressure on landfills and composting. The Company has commercialized a natural biological process, which utilizes the life cycle of a beneficial insect, the Black Soldier Fly, and has been operating a commercial demonstration plant for over one year. The process converts a mix of food waste, such as ***fruits and vegetables, stale breads, grains and fish processing waste***, directly into sustainable animal feed ingredients with no loss of the nutrients, which can be used as substitutes for more resource-intensive products such as fishmeal, soymeal, palm oil, coconut oil and rendered products. The natural fertilizer product has been registered in the State of Washington and is a certified organic product with field-demonstrated efficacy including natural pesticide activity.

Enterra is now expanding to a $10 million facility in Langley, near Vancouver, with over 4,700 m^2 area, with capacity to treat up to 50,000 tonnes per year of food waste. All inputs to the plant are from local sources and all products are sold locally. The presentation will describe the technology, demonstration plant results, and product quality and will provide an update of the expansion project at the Langley plant.

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Environmental sustainability of insect production

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In recent years the topic of insects as a source of food or feed has received much interest from both the scientific community and the media. An increasing world population and a rise in purchasing power of people in developing countries leads to increased demand for limited resources, such as proteins and energy, and a concomitant price increase. It has been suggested that insects are a more sustainable source of food than conventional livestock. However, few studies have been conducted to verify this claim. For five insect species, direct greenhouse gas and ammonia production has been quantified [1]. This study suggests that insects could indeed serve as a more environmentally friendly alternative for the production of animal protein with respect to direct greenhouse gas and ammonia emissions. A follow up study quantified the total greenhouse gas production, usage of fossil fuels and land use of a system producing Yellow mealworms (*Tenebrio molitor)* and Super worms (*Zophobas morio*) by means of a life cycle analysis (LCA) [2]. The production of edible protein in this system resulted in lower greenhouse gas emissions, required similar amounts of energy and required much less land than production of edible protein from milk, chicken, pork or beef. From this LCA it can be concluded that the environmental impact is mainly caused by the temperature requirements of the mealworms, and by the production of feed for these species. Efforts to decrease the environmental impact of insect production systems should therefore be directed towards improving energy efficiency and feed conversion efficiency, as well as selecting organic by-products suitable as feed ingredients.

1 Oonincx DGAB, Van Itterbeeck J, Heetkamp MJ, Van den Brand H, Van Loon JJA, et al. (2010) An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. PLoS One 5:e14445.
2 Oonincx DGAB, De Boer IJM (2012) Environmental Impact of the Production of Mealworms as a Protein Source for Humans – A Life Cycle Assessment. PLoS One 7: e51145.

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Open Source: Why we need open knowledge sharing to help insects feed the world

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One secret behind the incredible speed of growth in the technology industry is the concept of open source. By sharing the source code that defines software - and incorporating improvements submitted by others - technologists are able to work collectively towards improving their tools. The majority of the Web is now powered by open source code, with the market share of proprietary technologies decreasing every year. It is the engine that powers a multi-billion dollar industry.

Until recent years, farming was inherently open source. Improvements in technology were shared for mutual benefit, enabling the explosion of new developments that led to modern agriculture. Lately, in an industry where intellectual property is increasingly considered the only currency that matters, giving away the means of production may seem counterintuitive.

This presentation would argue the opposite - that the fledgling food and feed insect sector can only begin to thrive once its core technologies are shared openly and become subject to a cycle of constant renewal and improvement powered by millions of farmers worldwide.

It will demonstrate how this effect has powered the technology industry, and how it has the potential to deliver a hundred years of progress in the space of a decade. It will show how open source can be a component of a highly profitable business model. It will also discuss the dangers inherent in holding back knowledge during the early days of an industry. Finally, it will show how you can begin to benefit from open sharing while still protecting your rights.

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Global awareness starts locally: the "Buggy Buffet" model to enhance conversation and adoption

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The overall objective of the International Conference 'Insects to Feed the World' is ".to promote the use of insects as human food and as animal feed in assuring food security." While most papers at this International Conference will focus on harvesting and producing insects as food and feed, environmental issues, nutritional benefits, food safety and security, legislation and policy, it is also important to evaluate consumer attitudes and investigate ways to encourage more people to consider insects as part of their diet. If we want to reach people globally, we each need to begin locally to offer entomologically-related gastronomical experiences to educate more people, change attitudes, and lay the local groundwork to enhance global efforts. One outreach activity that we have conducted for seven years is our Annual *'Buggy Buffet'* ('Insect Smorgasbord'). This activity, held every fall at the University of Tennessee and open to the public, is a *FREE* insect-tasting event, where insects are cooked, served, and eaten to demonstrate their importance as food throughout the world. This event is sponsored by students in a Freshman Seminar course titled "A Bug's Life" and the Department of Entomology and Plant Pathology. Students gain valuable experience and knowledge during this activity, which is closely tied to the University's "Ready for the World" initiative. During our 2013 'Buggy Buffet', more than 300 people of all ages attended – many of them for the first time. A menu of insect-themed foods was developed and served. This activity offers the opportunity for people to obtain first-hand experience with entomophagy, as well as discuss their experiences and the 'insects as food' concept with other participants. The reaction and reception to our 'Buggy Buffet' has been extremely positive, with most first-time attendees surprised at the tastefulness, nutritiousness, and attractiveness of the insect-based meals. During the 'Buggy Buffet', opportunities are available to share entomophagy-related information with attendees. Various print (e.g., newspapers, magazines, etc.) and electronic (e.g., television, radio, etc.) media participate in the event and provide an overview of the activity to a broader audience. This outreach effort enhances public knowledge about the benefits and availability of insects as food. These types of public entomophagous activities frame insects as food in a positive manner on a local and regional scale. This paper describes the use of this model to enhance conversation and adoption of insects as food and feed worldwide. Global awareness starts locally!

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The hockey stick pattern in the acceptance of edible insects in The Netherlands

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[2] Venik, Dutch Insect Farmers Association, The Netherlands, www.venik.nl
[3] Rijn IJssel Vakschool, Marijkeweg 5, 6709 PG Wageningen, Wageningen. http://www.rijnijssel.nl/Vakschool%20Wageningen

Insects are a delicacy in many countries. However, the populations of Europe and North America have not yet generally discovered this treat. Yet, there is a clear development visible. We have promoted entomophagy in The Netherlands since the late 1990s and have experienced a marked change in the perception of edible insects among the general public. This change was not a linear process. In this presentation we will share our experiences and strategy. Key to success is the technological congruence (also called the Golden Triangle) of the research community, the private sector, universities, state and local governments, foundations, and non-profit organizations. We will address factors that we had control of as well as factors that were beyond our control. We are convinced that the developments in The Netherlands are not specific for this country but can be helpful to promote edible insects as a valuable protein source in other countries as well.

1 Van Huis, A, Van Gurp, H and Dicke, M (2014) The Insect Cookbook - Food for a Sustainable Planet. Columbia University Press, 191 pp.

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Consumer acceptance of insect-based meat substitutes

Caparros Megido, R.[1], Gierts, C.[1], Blecker, C.[2], Brostaux, Y.[3], Danthine, S.[2], Paul, A.[2], Haubruge, É.[1], Alabi, T.[1] and Francis, F.[1]

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Meat plays an important role in the consumption pattern of most European and North American consumers [1]. Meat production is responsible for a well known environmental pressure due to the inefficient conversion of plant protein to meat protein and alternatives sources, such as insects or algae, will be rapidly required [2]. In a recent theorical study, de Boer et al. (2013) show that consumers prefer to eat a hybrid meat product (i.e. a mix of meat and its substitute) rather than a pure meat substitute [3]. Based on these preliminary results, hedonic tests were realized to assess the acceptability of insect-based burgers in a target population composed of people from 15 to 25 years old, considered as the future insect consumers. Isolated in a tasting booth, each participant was invited to taste four burger samples containing a ratio of 20 gr of protein by 100 gr of burger. The first burger was prepared with 95% of grounded beef (1), the second with 95% of green lentil (2), the third with 45% of green lentil and 50% of mealworms (*Tenebrio molitor* L.; Coleoptera, Tenebrionidae) and the fourth with 45% of grounded beef burger and 50% of mealworms. The last 5% of each burger consists of an aromatization portion containing onions, carrots, tomato paste and garlic. Participants were asked to rate each sample on a 9-point hedonic scale, where extreme sides were noted from "extremely dislike" (left) to "extremely like" (right). Tukey post-hoc comparisons on the appreciation results showed that beef-based products (with or without mealworms) were relatively preferred to lentil-based products (with or without mealworms), probably because hybrid meat burgers seem more familiar to the consumers than vegetable burgers [4], and that no liking differences were noticed between the two beef-based burgers and between the two insect-based burgers. These results confirm that shape and appearance are key criteria in the acceptation of meat substitute by non-vegetarian consumers and that insects will preferentially be consumed, in the future, if they are presented in an invisible way and associated with familiar flavors [2,4,5].

1 FAO (2009) How to feed the world in 2050 ?
http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf. Accessed April 3, 2012
2 Elzerman JE, Hoek AC, Van Boekel MAJS, Luning PA (2011) Consumer acceptance and appropriateness of meat substitutes in a meal context. Food Quality and Preference 22: 233-240.
3 De Boer J, Schösler H, Boersema JJ (2013) Motivational differences in food orientation and the choice of snacks made from lentils, locusts, seaweed or "hybrid" meat. Food Quality and Preference 28: 32-35.
4 Schösler H, Boer JD, Boersema JJ (2012) Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. Appetite 58: 39-47.
5 Caparros Megido R, Sablon L, Geuens M, Brostaux Y, Alabi T, et al. (2013) Edible Insects Acceptance by Belgian Consumers: Promising Attitude for Entomophagy Development. Journal of Sensory Studies: In press.

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Way forward to bring insects in the human food chain

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Over the last 2 years the recognition that insects can contribute to global food security has received a remarkable boost by the media, and is getting more attention from researchers, food and feed sector agencies worldwide. Although research and development on edible insects is increasing; a tremendous amount of work still needs to be done by a wide range of stakeholders to fully realize the potential that insects offer either for direct human consumption or for indirect use in feedstock both in developing and in developed countries. To assure that insects can remain part of the diets of 2 billion people, action is urgently needed to ensure more sustainability in gathering wild insect populations, to promote simple semi domestication techniques, and to farm the insects at a household or an industrial level. Preservation and processing techniques are needed to increase shelf life, conserve quality and increase the acceptability of insect food products. Processing methods are also needed to transform insects into protein meal for animal/fish feedstock and for the extraction of insect products to be used as industrial ingredients.

Integrating edible insects as *healthy* food into the political agenda of food security, health and nutritional agencies and campaigns requires a better and more comprehensive understanding on the nutritional values of (more) insects species. Particularly consumer's health and environmental impacts risks assessments of using insects in the food chain needs further investigation. National and international poverty alleviation agencies and aid programs need to be made aware that gathering and farming insects is a viable option to help urban and rural poor improving their livelihoods through reviewing the socio-economic benefits that insect gathering and farming can offer; with a focus on improving the food security of the poorest of society.

Legislators are called to include insects as feed and food into existing national policy and legal frameworks covering the food and feed sectors. More scientific evidence to investigate the sustainability and quantify the environmental impacts of harvesting and farming insects compared with traditional farming and livestock-raising practices would help to inform the public and consumers about the real foot imprint and costs of our food choices and on their socio-economic and environmental consequences.

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Promoting entomophagy through insect eating festivals in Lanao del Sur, Philippines

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Three insect eating festivals were held at the botanical garden of the Mindanao State University (MSU), Marawi City, Lanao del Sur, Philippines. These festivals aimed to promote insect eating as the cheapest method of controlling insect pests and overcome the problem of social acceptance. Students enrolled in Crop Protection 51, Entomology 51 and Integrated Pest Management from academic years 2011-2013 under the College of Agriculture were encouraged to concoct recipes utilizing insects as food.

Insect pests of rice such as the Chinese grasshopper*, Oxya chinensis*, slant-faced grasshopper, *Attractomorpha psittacina*, rice bug, *Leptocorisa oratorius*, and Malaysian black bug, *Scotinophara coarctata* , were collected, fried and made into local delicacies such as insect turon (rolled peanuts with insects), insect polvoron and insect chayote bars. Likewise insect pests of stored products like the rice moth, *Corcyra cephalonica* and the red flour beetle*, Tribolium castaneum* were used as ingredients in polvoron, and rice cakes. The Asiatic palm weevil, *Rynchoporus ferrugineus*, was cooked as adobo. Rice bugs were made into burgers, bees were used as sandwich fillers while dragonflies were utilized as food toppings. Other important insect pests that were utilized during the second and third insect eating festivals included the termites, ants, coconut leaf beetles, *Brontispa longissima* and cabbage worm, *Crocidolomia pavonana*.

The festivals promoted entomophagy based on the increasing number of people who participated them. Employees and students responded positively by eating insects. Hopefully the next festival will draw more people and additional tasty recipes will be offered.

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In-vitro study of esterase enzymes in relation to cypermethrin resistance in the larvae of the mosquito, *Culex pipiens*

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Double reciprocal plots of esterase activity in larval homogenate of *Culex pipiens* from susceptible and cypermethrin-selected generations toward 1-naphthyl acetate as substrate was carried out. These plots enable Michaelis – Menten constant (K_m) and maximum velocity (V_{max}) to be evaluated. Data of the kinetic constants for the hydrolysis of 1-naphthyl acetate (1-NA) indicated that the Michaelis – Menten constants, (K_m values) were 2.01 x10^{-4}, 1.9 x10^{-4}, 2.17 x10^{-4}, 1.9 x10^{-4}, 1.8 x10^{-4}, 1.93 x10^{-4} and 1.96 x10^{-4} M for 1-NA hydrolyzing esterases for 1-naphthyl acetate hydrolyzing esterase from 4th instar larvae of *C. pipiens* homogenates of S-strain, cypermethrin- selected generations (G_0, G_3, G_5, G_7, G_9 and G_{10}), respectively. The corresponding V_{max} values were 11.05, 14.47, 23.87, 35.71, 72.99, 144.93 and 217.39 *n*mol substrate hydrolyzing/min/mg protein. The enzymatic half-life ($t_{0.5}$) values were 12.06, 9.1, 6.3, 3.69, 1.71, 0.92 and 0.62 (Min (mg protein/ml)), respectively. Values of K_m, V_{max} and $t_{0.5}$ obtained from the homogenate of S-strain and the corresponding values of cypermethrin-selected generations in relation to cypermethrin resistance were discussed.

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Encouraging insect consumption - A case study from India

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In India, eating of snails, oysters, shrimps, dried sea slugs and birds' nests already exists but the north-eastern state of India, Manipur, encourage insect consumption, especially in view of the fact that many people cannot afford fish or other animal meat as these are available in a very small quantity. According to Roy and Rao, 1957 the people here are very fond of insect larva known as `chind kira' found on the date-palm tree. These yellowish white larvae, each weighing about 40 to 50.0gm, are collected from young date-palms. Larvae of bees are also eaten. Eggs of ants are collected from the leafy nests and considered as a delicacy. 'Chind kira' is said to be very tasty. The tribal people put the fatty larvae (chind kira) simply on a hot pan the larvae are fried in their own fat. There are interesting ways of eating ants. Ants captured from the nests in the trees are covered and tied up in cups made of leaves and roasted while covered up in the leaf cups. After the ants have been roasted, these are squeezed into a paste and baked with salt and chilly to make a paste or chutney. Sometimes these ants are killed and dried in the sun. Sun dried ants are powdered and stored for future use. The powder, which is very sour to taste is used for the preparation of vegetable and meat curry. Insects represent the cheapest source of animal protein in Manipur where other forms of livestock is lacking due to harsh topography and their consumption is encouraged because many of the people cannot afford fish or animal meat.

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Exploring entomophagy in northern Benin: Practices, perceptions and possibilities

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[2] University of Liverpool, Institute of Intergrative Biology, Liverpool
[3] CRGB, Centre de Recherche pour la Gestion de la Biodiversité, Godomey, Benin
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Food security is a critical issue for many low income countries across the African continent. In areas unsuited for intensive agricultural production, local natural resources can play an important role, particularly those which are sustainable and on which people have relied on for centuries. In many regions of the world insects have been consumed for generations, and represent a reliable source of animal proteins among populations that otherwise have limited access to meat. This work in Benin was motivated by the attempt to understand how edible insects could contribute in an area where food security is significant issue. Initially our work focused on a case study of an insect-eating community in the Atakora region, in Northern Benin. Data on edible insects in the Wama communities of the district of Tanguieta were collected by conducting interviews, focus groups and insect collections in two Wama settlements, Kosso and Cotiakou. Eighteen edible insect species were recorded, predominantly Coleoptera (52%) and Orthoptera (29%). This project has found a further nine arthropod species eaten in the region including new groups of arthropods such as Hemiptera (family: Coreidae) and Acari (family: Ixodidae). Interestingly, insect collection and consumption was found to be an ancestral tradition in the Wama community, mostly carried out by children. In light of malnutrition in North Benin being a major problem in young age groups, promoting this tradition as well as exploring the potential of implementing small scale captive rearing of selected species could be a promising opportunity to further develop food security in the region and beyond. The opportunities and barriers of expanding entomophagy and rearing in Benin are presented.

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The influence of the feeding Flour Beetle *Tribolium confusum*-infested fodder on the selected indices of the health status of rats

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Tribolium confusum, belonging to the order Coleoptera, family Tenebrionidae, is a rusty-brown beetle, 2.6-5.0 mm of body length, being the most frequent silage pest in the world.

Adult forms live up to 3.5 years. They most often feed on the damaged grain, grain products or grain fodder. They secrete bezoquinones being suspected carcinogenes.

The aim of the study was to assess the degree of fodder contamination with benzoquinones secreted by *Tribolium confusum* under different levels of infestation, the influence of the infested fodder on the beetle population and the influence of the infested fodder on the health of rats.

The feeding studies were done on female rats divided into 3 groups: a control group and two experimental groups. Experimental groups were fed with a fodder infested by 150 individuals of *T. confusum* per kg (group D1) and 300 individuals of *T. confusum* per kg (group D2).

The insects were grown in the fodder for 5 months and the contaminated fodder was given to animals for 8 weeks. After that period the animals were sacrificed, blood was drawn for morphological, biochemical and immunological analyses, as well as the samples of internal organs were taken for histopathology.

The study has shown that the differences in the degree of the fodder infestation did not result in the differences in the benzoquinones levels, however, the higher infestation resulted in a more significant self-restriction of the beetle population growth (the number of dead individuals increased almost 5-fold). The infestation level did not affect the fodder consumption and the body growth rate. The urinalysis for benzoquinones presence, the fecal benzoquinones excretion during the experiment and histopathological changes confirm the presence of the toxins in the organism and their negative health effect.

The obtained results point to the possibility of the benzoquinones accumulation in the organisms of farm animals fed with a fodder containing pests, and, in consequences, may raise the suspicion of the transfer of benzoquinones to the human organism with a consumed food products coming from such animals.

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How can museums contribute for food provision and security in Africa – a stakeholder's approach

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The edible insects, among others belonging to the order Lepidoptera, gain a huge economic and societal interest since they can significantly improve diets of humans and feed of livelihood at present and in the future. On the other hand the museums and their insect collections for centuries were the headquarters of taxonomic efforts trying to achieve some of the collection orientated fundamental goals, e.g.: 1) to maintain insect collections presenting the natural richness of natural diversity; 2) to accumulate new evidences of changes in natural diversity of insects; 3) to support the taxonomy as a biodiversity orientated science now and in the future. However, for long time museum based fundamental science and society needs had almost no overlapping areas. The 21st century presents us the acute challenge not only to feed the 9 billion people in twenty years but also to give the answers how taxonomy, as the fundamental museum based science, can serve the society needs. Here we present an exemplar case study that the robust taxonomic databank on 36,611 species group names of Afrotropical moths and verified, referenced 4,155 records of plants on which insects feed, as well as 59,489 detailed distribution data in the Afrotropics can contribute to the initiative "Insects to feed the world". The interactions of herbivorous insects play a key role in the tropical natural environment and therefore, we promote the holistic approach studying Afrotropical ecosystems and inhabited areas by humans as one integrative unit. Societal needs cannot be separated from the knowledge on sustainable management of natural resources. The challenges related to the globalization, displacing and deprivation of millions of people in Africa also drastically changed the distribution pattern of natural resources. Our databank provides and disseminates online (free) a historic and constantly updated coverage on herbivorous Lepidoptera in the Afrotropical region in a structured, user friendly way, with multiple search possibilities and visual iconography.

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POSTER ABSTRACTS

Exploring entomophagy in northern Benin: Practices, perceptions and possibilities

Riggi, L.G.[1], Verspoor, R.L.[2], Veronesi, M., MacFarlane, C. and S. Tchibozo, S.[3]

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Food security is a critical issue for many low income countries across the African continent. In areas unsuited for intensive agricultural production, local natural resources can play an important role, particularly those which are sustainable and on which people have relied on for centuries. In many regions of the world insects have been consumed for generations, and represent a reliable source of animal proteins among populations that otherwise have limited access to meat. This work in Benin was motivated by the attempt to understand how edible insects could contribute in an area where food security is significant issue. Initially our work focused on a case study of an insect-eating community in the Atakora region, in Northern Benin. Data on edible insects in the Wama communities of the district of Tanguieta were collected by conducting interviews, focus groups and insect collections in two Wama settlements, Kosso and Cotiakou. Eighteen edible insect species were recorded, predominantly Coleoptera (52%) and Orthoptera (29%). This project has found a further nine arthropod species eaten in the region including new groups of arthropods such as Hemiptera (family: Coreidae) and Acari (family: Ixodidae). Interestingly, insect collection and consumption was found to be an ancestral tradition in the Wama community, mostly carried out by children. In light of malnutrition in North Benin being a major problem in young age groups, promoting this tradition as well as exploring the potential of implementing small scale captive rearing of selected species could be a promising opportunity to further develop food security in the region and beyond. The opportunities and barriers of expanding entomophagy and rearing in Benin are presented.

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How can museums contribute for food provision and security in Africa – a stakeholder's approach

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The edible insects, among others belonging to the order Lepidoptera, gain a huge economic and societal interest since they can significantly improve diets of humans and feed of livelihood at present and in the future. On the other hand the museums and their insect collections for centuries were the headquarters of taxonomic efforts trying to achieve some of the collection orientated fundamental goals, e.g.: 1) to maintain insect collections presenting the natural richness of natural diversity; 2) to accumulate new evidences of changes in natural diversity of insects; 3) to support the taxonomy as a biodiversity orientated science now and in the future. However, for long time museum based fundamental science and society needs had almost no overlapping areas. The 21st century presents us the acute challenge not only to feed the 9 billion people in twenty years but also to give the answers how taxonomy, as the fundamental museum based science, can serve the society needs. Here we present an exemplar case study that the robust taxonomic databank on 36,611 species group names of Afrotropical moths and verified, referenced 4,155 records of plants on which insects feed, as well as 59,489 detailed distribution data in the Afrotropics can contribute to the initiative "Insects to feed the world". The interactions of herbivorous insects play a key role in the tropical natural environment and therefore, we promote the holistic approach studying Afrotropical ecosystems and inhabited areas by humans as one integrative unit. Societal needs cannot be separated from the knowledge on sustainable management of natural resources. The challenges related to the globalization, displacing and deprivation of millions of people in Africa also drastically changed the distribution pattern of natural resources. Our databank provides and disseminates online (free) a historic and constantly updated coverage on herbivorous Lepidoptera in the Afrotropical region in a structured, user friendly way, with multiple search possibilities and visual iconography.

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Exploring entomophagy in Northen Benin: Practices, perceptions and possibilities

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Food security is a critical issue for many low income countries across the African continent. In areas unsuited for intensive agricultural production, local natural resources can play an important role, particularly those which are sustainable and on which people have relied on for centuries. In many regions of the world insects have been consumed for generations, and represent a reliable source of animal proteins among populations that otherwise have limited access to meat. This work in Benin was motivated by the attempt to understand how edible insects could contribute in an area where food security is significant issue. Initially our work focused on a case study of an insect-eating community in the Atakora region, in Northern Benin. Data on edible insects in the Wama communities of the district of Tanguieta were collected by conducting interviews, focus groups and insect collections in two Wama settlements, Kosso and Cotiakou. Eighteen edible insect species were recorded, predominantly Coleoptera (52%) and Orthoptera (29%). This project has found a further nine arthropod species eaten in the region including new groups of arthropods such as Hemiptera (family: Coreidae) and Acari (family: Ixodidae). Interestingly, insect collection and consumption was found to be an ancestral tradition in the Wama community, mostly carried out by children. In light of malnutrition in North Benin being a major problem in young age groups, promoting this tradition as well as exploring the potential of implementing small scale captive rearing of selected species could be a promising opportunity to further develop food security in the region and beyond. The opportunities and barriers of expanding entomophagy and rearing in Benin are presented.

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Study on proteolysis of *Palembus dermestoides* (Fairmaire) and antioxidant activity of the hydrolysates

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Adults of *Palembus dermestoides*（PD）have a high commercial potential due to their rich nutritional ingredients, such as essential amino acids, vitamins, microelements and unsaturated fatty acids. In this paper, we studied extraction and proteolysis procedures (process) for proteins from the PD adults. The antioxidant activities of the isolated protein hydrolysates with different molecular weights were evaluated; and the ones with high antioxidant property were further tested on their potential anti-aging effect.

Three protein extraction methods with different extracting agents, alkaline, salt, and Tris-HCL buffer solution were used, respectively. Alkaline extraction method obtained the highest amount of proteins, followed by the Tris-HCl extraction method, while salt was the least efficient extraction agent. The optimal conditions of the alkaline method were found at 1.0%, 80°C, 60 min, and a solid/liquid ratio of 1:15. The best conditions for the salt method were: 1.0%, 20° C, 2h extraction duration and a solid/liquid ratio of 1:10. The best conditions for the Tris-HCl method were: pH 8.1, temperature 10 °C, 30 min duration, and a solid/liquid ratio of 1:10.

The defatted PD beetle proteins were hydrolyzed with four different proteases (papain, neutral, trypsin, and pepsin), and their degrees of hydrolysis, the stripping rates of proteins and the average lengths of peptide chains were examined. Our results showed that papain was the most effective protease with 19.61% hydrolysis, 2.52 stripping rate, and a mean peptide chain length of 5.10. The optimal papain hydrolysis conditions were further determined as 2225U papain enzyme/g insect, at 42 °C for 4h to achieve a high degree of hydrolysis (22.67%).

The zymolytes were separated into three fractions using ultrafilteration membranes with 10000 MWCO (Molecular Weight Cut Off) and 6000 MWCO, respectively. In the non-oil system, the antioxidant activities of these three fractions of peptides were studied. The result showed that all three fractions had a strong radical scavenging activity in eliminating DPPH·, OH· and superoxide anion, with the 1st fraction (<6000 MW) being the strongest. It could remove superoxide negative ion (O_2^-·) and hydroxyl free radicals (·OH) at similar levels as did the known strong antioxidant Vc, but showed even stronger efficacy on removing 1, 1-dipHenyl-2- picrylh-yrazyl free radicals (DPPH·) than did the $V_{C.}$

Further anti-aging experiments on lab mice with different dosage of <6000 MW zymolyte showed that SOD activity in mouse livers was significantly higher from groups treated with medium and high doses of zymolytes than from the aging model group ($P<0.05$), and the significant differences between medium dose group and aging model group reached at $P<0.01$ level. Significant effects on SOD activities in serum and brain also occurred between medium dose group and the aging mode group ($P<0.05$), but not among the other groups. Significant effects of the zymolytes on GSH-PX activities in serum were observed in all the three dose groups, with the medium dose being the strongest ($P<0.01$). Similar effect patterns were also observed on GSH-PX activities in liver, but both medium and high dose groups showed similarly strong significant difference level at $P<0.01$ than from the aging model group, whereas significant differences at $P<0.05$ level were observed among high dose, low dose groups and the aging model group. The effects of low and medium doses of zymolytes on content of MDA in serum were strongly significant at $P<0.01$ level. Therefore, the protein zymolytes of PD adult beetles could significantly delay the aging in mice.

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Neither wild nor farmed: What can we learn from insect 'semi-domestication'?

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In recent decades, global studies of human communities have shown the distinction between 'domestication' and 'wild harvesting' to be a false dichotomy. Many plant and animal species are traditionally managed and manipulated to increase yields, and yet remain phenotypically indistinguishable from their wild counterparts [1]. This is also the case for many species of edible insect [2]. In this presentation we propose a four-part schema for classification of insect semi-domestication, and we illustrate the utility of our model using data on insect management in Africa, Asia and Oceania. Since improved classification is one of our aims, we use an extremely broad definition of semi-domestication as the basis for this study. We consider only insects that are collected opportunistically to be truly 'wild', and only those that have undergone recognised genetic change in response to a long history of human management to be true 'domesticates'.

Our categories are characterised by the following management practices: 1) The enforcement of social and cultural norms that dictate the timing and extent of the harvest of edible insects; 2) The manipulation of the natural environment to encourage insect breeding, feeding and/or habitation; 3) The construction of a habitat in which insects are intentionally placed for part of their life cycle, usually accompanied by food provisioning; 4) Keeping insects within a manmade, controlled environment for their entire life cycle.

We present original data to exemplify each of these categories. Our examples are limited to four orders of edible insects that are subject to varying degrees of management on three continents, but a review of published literature shows that examples can be found in every order of insect and on every continent.

We conclude that these categories of 'semi-domestication' are likely to have had varying influences on the current geographical distribution, prevalence and genetics of edible insect species, particularly in regions with a long history of population management. Such knowledge may be crucial to in order to accommodate a diverse and potentially fluctuating demand for food insects in future decades. However, if a dichotomy between 'wild' and 'domestic' is allowed to persist, there is a danger that the knowledge and practice of edible insect management may be lost in the process of agricultural intensification.

1 Bharucha, Z and Pretty, J (2010) The roles and values of wild foods in agricultural systems, Philosophical Transactions of the Royal Society of Biology 365, 2913–2926

2 Van Itterbeeck, J and Van Huis, A (2012) Environmental manipulation for edible insect procurement: a historical perspective, Journal of Ethnobiology and Ethnomedicine, 8:3

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Influences of different light sources on the life history of the Black soldier fly

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Black soldier fly larvae can be used to dispose poultry manure and reduce manure accumulation and its prepupa contains rich nutrient substances, especially a high protein content, which can be used as forage additives.
However, rearing the black soldier fly in artificial condition would face a large problem that no or few mating occurred when in the day without sunlight. We used different lamps (sunlight-, quartz-iodine -, and rare earth lamps) to study black soldier fly mating incidence. The results showed that while the sunlight was replaced by the quartz-iodine lamp, mating activity could be observed and fertile eggs could be collected as normal. The numbers of eggs collected were about 61% of that under sunlight. No mating occurred when using the rare earth lamp. Hatching rate, larval and pupal development of the black soldier fly collected from the sunlight and quartz-iodine lamp were not significantly different ($P < 0.05$). The quartz-iodine lamp had no effect on the passage of the insect compared with sunlight by rearing 3 generations ($P < 0.05$). This result is useful in developing artificial rearing methods for the black soldier fly during the winter and cloudy summer days. This is the first report using the artificial light sources to elicit the mating activity of the black soldier fly successfully.

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Life cycle of three *Hermetia illucens* L. strains and their conversion effect on manure

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Black soldier fly (*Hermetia illucens* L.) is a very resourceful insect. It can convert animal waste into animal feed and the prepupa can be used as feed additive. However, the conversion time of black soldier fly larvae is long and the conversion rate needs improving.
In this study, we tested the development of three strains of black soldier flies and evaluated their ability of converting reducing dry matter and associated nutrients in manure. Black soldier flies were from three different places. They were fed with the same feed. Gainesville diet, which was developed for rearing house flies *Musca domestica* L. and the diet currently suggested for mass rearing the black soldier fly: alfalfa meal: wheat bran: Corn meal 3: 5: 2. They were reared at 28℃ and RH 75%.

The three strains differed in life history traits. The final larvae, prepupae and adults of Texas strain all weighed less than the other two strains, and Wuhan strain weighed most. Additionally, the larval development of Wuhan strain took 5-6 days less than the Texas strain, 3-4 days less than Guangzhou strain. Larvae of Wuhan strain reduced the dry matter and N mass more than the other two strains in each treatment with the same manure. Reduction rate of dry matter and N mass of poultry manure was higher for the Wuhan strain than for the other two strains. Based on results of this study, the Wuhan strain could be an outstanding strain to be used to convert animal waste, and the poultry manure could be a suitable food for the black soldier fly.

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Research of co-conversion of livestock and poultry manure by black soldier fly and micro organisms

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Black soldier fly (*Hermetia illucens L.*), which is a species of important insect, can be used for managing large concentrations of animal manure and other biosolids. At the same time, after the manure is digested completely, the larvae/prepupa contain high protein and fat content, which is a high quality animal feedstuff. So the black soldier fly is considered to exploit this possibility. For manure management, this purpose of this research is to add relevant microorganisms during the manure conversion process by black soldier fly which aims at promoting the conversion and the development of black soldier fly meanwhile facilitating the utility of the manure by black soldier fly.

Eight strains of bacteria with the activity of cellulase and protease were isolated from the larvae gut in aseptic condition. And there was one strain named HNB-3, which had much higher ability in digesting cellulose and protein. The categories were identified by appearance observation, physiology and biochemical experiment, and 16S rRNA gene sequence contrast. HNB-3 was *Bacillus subtilis.* The enzyme activity of the HNB-3 was determined by using the methods of DNS and Folin. HNB-3 had the highest cellulase activity (7 IU) and protease activity (12 U/ml).

Swine manure was converted using the black soldier fly larvae and the *Bacillus subtilis* HNB-3 by different ratios. Meanwhile, adding fermentation liquor to the swine manure in different inoculation time. Initial exploration of the swine manure co-conversion by black soldier fly and microorganisms were completed. In the conversion process, adding 20 ml HNB-3 could increase the weight of the larvae and conversion efficiency, compared with control group, larvae weight and conversion efficiency increased by 16.87% and 2.46%.

Secondly, 29 strains from compost materials were separated by using normalized separation method of microbes. 22 of the 29 strains had the activity of protease, amylase and cellulose, respectively. Using 29 strains to co-converted chicken manure with black soldier fly larva. Four strains: R-06, R-07, F-05, F-06 were selected to make different compound agents to co-convert chicken manure with black soldier fly larva. The experiment result showed: when the ratio was R-06 : R-07 : F-05 : F-06=1:4:1:1, the effect was the best, comparing with the blank control, the larva weight increases by 27% and the conversion rate increased by 2.07%.

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Kitchen waste converted by black soldier fly and partly substituting soymeal in chicken feed

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The black soldier fly is a kind of important worldwide spread insect and its larvae are scavengers and thrive on many kinds of decaying organic matter including carrion, manure, plant residue and waste products of beehives. On the one hand, using the black soldier fly to digest kitchen waste, we can obtain a lot of larvae containing high protein and fat that can be used as feed additives; on the other hand, for the purpose of environmental protection, the digestion process can effectively reduce the odor and moisture content of kitchen waste. The kitchen waste can also be used as a biological organic fertilizer after conversion process.

Based on successful experience of swine manure conversion by the black soldier fly larvae, the conversion process of the kitchen waste by the black soldier fly larvae was optimized to obtain a high nutrition content of the insects. The results showed that the optimal inoculation amount of larvae was 1500 larvae/kg in which group the larvae weight were 23.99 g (per 200 larvae). The conversion rate was 32.06%. The kitchen waste utilization rate was 63.01% and the kitchen waste moisture content was 53.47%. The 1500 larvae/kg group was better than other groups.

The larvae inoculation ages were also optimized. The sixth day, the eighth day, the tenth day and the twelfth day of larvae were chosen for the kitchen waste conversion. The results showed that the group of the sixth day was the best. The conversion period of the sixth day group was 11 d and obviously shorter than other group.

We also replaced the artificial feed partly using the kitchen waste to feed the black soldier fly larvae. The experiment showed that it got a better result when the ratio of kitchen waste to the artificial feed was 50%. The larvae weight was 16.36 g(100 larvae). The adult weight was 4.14 g (50 adults). The eclosion rate was 96%.

The black soldier fly larvae were used as feed additives of the chicken feed to replace soybean. The replacement proportion was 10% and 12%. The results indicated that 12% of the replacement proportion was the best, the feed/gain(F/G) was 2.26, the average daily feed intake (ADFI) was 88.30 g/d and the average daily gain(ADG) was 39.48 g/d. The results showed that the black soldier fly larvae could partly replace soybean as feed additives of the chicken, and the optimized ratio was 12%.

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Fishmeal substituted by production of chicken manure conversion with microorganisms and black soldier fly

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Hermetia illucens belongs to Insecta, Diptera, Stratiomyidae. It is a worldwide resource insect and its larvae can feed on animal manure, rotten organic matter such as carrion, rotten fruit, vegetable and plant waste. It has the traits of huge food consumption, fast reproduction rate and convenient artificial breeding, and it can be utilized to dispose manure of livestock and poultry which has attracted people's attention widely. At the same time of converting manure to the biomass of black soldier fly larvae, which also reduces the manure pollution. The black soldier fly larvae fed by manure contains rich and proportional essential amino acids and minerals, which can substitute for soybean meal, fish meal and fish oil partially and is a better feed resource for livestock and poultry.

This paper was about using black soldier fly larvae to replace fish meal partially in the feeding of yellow catfish and assessing breeding effect.

Microorganisms and black soldier flies were used to convert chicken manure, after the conversion, black soldier fly larvae were collected and dried under 50℃. Using larvae powder to substitute 0%, 13%, 25%, 37%, 48%, 68%, 85% and 100% of the fish meal in the basic feed to make 8 yellow catfish recipes. After 65 days feeding, the weight gain rate of yellow catfish in the substitution of 25% larva powder for fish meal increased 824.29%, specific growth rate was 3.42%/d, feed coefficient was 0.91.The growth index, immunity index and body component showed no significant difference compared with control group, this experiment result provided solid evidence for the black soldier fly larva substitution for fish meal in the aquaculture.

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Discovery of new anti-microbial peptides in black soldier fly and their function

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Black soldier fly can live in severe environments, i.e. environments with large amounts of pathogenic bacteria in rotten materials or manure with no death caused by pathogens. This indicates that black soldier fly can resist pathogens.

We designed 37 pairs of degenerate primers according to the conserved sequences of antimicrobial peptides of insects (mainly Diptera) from different antimicrobial peptide databases such as the APD, and screened the antimicrobial peptide genes by using these primers. We have acquired 7 gene fragments for three types of antimicrobial peptides cecropin, sarcotoxin, stomoxyn from *Hermetia illucens L*. that acupuncture induced with *E. coli* and *Staphylococcus aureus*, and marked seven genes cecropin, sarcotoxin1, sarcotoxin1(a), sarcotoxin1(b), sarcotoxin3, stomoxyn, stomoxyn(a) respectively. We did bioinformatic analysis of seven gene fragments, and predict the secondary structure and three-dimensional structure that might exist. So we concluded that 7 genes were new antibacterial peptide genes according to the sequence alignment analysis and the forecast-analysis of protein structure.

We also inserted new stomoxyn gene to the yeast expression vector pPICZαA successfully, and expressed in *Pichia Psstoris*(Pp)GS115. The anti-bacteria function of isolated protein expressed by *Pichia Psstoris*(Pp)GS115 was tested, the result turned out that stomoxyn antimicrobial peptide showed broad-spectrum antimicrobial activity, it could resist *Staphylococcus aureus*, *E.coli* and rice blast pathogen.

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Edible insects of Western and Central Africa online

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Via the project LINCAOCNET financed by the Fonds francophone des Inforoutes and the Belgian Cooperation, information on edible insects and plant hosts from 10 Western and Central African Countries were collected. The results show that between 7 to 23 species are eaten in the different countries. The preferred taxa also differ largely between countries and regions. The study combined onsite collecting fieldwork with interviews of the local population on their traditional knowledge. For example the offer on the different market places, the applied prices and recipes were taken into account. The collected standard observation data (temperature min, temperature max, clouds, start time, stop time, remarks about locality, and general remarks) was put online using templates to import batches of field data into a centralized system and link them to multimedia documents (http://gbif.africamuseum.be/lincaocnet/). The outreach to the general public and local users was particularly addressed within the project. In this regard the local common names were both provided in written form, but also recorded for proper pronunciation in the local languages.

Public awareness activities in form of presentations, posters and participation to several conferences on the importance of the nutritional substances within edible insects and their potential to overcome food security issues were organized both locally in Africa and in other parts of the world. Further outreach efforts, consisted in the organization of insect tasting events for museum visitors and schools during the Night of the Research and School French Foreign Montaigne in Benin.

This poster will summarize the project in form of richly illustrated examples of outcomes and outreach activities.

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Positive effects of dietary housefly (Musca domestica) pupa for fish and mammal

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Deficiency in edible biomass is a big problem in aquaculture, as well as food for human. Carnivorous fish aquaculture has big incoherence that cultured fish requires large inputs of wild fish for feed. It invoked mass capturing of aquatic fish, and seems to be one factor for the decline of aquatic resource, as well as environmental deterioration. Reduction of the amount of fish meal is a priority issue for sustainable aquaculture. Insects have a great potential to be a source of both food and feed. They have drawn attention as unutilized natural resource to resolve the feed problem. On the other hand, some insects have been utilized as medicine for human health, and various useful substances have been isolated from insects. Therefore, it is possible that utilization of insect as food and feed just provides not only protein source but also various positive effects for human and fish.

Housefly (*Musca domestica*) is one of the insect species which farming method has been established. Housefly can easily convert livestock manure into biomass. Here, we studied the availability of housefly pupa for fish and mammalian feed, and found various positive effects on fish and mammal. Red sea bream (*Pagrus major*), Japanese eels (*Anguilla japonica*) and Japanese yellowtails (*Seriola quinqueradiata*) had strong preference for housefly pupa, and feed containing housefly pupa promoted fish growth in short and long feeding trial. We also found dietary housefly pupa gave fish tolerance to disease with immunostimulation. Furthermore low-density lipoprotein cholesterol reduction for fish and mammal were found interestingly. These results showed great potential of insects as source of feed and food. Various benefits of insects for feeding fish and mammals, including human, are expected.

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Belgian grasshoppers: A nutritious food source

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Rapid urbanization and rising economies are creating shifts in the composition of global food demand, so it is necessary to explore new sources of food with better nutritional profile. Among the alternative food that exists are the grasshoppers, about 80 species of which are consumed worldwide. Grasshoppers are not only rich source of proteins and lipids but also some important minor component like vitamins and minerals. Edible species of grasshopper in Belgium were identified and attempts were made for the lab rearing of meadow grasshopper (*Chorthippus parallelus*). The lipids as well as protein contents of meadow grasshopper (*Chorthippus parallelus*) & long winged conehead (*Conocephalus discolor*) were investigated. The fatty acid compositions of these two species were determined by gas chromatography. Some of the physicochemical properties of the lipids extracted were also analyzed. These two grasshopper species could be really nutritious source of food.

For more info visit: http://www.gembloux.ulg.ac.be/agricultureislife/?page_id=200

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Biowastes to Bioenergy

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Energy shortage and environmental pollution are two critical issues for human beings in the 21st century. The emission of organic waste is growing extremely, such as animal manure and animal byproducts, municipal and industrial waste, but they also can be potential resources to produce biomass which has been considered as an alternative option to shift the society's dependence on fossil.

In the conversion process of dairy manure by black soldier, according to the composition of weight, fat containing of insect body and conversion rate, for dairy manure, the optimal inoculation quantity, conversion period, and feed time were 1000, 21d, and 4 times, respectively. The fat containing of black soldier fly reached 30.85%. 43.7 g black soldier fly dry matter and 13.2 g fat extraction could be get with 1000 g dried dairy manure. For pig manure, the optimal inoculation quantity, conversion period, and feed time were 1500, 14d, and 3 times, respectively. 1000 g dried manure can be converted into black soldier fly fat as high as 25.5 g. For restaurant waste, the optimal inoculation quantity, conversion period, and feed time were 2000, 8d, and 3 times, respectively. 50000 g restaurant waste can be converted into 377 g black soldier fly fat, 1000 g dried restaurant waste can be converted into 41.3 g black soldier fly fat. Use black soldier fly to convert different organic wastes, such as pig manure, chicken manure, dairy manure and restaurant waste, the fat containing of black soldier fly has been changed with high efficient.

Organic waste was successfully converted into biodiesel and protein feedstuff using black soldier fly in previous studies. The grease of black soldier fly is a new raw material for biodiesel which could be gotten from organic waste, and efficient grease production has achieved.

Compared with energy plant, black soldier fly has high reproductive capacity and short lifecycle, while the energy plants need long lifecycle and plenty of land. From comprehensive analysis of society, economy and environment, black soldier fly can recycle waste into clean energy, and reduce environmental pollution of organic waste. This work will provide a theoretical basis to further enhance the fat content of the black soldier fly from organic waste.

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Effects of egg associated bacteria on the development of black soldier fly[§]

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Symbiotic relationship between different Insects and microorganisms widely exist in the nature, in which microbes often play a major role in the development and reproduction of insects and in return will acquire favorable microenvironment and nutrition from insects. Black soldier fly (BSF), *Hermetia illucens* (L.), an omnivorous resource insect, has been of interest for its potential as waste management agent, such as animal manure, and as superior animal feed ingredients due to its insect biomass rich in protein and fat. But the research about the microbiology of BSF is surprisingly rare. Hence, a growth study with sterile BSF larvae obtained by egg surface sterilization was conducted to determine the changes of their life history traits compared with normal larvae provided with identical sterile artificial diet. The significance of bacteria to the development of BSF was further confirmed by bacteria replenishment to sterile larvae. The results demonstrated that percentage survivorship to prepupal and adult stages of sterile larvae were significantly lower than that of normal larvae. Only 57.5% of sterile larvae successfully reached adult stage. Developmental delay was detected with sterile larvae; they took 50% longer to develop to prepupal stage (30 d). Additionally, sterile larvae also took longer to reach adult stage. Adults resulting from sterile larvae (9 d) lived 2 d less than those from normal larvae. Prepupa and adults resulting from sterile larvae weighed significantly lighter. After bacteria replenishment by adding egg wash or mixed egg-associated bacteria suspension, some of the life history traits of sterile larvae were significantly improved, drawing close to that of normal larvae. It is shown that egg-associated bacteria are very important to the development of BSF larvae.

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Optimization of cricket breeding production system for human food in Ratanakiri province (Cambodia)

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Despite many natural resources, Cambodia is considered as a relatively poor country with a Gross National Income per capita averaging about 880 USD in 2012 [1]. Annâdya project in the Ratanakiri province (Cambodia) aims to improve the food security and nutrition of smallholder households by introducing and facilitating the adoption of productive and environmentally sustainable agricultural technologies [2]. The main purpose of this work was to optimize a cheap cricket breeding production system for local farmers to contribute to the reduction of protein deficiency and to create new source of incomes. Cricket development, *Teleogryllus testaceus* (Walker), was compared between seven diets composed of different ratio of aerial parts of taro, young cassava leaves, young cashew leaves, brown rice flour (with or without the addition of banana slices) and between the traditionally used chicken feed diet. Cricket mortality was relatively low on all diets (<10 %) excepted on the two cashew-based diets where mortality achieves 90 %. Mean adult body mass of the cricket was significantly higher on control diet (chicken feed) and on the two cassava-based diet (80% of cassava leave flour, 20% of brown rice with or without banana slices) than on the other diets ($F = 20.87$, $P<0.001$). The nutritional analyzes of the seven diets shows that the ideal diet should contain 19% protein, 5-6% fat, and a percentage of carbohydrates as high as possible. While the cricket mass body gain seems to be proportional to the carbohydrate content of the diet, the use of older cassava leaves, more rich in carbohydrates than the younger ones, is an interesting solution to substitute relatively expensive brown rice and banana slices also consumed by local population [3]. In the future, consideration should be given to the adjustment of cassava leave maturity in function of the cricket growth stage as it is already done with chicken feed in Thai cricket farms [4].

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2 DEVCO - EuropeAid (2012) Technology Transfer for Food Security: Helping Asia's Poorest. http://annadya.org/wp-content/uploads/2012/11/asian_food_leaflet_a4_2012.pdf. Accessed 19/02/14
3 Hue KT, Van DTT, Ledin I, Wredle E, Spörndly E (2012) Effect of harvesting frequency, variety and leaf maturity on nutrient composition, hydrogen cyanide content and cassava foliage yield. Asian-Australasian Journal of Animal Sciences 25: 1691-1700.
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Situation and perspective of entomophagy in Kinshasa

Nsevolo, P.[1], Caparros Megido, R.[1], Blecker, C.[2], Danthine, S.[2], Paul, A.[2], Haubruge, É.[1], Alabi, T.[1] and Francis, F.[1]

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Eating edible insects in Republic Democratic of Congo is a tradition for centuries but a lack of knowledge remains about an actualized inventory of species consumed in the country [1]. Moreover, a rigorous taxonomic matching of the used vernacular name of edible insects and a precise characterization of the sector of entomophagy are still needed. According to our studies focused on the city of Kinshasa, 14 edible species were inventoried as regularly consumed. They belong respectively and by degree of importance to the Lepidoptera (46.7%), Isoptera (18.6%), Orthoptera (17.6%), Coleoptera (9.7%) and Hymenoptera (3.7%) orders. Generally 80.0% of the Kinshasa population consumes at least one species of insects 5 days per month. The key peoples in the edible insect sector are mostly women. The incomes generated by this activity contribute to the wellbeing of households, to reduce poverty and food insecurity in the capital Kinshasa [1,2]. Future studies should focus on sustainable ways of harvesting wild populations, the use of improved conservation practices, the enhancement of cottage industries for farming insects and the development of economically feasible ways of mass-rearing edible species [3].

1 Mapunzu M (2002) Contribution de l'exploitation des chenilles et autres larves comestibles dans la lutte contre l'insécurité alimentaire et la pauvreté en République démocratique du Congo. Contribution des insectes de la forêt à la sécurité alimentaire L'exemple des chenilles d'Afrique Centrale. Rome: FAO.
2 Kankonde M, Tollens E (2001) Sécurité alimentaire au Congo-Kinshasa: production, consommation et survie. Paris: L'Harmattanx.
3 Van Huis A (2003) Insects as food in Sub-Saharan Africa. Insect Science and its Application 23: 163-185.

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Wild edible Arthropods of tapia woodlands (*Uapaca bojeri*) in Madagascar

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The tapia woodlands (*Uapaca bojeri* Baill., Phyllantaceae) shelter a wide variety of resources used by local villagers. In particular, the silk moth *Borocera cajani* Vinson, 1863 - or *landibe* - has been under pressures from anthropic and natural origins for many years. Mainly, silk production and entomophagy are held responsible for population decline. Other wild products of the area seem to follow the same trend, leading to a considerable exhaustion of the ecosystem. A conservation project was launched in purpose to approach all angles of this ecosystem-sized problematic. We participated, with an entomological approach, notably i) by inventorying wild edible products sheltered by tapia woods thanks to interviews with local villagers, and ii) by drawing up chemical profiles of available resources, in order to replace them in their alimentary context. Interviews highlighted at least 46 wild edible products, 15 of which were Arthropods sheltered by tapia woods or surrounding crops. Many resources were characterized by landibe-similar declining patterns. Protein and fat contents, detailed to amino and fatty acids profiles, emphasized how beneficial they are to human populations depending on them. A third set of data, generated thanks to nocturnal light trapping, allowed to hypothesize that, beyond the anthropic pressure, the main factor enhancing *landibe* populations decline is habitat fragmentation. Our data contributes to explaining the degree to which the ecosystem is degraded, and will be used to build guidelines to protect wild edible resources of the tapia woodlands.

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Impact of insect species and preparation ways on composition and digestibility for feed and food

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Protein availability for feed and food is a crucial factor for the future. In 2050, a human population of 9 billion people is expected to be provided by animal proteins. This situation is evaluated to need a production increase of around a 2 times ratio. Higher amounts of feed to rear the animals or new source of animal such as insects are expected in relation to the nutritional characteristics including digestibility efficiency. The aim of this work was to consider two insect models, namely mealworm and gryllid, as protein sources of nutrition, by studying the growth rate and responses of rat fed with different diets including insects as the main protein source and differentially prepared (various preparation technique from crude to cooked insects by varying time and temperature). Chemical analysis were performed to determine the fat and crude protein contents. These values ranged from 25±1%, 59±2% and from 15±1%, 75±3% for mealworms and for crickets respectively. Feeding assays were performed on rats with the intention to measure the nutritional value of diets including insects. Lower ingestion rates and a weaker growth rate were recorded for the insect diets compared to the control diet based on casein. That observation was higher with diet based on raw or heated mealworms. Nevertheless, the protein digestibility corrected amino acid score (PDCAAS) of rats the diets scored varied from 80 to 85 indicating that insects were quite good proteins source. Heat treatments never had positive effect on the nutritional value.

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Towards entomophagy in Belgium: development of accessible snacks by incorporation of unrecognizably processed insects

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The consumption of edible insects or entomophagy is globally promoted as one of the measures to ensure sustainability in food production [2]. However, despite the excellent nutritional properties of insects, the barrier to consume them is high in the Western world. One way to overcome this barrier is to incorporate insects in an unrecognizable way in food.

Researchers of Lab4Food [1, 3] selected three snacks and a variant of each was prepared by including insects. The insects used were freeze dried grasshoppers (*Locusta migratoria*) and fresh mealworms (*Tenebrio molitor*). These insects were grinded or chopped and added to the snack or an ingredient was replaced by the insects. The snacks were used in a hedonic sensory test and included a raspberry-mousse almond cake with or without processed grasshoppers, a pesto wrap containing a traditional pesto or a pesto in which the pine nuts were replaced by mealworms and a mini pizza containing minced meat or chopped mealworms. Participants of the sensory test knew in advance that insects were processed in some snacks and had to compare the original products with the snacks containing the insects. Parameters included were appearance, flavor, mouthfeel and texture.

The study consisted of three parts. A questionnaire was given before (part I) and after (part III) the sensory analysis (part II). Part I of the study showed that the majority of the participants (62%) had never eaten insects (knowingly) before. When asking why the participants would eat insects, 38% answered "ecological aspects", 37% "health reasons", 9% "cost", while 9% of participants reported "curiosity" as a reason to eat insects. After the sensory analysis (part III) important arguments for entomophagy still remained ecological and health reasons, however 18% of the participants also wanted to eat insects because of the taste.

When looking at the sensory analysis (part II), the various insect snacks were rated as tasteful. Moreover, the participants hardly noticed the difference between the snacks with or without insects.

These results indicate that the inclusion of insects is accepted by western consumers when they are unrecognizably processed into ready-made snacks, and when the appearance, flavor, mouthfeel and texture of the snacks are experienced as "normal".

1 Boeckx, H, Peeters, K, Van Der Borght, M (2012) Insectensnacks, gezond en lekker … of toch niet? Tijdschrift voor Voeding en Diëtetiek, 38 (6), p. 18-22.
2 FAO (2013), Edible Insects: future prospects for food and feed security, Food and Agriculture Organization of the United Nations, Rome, 2013.
3 Van Gorp, N (2012), Insecten als humane voeding - productontwikkeling, unpublished thesis, Thomas More Kempen, Life Sciences Geel, Nutrition and Dietetics.

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Effect of sanitation treatment on the microbiological quality and nutritional value of edible insects

Alabi, T.[1], Fievez, T.[1], Jonas, M.[1], Caparros, R.[1], Blecker, C.[1], Danthine, S.[1], Paul, A.[1], Haubruge, E.[1] and Francis, F.[1]

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Increasing world population with growing demands for meat products lead to address insect consumption as a sustainable way to ensure food and feed security. However edible insect promotion may not be done without industrial mass production and storage process which respect sanitation procedures. Nutritional value and sanitation procedures must enhance consumer choices for insect products. Microbial safety of edible insects needs to be certified as for any other common food.

Under several sanitation treatments, an assessment of the microbiological content of *Tenebrio molitor* and *Acheta domesticus*, two edible insects reared on different diets was performed with nutritional value pattern analysis.

Fresh crushed insects were characterized by high micro-organisms content (10^7 cfu/g total aerobic or anaerobic colony counts) among which fecal indicators, yeast and molds. Freeze drying process did not reduce any micro-organisms level in both insects, but pasteurization at 70°C for 60 min totally destroyed the microbial flora. Insects canned sterilization at the four tested treatment schemes led to the same reduction results. Nutritional value of protein, lipids and amino-acid were impacted by aseptic process investigated.

Several issues to manage insects associated micro-organisms that can be limiting factor to ensure a safe food with high nutrients were shed light by this study.

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2 Klunder, HC, Wolkers-Rooijackers, J, Korpela, JM, Nout, MJR, (2012) Microbiological aspects of processing and storage of edible insects. Food Control 26 (2), 628-631.

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The sustainability in agribusiness case research centre: Opportunities at insects to feed the world conference

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The Sustainability in Agribusiness Case Research Centre, aims to become the leading international reference point for researchers interested in developing and publishing blind peer reviewed teaching cases on agribusiness sustainability. The Centre will launch at the Wageningen International Conference on Chain and Network Management, June 4-6 Capri, Italy, and at the International Food and Agribusiness Management Association World Forum, June 17-19 Cape Town, South Africa.

This Centre will: Build on the commitment of a group of international academic colleagues and industry partners, and develop strategic links with industry and other stakeholders to promote research leading to "state of the art" agribusiness sustainability teaching cases, facilitate the development of case writing skills and activities in academia and industry, promote the benefits of case use in university and industry. [1] Grow the International Sustainability in Agribusiness Student Case Competition, securing its original Guelph offering and leading to similar events at selected international locations. [2]

Three immediate targets:

1. Q2-15: attract 30 active international case writers and 15 committed and active industry members.
2. Q2-15: publish a volume of peer reviewed sustainability in agribusiness cases.
3. Q4-15: add one or two additional offerings of the Sustainability in Agribusiness Student Case Competition.

Academic Research Activities and Centre Visibility

- The Centre will promote the writing and publication of blind peer reviewed sustainability in agribusiness teaching cases, in collaboration with an established case publisher (advantage: their distribution and sales infrastructure), or by publishing a volume in collaboration with an academic publisher every 12-18 months (advantage: use their distribution network to reach essentially all academic institutions).
- The Centre will maintain its own web page and secure industry visibility for the activities of the Centre and promote their benefits.

Why this presentation. Industry, institutional and academic participants to Insects to Feed the World offer several interesting case leads. We are here to develop this opportunity to foster debate and enhance global visibility, inform and educate students and mid-career professionals, contribute to the shaping of public opinion about the issues covered by the cases. With quality control provided by the peer review process, well written teaching cases may be used to address each of the conference objectives [3]
Join us, let's work together to help achieve these objectives.

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2 (2013) Agribusiness Sustainability Student Case Competition and Case Conference, College of Business and Economics, University of Guelph, available online, https://www.uoguelph.ca/business/agribusiness-sustainability-competition, accessed on February 24 2014.
3 (2014) Insects to Feed the World, available online, https://www.wageningenur.nl/en/show/Insects-to-feed-the-world.htm, accessed on February 24, 2014

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Human consumption and nutrient composition of adult stage of *Zonocerus variegatus*

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Man has been consuming and using insects from time immemorial for various reasons. This study was carried out to investigate reasons for eating *Zonocerus variegatus* as well as determine its nutritive value after processing. A well structured questionnaire was administered on people of Ikare, Oka-akoko, and Owo in Ondo State, Nigeria. Similarly, proximate analysis of the adult *Z.variegatus* was carried out. Results showed that inhabitants of the three towns were aware of the biology of the insect, like reproductive behavior and its annual occurrence. The majority of respondents consumed it as an item of diet (83.8%, 77.5% and 68.4% in Oka, Owo and Ikare respectively). They also thought that consumption of *Z. variegatus* is an effective control measure. The crude protein content of the processed adult *Z.variegatus* was 61.65% while ether extract, ash and carbohydrate content were20.73%, 1.25% and 4.25% respectively. Mineral content (ppm) of the processed adult insect were 150.0, 33.0, 9.1, 75.6 and 10.7 for K, Na2+, Ca2+, Mg2+ and Fe2+ respectively. *Z. variegatus* adult stage may thus be consumed as non-conventional protein source by man and his livestock.

1 Idowu, AB and Modder, WWD (1996) Possible control of the stinking grasshopper, *Zonocerus* variegatus by human consumption, Niger. Fld. 61: 7 – 14.
2 Idowu, MA, Idowu, AB and Faseki, MF (2004) Nutrient composition and processing of variegated grasshopper *Zonocerus variegatus* (L.)(Orthoptera: Pyrgomorphidae) for human consumption Niger. J. Entomol. 21:65-70
3 Banjo, OA, Lawal, M and Sangonuga, P (2005) The nutritional value of fourteen species of edible insects in sourthern western, Nigeria. African journal of Biotechnology 5(3): 298-301
4 Idowu, AB and Sonde, OA (2004) The contribution of food plants to the growth and development and fecundity of *Zonocerus variegatus* (L). Nigerian Journal of Entomology 21: 24-28

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Purification and characterisation of soluble proteins based on expanded bed adsorption (EBA) chromatography for food application

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A wide range of functional proteins can be purified from insect sources. The EBA technology is applicable to a wide range of industrial feedstocks and thus, has potential for insect protein purification. The extraction process has been developed with focus on large-scale production of water soluble proteins. The study shows how an innovative technology based on expanded bed adsorption (EBA) chromatography has been used for extraction of two protein fractions. The EBA technology allows crude unclarified feedstock to pass unhindered through a column only retaining target molecules. A subsequent wash removes the last traces of unwanted compounds before the elution releases the target molecules efficiently.

Preliminary results of the produced rapeseed protein isolates show that the products contain up to 98% protein and the major anti-nutritional factors from the protein source such as polyphenols and glucosinolates (bitter tasting phenolic compounds) have been reduced by up to 97%. The level of residue phenols is most likely below taste thresholds of individual phenolic acids. The results also suggest that the protein isolates can be useful as protein source with high nutritional value and a rich source of antioxidant activity for feed or food applications.

Functional properties of two EBA extracted protein fractions such as gelling properties, water and oil holding capacity, foam capacity and stability properties have been investigated. Some of the properties are highly sensitive to pH. The two fractions show promising functional properties that are very relevant to the food industry among others high oil binding capacity and high solubility. Both fractions have oil holding capacities just above 500%, which is higher than the values reported in literature, which is about 100% [1] and varies from 204-295% for canola meal [2].

1 Manamperi, WAR, and Pryor, SW (2010) Properties of Canola Protein-based Plastics and Protein Isolates Modified Using SDS and SDBS, *J. Am Oil Chem Soc.,* 42, 541-549.

2 Ghodsvali, A, Khodaparast, MHH, Vosoughi, M, and Diosady, LL (2005) Preparation of canola protein materials using membrane technology and evaluation of meals functional properties, *Food Research International*, 38, 223-231.

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Micro encapsulation as a means of protecting functional proteins and oils

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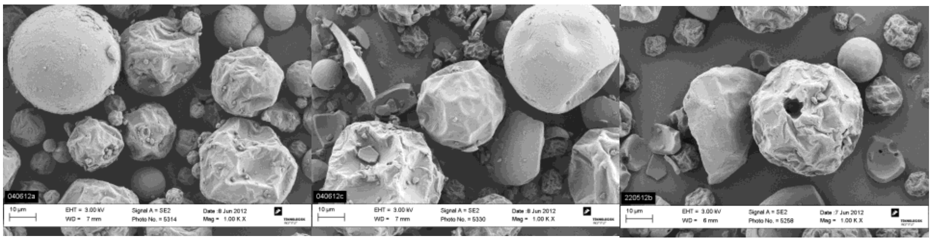
Many functional proteins, peptides and oils can be derived from insect sources, and a wide number of these are already described in the literature for a range of common (edible) insects [1,2]. With the right formulation and protection many of these compounds can be applied in an extensive variety of functional foods to enhance the nutritional value or even be able to have beneficial health effects. The functional effects are, however, dependent on the right type of formulation to ensure the protection of proteins, peptides and oils during food processing as well as in the digestive system.

Micro- or nano-encapsulation technologies are often applied to protect and deliver these delicate compounds and maintain the high nutritional value. Many encapsulation techniques involve emulsions and these are of particular interest in relation to encapsulation of food ingredients. In the case of functional, highly unsaturated oils, the oil itself may be the active ingredient, or active ingredients may be dissolved inside the emulsion droplets. One reason why the stabilization of functional oil is particularly complicated is related to the autocatalytic oxidation reaction of polyunsaturated lipids, which is complicated and proceeds rapidly when initiated. Functional peptides also face some issues in relation to protection towards e.g. high temperature processing, degradation during storage, stomach pH and correct delivery in the intestinal system.

Microencapsulation of functional peptides and polyunsaturated oils, in multifunctional systems may at the same time solve stability problems and improve the bioavailability and the associated health benefits.

Functional encapsulation systems for both highly unsaturated oils and peptides have successfully been developed. In these formulations a high degree of oil stability has been obtained, and functional peptides have been formulated to provide a longer gastric fluid stability.



Spray dried particles containing peptide in a starch formulation.

1 Rumpold, BA and Schlüter, OK (2013) Nutritional composition and safety aspects of edible insects, Molecular Nutrition & Food Research. 57

2 Yi, L, Lakemond, CMM, Sagis, LMC, Eisner-Schadler, V, Van Huis, A and Van Boekel, MAJS (2013) Extraction and characterisation of protein fractions from five insect species. Food Chemistry 141

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Entomophagy and capitalism

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The hopes invested in entomophagy are all but modest: insects are supposed to help mankind in solving problems such as the ecological crisis and malnutrition. Their potential as a good and efficient food source seems obvious and is recently becoming the subject of much scientific documentation. However, cultural, social and economic aspects are inextricably intertwined with more measurable "hard" factors, and I argue that the former should not be superseded by a merely "technical" feasibility. Ecological problems and especially food insecurity are not simply natural facts, but largely an outcome of social processes and inequalities.

While the motives underlying the increasing attention for entomophagy may be philantropic, under a capitalistic system entomophagy's potential tends to be reduced to the exchange value of insects as commodities. If the food insect market grows and develops within conventional economic structures, this will probably be accompanied by an accumulation of capital and power, thus leading to a reproduction of social inequity. Apart from perpetuating poverty (and hunger), such a development would likely prevent entomophagy from reaching its full ecological potential.

Tendencies of this kind can already be observed in Thailand and Laos. Empirical evidence (original field research) suggests that the commodification of insects as food can and does take the form of a neoliberal expansion rather than creating a "green paradise". Spheres which so far were largely based on subsistence are being interfused with market and efficiency principles, creating new necessities and dependencies. As a consequence, insects of a high quality are rendered unaffordable to significant parts of the population. Simultaneously, in the course of the professionalization of entomophagy, truly ecological modes of production and consumption are marginalized. In sum, the effects of modern transformations of entomophagous practices have been highly ambivalent at best. Whether insect eating has the positive effects hoped for will depend largely upon the form it takes, because the issues addressed go far beyond the act of consuming arthropods.

If entomophagy is integrated into a context promoting equal power relations and fostering local modes of production, it may indeed make a difference. This argument does not necessarily call for "original subsistence", but encourages a critical discussion on the possible continuation of the status quo in a new green disguise. Ignoring the danger of entomophagy becoming a part of the (social) problems that it is expected to solve may hinder its potential from unfolding.

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Comparison of honeybee pupae composition from healthy and parasitized brood by *Varroa*

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Beekeeping for honey production and crop pollination is based on deep knowledge and well developed technologies in great parts of the world. Honeybee (*Apis mellifera*) brood is also largely used as human food in tropical regions and has a great potential to become a future source of proteins or medicines. The ectoparasite Varroa mite (*Varroa destructor*) affects colonies and largely endangers the bee production. The impact of infestation on the nutritive qualities of honeybee brood is unknown. We compared the main components of infested and parasite free pupae, harvested from the same colonies that were not treated against the parasite during the last six months. Honeybee pupae contained 19.9 ± 1.3% (mean ± SD) of dry matter which was analyzed for components. The protein content of infested and parasite free pupae was not different and was very high, 55 ± 4% of the dry matter. Also the protein profile, analyzed by SDS-PAGE, showed a consistent pattern with no reliance to Varroa, but differs by age. The total lipids was also not affected by the parasite, but was differentiated following young and old pupae: 16.4 ± 1.2% and 13 ± 1% respectively. It was mainly composed of the following fatty acids, differentiated by and: oleic acid (37% in young, and 46% in old pupae), palmitic acid (29% in young, and 33% in old pupae) and stearic acid (16% for both young and old pupae). Trace levels (2%) of essential omega 3 and omega 6 fatty acids were detected too. Cholesterol levels were minimal (<0.05%). A high antioxidant activity was detected in both infested and parasite free pupae by Ferric Reducing Antioxidant Power assay (0.1 mg pupae was equivalent to 0.3mM trolox and 0.3mM vitamin C), activity of peroxidase and catalase enzymes. Vitamin C content was constant too. All examined data showed no effect of Varroa infestation on nutritional composition of pupae. In the following up study, the amino acid composition and the mineral content will be analyzed as well between Varroa infested bees and non-infested. The findings suggest that Varroa has no significant effect on the honeybee brood nutritive quality and it can all be taken into consideration in future purposes to produce food, animal feed and medicines.

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Hermetia as a transformer of organic waste streams for aquaculture feed

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Fish meal and fish oil have been, and still are the main ingredients in modern fish feeds in aquaculture. Increased consumer and environmental awareness have resulted in development in other directions, as substantial amount of worldwide wild fish catches is processed into fishmeal and fish oil for feed production, raising concerns regarding the sustainability of this arrangement. With regards to both resource utilization and environmental issues, it is therefore important to look at other biological streams as raw material sources for fish feed, such as transformation through insects. Significant amounts of raw materials are underutilized in Iceland, including waste from agriculture, fish processing, households and manure from livestock production. Due to the low protein content of most waste streams mentioned, this raw material is not suitable for direct use in fish feed. However, with low expenditure, these raw materials can be utilized for the cultivation of invertebrates which in turn transforms them into high quality protein and oil ingredients for feed. In addition, this would reduce the enormous amount of waste generated. Pre-feasibility studies have shown that the Black soldier fly (*Hermetia illucens*) represents a promising option in this context and there is a growing interest in its use for the production of feed protein. This study seeks to answer questions related to optimal raw material use for the Black soldier fly larvae as ingredient for fish feed and potential raw material reduction. Results so far have shown that the larvae can be grown on different substrates but with variable efficiency. By taking advantage of available nutrients and water, the larvae can reduce the amount of feedstuff by 50-95 %, making the benefits of their use substantial in relation to resource utilization and environmental impacts. Feed conversion ratio (FCR) in specified raw materials with certain environmental conditions was assessed, i.e. reduction of raw material versus adult larva. The nutritional value of the larvae was analysed as potential feed ingredient after each test diet, with parallel experiments performed with different raw materials and raw material composition.

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Cholesterol and edible insects

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Edible insects appear to be very promising part of the diet for the future of food either in third world countries or in developed countries. Unlike countries where insects provide and in long term will provide mainly basic nutrients (proteins, fats, saccharides) a country with plenty of food sources will use insects rather as a source of complementary nutritional substances. One of the components, which content in food is monitored in developed countries is cholesterol. Therefore, we started analysing of the cholesterol in selected insect species available and suitable to eat in Central Europe after Bednářová et al. [1]. The results of previous measurements show that, as in commonly consumed foods, there are significant differences in cholesterol content among insect species. Therefore for the future use of insects in the food sector, suitable species will have to be chosen according to specific nutritional needs of the consumer. This is also necessary, as according to previously published scientific studies [2], the human body needs cholesterol and at the same time its level in the body can be regulated by the intake of other nutritional substances in food. For example, the consumption of dietary fibre can reduce cholesterol levels by 10 % [3].

In our analysis, the interesting species, as far as the cholesterol content is concerned, seems to be cricket *Gryllus assimillis*, whose cholesterol content is comparable to egg yolk - 310mg.100g^{-1}. The first results show that this area deserves more attention, and that insect as a food alternative should not be accepted uncritically.

1 Bednářová, M, Borkovcová, M, Mlček, J, Rop, O, Zeman, L (2013) Edible insects - species suitable for entomophagy under condition of Czech Republic. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 61, 587-593
2 Pfrieger, FW, Ungerer, N (2011) Cholesterol metabolism in neurons and astrocytes. Progress in Lipid Research, 50, 357-371.
3 Knopp, RH, Superko, HR, Davidson, M, Insull, W, Dujovne, CA, et al. (1999) Long-term blood cholesterol–lowering effects of a dietary fiber supplement, American Journal of Preventive Medicine, 17, 18-22.

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Entomophagy in the Czech Republic

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Systematic research in the field of entomophagy in the Czech Republic began in 2002. The first objective was to define the sources of edible insects. In this research it has been shown that collecting insects in nature it is not suitable, and if we want to avoid import of insects, it is necessary to use insects from Czech breeders. In the next phase of the research, acceptability of all insect species bred in Czech Republic was observed. To determine the sensory attractiveness, more than 2500 questionnaires were evaluated. Respondents marked seven species as acceptable, e.g. *Tenebrio molitor* and *Gryllus assimillis* [1]. In the next step of the research, nutritional analyses of these seven species were carried out. Significant differences among the species were detected, thus the suitability of these species for specific groups of consumers may vary [2]. Subsequently, another survey was conducted, to find out what form the Czech consumers prefer while eating insects. Approximately 90 percent of Czech respondents prefer not to see insects in food. Survey was also conducted among breeders and food producers, to find out their will to adapt themselves on breeding insects as food, while the results showed great willingness. Also, the attitude of catering facilities (e.g. restaurants) to edible insects is positive. Consumers, breeders, food producers and sellers are ready for establishing insects as a part of Czech diet. The only thing that prevents it is the absence of legislation, both European and Czech.

1 Bednářová, M, Borkovcová, M, Mlček, J, Rop, O, Zeman, L (2013) Edible insects - species suitable for entomophagy under condition of Czech Republic. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 61, 587-593
2 Bednářová, M, Borkovcová, M, Komprda, T (2014) Purine derivate content and amino acid profile in larval stages of three edible insects. Journal of the Sciences of Food and Agriculture, 94, 71-77.

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Breeding flies in Ghana: Implications of scaling up from pilot trials to commercial production scale

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Global enthusiasm for insect farming is growing as a diverse range of potential commercial and environmental benefits become better recognised. Fly rearing is a good example: maggots can be cultured on various organic wastes or by-products (manures, food leftovers, etc.) reducing volumes, odours and alternative disposal costs. Products include a high quality protein source (maggots) that can be fed to livestock and fish in nutrient deficit areas, as well as nutrient rich biofertilisers (residues). This paper describes the iterative learning-process involved in the development of a pilot-scale production system in Ghana, the first of its kind in West Africa. The primary aim of the project was to demonstrate the feasibility of producing a local, low-cost and high quality source of nutrients that could be used in aquaculture; fish farming is growing fast in Ghana but constrained by availability of quality feed ingredients. Starting from a greenfield site, the choice was made to progressively scale-up to a medium-scale demonstration pilot for two fly species (*Hermetia illucens* and *Musca domestica*) producing several kilograms of maggots per week. The paper describes the main stages of development and the challenges faced when planning day-to-day improvements of the production system. We discuss criteria used to design the facilities, select the appropriate organic substrate for each insect species and standardise the production methods. Finally we review major bottlenecks encountered and the solutions adopted. Preliminary results suggest that this pilot is well adapted to local resource conditions. Further research is underway evaluating how the resulting maggots can substitute for conventional sources of proteins (fishmeal, soybean meal, etc.) in poultry or aqua feeds or be used to supplement nutrient-deficient diets. The model offers potential for development in at least two directions, a smaller-scale system based on limited investment, substrate and labour inputs for household-based or small-scale enterprise production, or a larger-scale intensive commercial system requiring more capital, equipment and labour, which would need to be integrated as part of a more complex emergent value-chain.

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Exploring insect wastes as a fertiliser: A preliminary study

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The important issue of insects meals is to feed animals in alternative to soybean or fishmeal which poses severe environmental issues as protein demand is increasing at the world scale [1]. In order to develop new environmentally sustainable feeds, FAO indicates insects as innovative protein source to be employed in feed [2-3]. The environmental benefits of rearing insects for food and feed are based on the high feed conversion efficiency of insects.

For these reasons large insects farms are developing in South Africa, South America, and China. This will increase the production of insect wastes. In order to increase the sustainability of the system, these wastes could represent a resource to be recycled efficiently. To our knowledge there are no studies on the use of insect wastes as fertiliser. In order to improve environmental and economic performance of insect farms, different strategies to use insect wastes into different production processes should be explored.
The aim of this work is to investigate the potential for use of insect wastes as fertiliser.
Three types of wastes produced were analysed: two wastes produced by *Tenebrio molitor* fed with bran (Ten-pot) or with standard pet feed (Ten-pet) and one waste produced by *Hermetia illucens* fed former foodstuff (Her-pot).

The wastes were characterized for macro and micro nutrients content, and other chemical parameters to evaluate their fertilising potential Ten-pot was also tested as a fertiliser in a pot trial where rocket (*Eruca vesicaria* (L.) Cav.) was grown, comparing Ten-pot with mineral fertiliser at the same N amount. Three fertiliser levels were tested: 0, 60 and 120 kg N ha^{-1}.

Chemical characterization showed a good potential for this material to be used as a fertiliser: all tested wastes showed low humidity values (18%), a sub-acid to neutral reaction, and a good and balanced nutrient amount (average NPK content was 4.1%, 2.4%, 1.9%), comparable with other organic manures. The physical quality of the product could allow easy storing, packing and transport without any further transformation or stabilization. It could be used also in organic farms. The pot trial showed good fertilisation value of Ten-pot at all fertilisation levels. Further investigation need to be performed on different crops and testing various types of excreta obtained from the most commercial insect species in order to explore the possibility to obtain a larger spectrum of commercial products with variable characteristics.

1 Sánchez-Muros MJ., Barroso FG., Manzano-Agugliaro F (2014) Insect meal as renewable source of food for animal feeding: a review. Journal of Cleaner Production 65, 16-27.
2 FAO (2013) Edible insects. Future prospects for food and feed security. http://www.fao.org/docrep/018/i3253e/i3253e.pdf
3 Rumpold BA, Schlüter OK (2013) Potential and challenges of insects as an innovative source for food and feed production. Innovative Food Science and Emerging Technologies 17, 1–11.

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Honey, pollen and propolis production of *Trigona laeviceps*

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One of the stingless bees, namely *Trigona laeviceps* is categorised as an insect with high pollen and propolis production, and the honey produced is more expensive than honey of *Apis* sp. In Indonesia there are as many as 37 stingless bee species, but until now they are not yet cultivated. This study aimed to analyse and compare the honey, pollen and propolis production of *T. laeviceps* kept in sengon wood and plywood stups. The study was conducted for 3 months, from March to May 2013. A Completely Randomized Design was used with different stup materials used, as treatment and 5 replications. The observed variables were flight activity, light intensity, temperature and relative humidity, air flow velocity, colony weight, honey, pollen and propolis production. The data obtained were tabulated and analyzed using Analysis of variance (ANOVA) and t test at 0.05. Daily flight activity of *T. laeviceps* kept in sengon wood was significantly higher ($p < 0.01$) than in ply wood stup (80.40 vs 42.33 bee/day). The light intensity affected the daily flight activity of *Trigona* bees (R^2=78.3% in sengon wood and 85.6 in ply wood stup). Colony weight in sengon stup was significantly higher ($P < 0.05$) than in ply wood (23.70 vs 8.44 g/week), whereas, the propolis, bee pollen and honey production all together, was not significantly different (21.66 vs 18.76 g per 8 weeks). These results indicated that daily flight activity of *T. laeviceps* was higher for the bees kept in sengon stup as compared to those in plywood stup.

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Growth performance of common catfish (*Ameiurus melas* Raf.) fingerlings fed insect meal diets

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A growth trial was performed to evaluate the effect of replacement of fish meal (FM) with insect meal (IM) on growth performance and survival rate of common catfish (*Ameiurus melas*). Fingerlings of *A. melas* were randomly distributed into 4 indoor tanks of 2 m^3 at a density of 2,000/tank (2 replicates), and kept at a temperature of 23-25°C in two separated recirculating aquaculture systems (RAS). Fish were divided in two groups: FM and IM, differing for the feed. Fish of the FM group were fed a control diet of 50% FM protein and 18% lipid whereas those of the IM group received the same diet but protein component consisted of 50% FM and 50% IM (*Tenebrio molitor*). Fish were fed with crumbled diets (200-500 µm) by means of automatic feeders (12 h) at a daily ratio of 6% (day 1- day 30), 5% (day 31- day 60), and 4% (day 61- day 90) of biomass. The trial lasted 90 days and fish weights were monitored at 30 days intervals. Growth performances were good in both groups. However, fish of the IM group reached a final mean body weight (4.2±0.6 g) significantly lower than that of the FM one (5.13±0.7 g). The survival rate of FM group (79%) was higher than that of IM (70%), too.

In conclusion, the results of this study demonstrated that the diet including insect meal was able to sustain growth in catfish fingerlings. Differences in the survival rate were significant between the two groups but the results can be considered fully satisfying. In fact, the survival rate of the IM group was more favourable if compared with the one obtained in first rearing ponds located at the catfish farm (30-50%).

The authors thank gratefully to Gaobeidian Shannong Biology CO., LTD (Gaobeidian, Hebei province, China) for providing Tenebrio molitor meal.

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Insects as feed and food: A comparison of domestication potential of some species

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A review of the research conducted at the Stellenbosch University in collaboration with Agriprotein (Pty) Ltd on the use of different species of insects for feed and food production is reported. Species reported on include mealworm (*Tenebrio molitor*), superworm (*Zophobas morio*), cricket (*Acheta domestica*), Lobster roach (*Nauphoeta cinerea*), Turkistan roach (*Blatta lateralis*), Cape red head roach (*Oxyhaloa deusta*), Palmeto roach (*Periplaneta americana*), Orange spot roach (*Blaptica dubai*) and the Madagascar hissing roach (*Gromphadorhina portentosa*). Further production potential data is given for the Black soldier fly (*Hermetia illucens*), Housefly (*Musca domestica*) and the Copper bottom blow fly (*Chrysomya chloropyga*). Each species was separated into five containers each containing 50 adults of known and balanced sex type except for *T. molitor*, *Z. morio*, *O. deusta* and *P. Americana* where sex types were unknown. Eggs were collected and placed in the insect hatchery. For beetles frass was sieved out on a weekly basis and stored in combination with uneaten vegetables. Cricket eggs were collected on a daily basis using containers filled with moist soil. Data recorded include reproductive potential and production parameters. It is concluded that the beetles and especially *T. molitor* has huge potential for mass rearing, this also holds true for *A. domestica*. Egg producing roaches i.e. *B. lateralis* and *P. Americana* are the easiest to manage while the production rate of *N. cinerea* and *B. dubai* are superior but separation of age groups are challenging due to the fact that they are live bearers, further research is being conducted in this area. *G. portentosa* appears to have inferior production potential and combined with the difficulties associated with live bearers do not appear to be a viable species for production at this stage.

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Insect rearing optimization of *Hermetia illucens* on different organic waste streams

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The growing demand for durable reduction of organic waste streams let to a search for alternative waste disposal methods. Rearing *Hermetia illucens (Diptera: Stratiomydae, L.)* larvae offers potential, because of its ability to convert waste streams into usable nutrients for the food and feed industry. However, research on optimisation of rearing *H. illucens* larvae on organic waste streams is still in its developmental stage. Therefore, the primary research aim was the optimisation of rearing *H. illucens* larvae on the organic waste streams fruit and vegetable waste and organic house waste fraction. Larval growth rate, defined as the growth curve of larval fresh weight per day, and bioconversion factors were determined for larvae reared on the two organic waste streams and a control of chicken feed. Our research examined differences in larval growth rate between organic waste streams, water contents and food portions. Furthermore, this study determined bioconversion factors of larvae reared on different organic waste streams and food portions. Lastly, we determined optimal larval growth rates on different food portions. Larvae grown on fruit and vegetable waste showed equal fresh weights to the control group and stopped growing after day 12 of its larval stage. Larvae grown on the organic house waste fraction showed a significantly lower fresh weight than the control group and stopped growing after the day 10. A possible explanation is that a parts of organic matter in organic house waste fraction was bound inedible for larvae and thus caused early stagnation in growth. Different water contents showed no significant differences in larval growth rate. However, more research on its effects on the growth rate is recommended. Different food portions were first named as small, medium and large sized portions, based on earlier research. Medium and large food portions yielded larvae with higher fresh weights compared to small food portions. Larvae reared on small food portions stagnated in growth on day 10 as compared to larvae grown on medium and large food portions who stagnated on day 12. However, no further increase in larval fresh weight was found when fed more food than the medium food portion. Bioconversion factors showed no differences between larvae reared on small, medium and large food portions of fruit and vegetable waste. However, a lower uptake of organic matter inside growth media and increase inside larvae were found from larvae reared on small food portions compared to medium and large food portions. Further our study showed optimal growth rates at 110 grams of fruit and vegetable waste per 100 larvae, with a stagnation in growth on day 11. The differences in harvest day can be attributed due to inconsistencies in growth media. Rearing on organic house waste fraction is not recommended as more food is needed to possibly reach the same fresh weight as found with fruit & vegetable waste. The addition of more food increases the risk of mould growth and mortality of larvae.

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Fatty acid profile and antioxidant content of pupae of a yellow strains of *Bombyx mori*

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Bombyx mori (Linnaeus, 1758). is one of the most studied insects in the word due to its remarkable economic value for silk production. The domestication of this insect promoted its intensive mass rearing and, at present, more than 1000 strains, including geographical and mutant ones, are recorded in world germplasm collections. In silk reeling process a large quantity of wastes accumulates in form of dry spent pupae which could be profitably utilized as added-value co-products. Spent pupae may represent an important alternative source of nutrition both for animal feeding and for humans, according to the increasing worldwide request for protein related to growing population and human wellbeing.

The most commercially valuable hybrids of silkworm are characterized by large white cocoons that have been originally selected to produce long and resistant silk threads. However, many mutants for cocoon color, including yellow, golden yellow, orange, pink and green are grown for commercial purposes in different areas of the world. Even though these strains are not very productive in terms of silk yield, their rustic and wilder characters make them able to retain some unique capacities as, for example, the ability to absorb carotenoids or flavonoids from their feed substrates. Once accumulated on the cocoons surfaces, these pigments protect the worm from oxidative processes induced by environmental factors (sunlight, UV rays etc.).

Although there is an extensive literature about the nutritional properties of commercially available silkworm hybrids, few data are available for cocoon-colored strains, which offer a still unexplored potential to improve the quality of insects meals.

In our experiments fatty acid profile and antioxidant content of dry pupae of a golden yellow strain of *B. mori* have been determined in comparison to pupal composition of a white cocoon silkworm hybrid.

Compositional analysis has been conducted on pupae meal coming from both larvae of Nistari strain and larvae of a white polihybrid strains reared under controlled conditions and fed with artificial diet.

Moisture and fat content have been gravimetrically determined; fatty acids and carotenoid fraction have been extracted and respectively quantified with a GC-FID and HPLC-PDA equipment. The total phenolic content and the antioxidant activity of pupa meal have been determined by spectrophotometric techniques.

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Conversion of nutrients from pig feces and food waste by the black soldier fly: Preliminary results

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The conversion of nutrients from two substrates by the black soldier fly was examined in a preliminary trial as commissioned by Millibeter, a company that seeks to make raw materials for industry and agriculture from waste. The substrates were fresh solid sow feces collected from the slatted floor (A) and mixed food waste consisting of vegetables, fruits and processed food (B). Two identical bioconversion units were constructed from 300 L-iron tippers (144x68x58 cm) that were sealed and equipped with one ball valve opening for feed supply and two smaller openings for aeration. The tippers were placed at the entrance of a pig barn with no extra heating. A 24-days-experiment (July, 2013) started with 75-100g larvae. Increasing amounts of substrate were daily added, totaling 45 kg of substrate per unit. At day 26, substrate and larvae were weighed, larvae were then separated from the substrate by wet sieving, were rinsed, dried and weighed. Pooled substrate sampled during cultivation and larvae samples were dried and ground. The substrate was analysed for dry matter (DM), crude protein (CP), crude fat (CFat), crude fibre (CF) and crude ash (CA) and the other carbohydrates (CH) were calculated by difference. The same analyses were carried out on the larvae samples except CF, which was considered to equal zero. The feces contained 20.2% DM, of which 15.3% CP, 8.3% CFat, 20.1% CF, 17.8% CA and 38.6% CH. The food waste contained 18.3% DM, of which 19.0% CP, 22.2% CFat, 8.6% CF, 9.3% CA and 40.9% CH. Larvae yielded 0.76 and 1.80 kg DM on pig feces and food waste, respectively. Larvae from A and B contained 30.6 and 36.1% DM, of which 38.4 and 34.0% CP, 32.4 and 47.2% CFat, 16.7 and 6.8% CA and 12.5 and 12.0 % CH, respectively. The conversion rate (nutrients in larvae/nutrients in substrate fed) in A vs. B amounted to 8.4 vs. 21.9% for DM, 22.2 vs. 34.3% for CP, 34.6 vs. 40.6% for CFat, 8.3 vs. 14.0% for CA and 2.9 vs. 5.6% for CH. The main conclusions are: (1) food waste clearly is a better substrate than pig feces, (2) conversion of crude fat is better than that of crude protein, (3) and conversion of crude ash and particularly carbohydrates is very low.

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Edible Saturnids harvested around Arabuko sokoke forest in Kilifi County, Kenya

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As the world’s population grows to an estimated 9 billion by 2050, demand for alternative protein sources will only continue to increase. Insects are prospective candidates because over 1,900 species of insect species are used as food [5], and they have high reproduction rate, short life span, high conversion rates, have less risky of zoonotic diseases, are easy to handle, produce low of GHG and they require few resources [4]. The societies living around Arabuko sokoke forest collect and consume various Saturnid larvae; however the identity of the caterpillars had not been documented. This study investigated the identity of the Saturnids in order to create an inventory of edible insects in Kenya. A pilot survey was done to determine the study sites. The study was carried during the long rainy season (June –August 2012) and short rainy season (November 2012-January 2013) in five villages bordering Arabuko sokoke at Latitude 03° 15' 942'' S to 03° 16' 581'' S, Longitude 39° 49' 047'' E to 39° 48' 376'' E at 126-137 meters above sea level. During the study, larvae were searched in the fields with the help of locals. The spotted larvae were covered with net sleeves measuring 1M×1M×1M and reared on their food plant until they showed pre-pupating behavior. The ready-to-pupate larvae were transferred into breeding cages with damp sand soil up to 20 centimeters in order to pupate. The formed pupae were harvested by emptying the breeding cages carefully. The pupae were kept in breeding cages with twigs to provide roosting place for the emerged moths to allow development of wings. The moths were collected and killed by pressing the thorax between the index finger and thumb. Killed moths were pinned and displayed for identification at the National Museums of Kenya-Invertebrate Zoology laboratory at Nairobi. Moths were identified by matching the specimen with the reference collection using the morphological features of the specimens and identity confirmed by Bar-coding. The moth species were identified and classified as members of Order Lepidoptera, Super family Bombycoidea, and Family Saturniidae while the Sub family is Saturniinae, and tribe is Bunaeini [3]. The edible Saturnids are: *Bunaea alcinoe,* Common Emperor*, Melonacera mennipe*, Chestnut Emperor and *Cirina forda,* Pallid Emperor [1, 2 &3].

1 Bethune–Baker, GT. (1911) Descriptions of new species of Lepidoptera from Tropical Africa. Annual magazine Natural History. (8) 8: 507-542

2 Gardener, BA, (1875) On a collection of Lepidoptera from Southern Africa, with descriptions of new Genera and species. Annual Magazine Natural History. (4) 16: 394-420

3 Holloway, JD, Bradley, JD and Carter, DJ. (1987) Lepidoptera, Guide to insects of importance to man. British Museum, Natural History.

4 Van Huis, A (2013) Potential of insects as food and feed in assuring food security. Annual Review of Entomology, 58: 563-583, WUR (2013) List of edible insects of the world. Wageningen, Wageningen University.

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Small scale experimental insect farming: Compliance of raw insects and processed flour with food hygiene requirements

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With a world population that will eventually reach 9 billion people by 2050, the dietary protein availability will especially represent a core issue, since the current meat production model, i.e. intensive animal farming, is neither sustainable nor "exportable" [1]. Livestock breeding requires massive deforestation, heavy water footprint and greenhouse gas emission, thus leading to significant ecosystem degradation. Since agriculture as well doesn't represent the ultimate solution to the problem, alternative protein sources should be investigated. Edible insect are already part of the food culture of several countries all over the world, but they could be further and better exploited by setting up peculiar "mini-livestock" farms and if pragmatically proposed on the Western food market. Many studies underlined that insects own a valuable proteic content [2]. Moreover, their essential amino acid profile is complete and quite similar to the one of traditional meat [3]. Suitable species can be selected for breeding in order to maximize the potentialities of such alternative farms. On the whole, a mini-livestock farm should optimize the protein production by achieving the best breeding yield, but in the meantime it should be compliant with human food safety standards. Under this perspective, insects diet and housing conditions represent the key factors of the whole process. The present project was developed in two distinct phases: the first consisted in the pilot set up of a small-scale insect farm, while the second one simulated a controlled food-processing process. For this purpose, two insect species were choosen: the house cricket *Acheta domestica* (adult form) and the honeycomb moth *Galleria mellonella* (last larval stadium). Both insects are easy to breed and, moreover, they are autochthonous to the authors' geographical area, thus avoiding the risk of introducing exotic species in the local ecosystem. The rearing conditions were accurately examined in order to create an organic diet and hygienic housing for the insects. The simulated food-processment aimed at obtaining a dry insect flour, possibly marketable as nutritional supplement. Hygienic compliance of both raw insect meat and processed flour with microbiological and chemical criteria [4] was further assessed by analytical tests. Microbiological and nutritional quality of crickets and moth larvae grown under experimental conditions was also compared with the one of isospecific insects generically bred as live food for pet animals.

1 Alexandratos, N, Bruinsma, J (2012) World agriculture towards 2030/2050 – The 2012 Revision. ESA Working Paper no. 12-03, Agricultural Development economic Division, FAO-UN. E-document available on: http://www.fao.org/docrep/016/ap106e/ap106e.pdf
2 Premalatha, M, Abbasi, T, Abbasi, T, Abbasi, SA (2011) Energy-efficient food production to reduce global warming and ecodegradation: The use of edible insects. Renewable and Sustainable Energy Reviews, 15:4357-4360.
3 Bukkens, SGF (2005) Insects in the human diet: Nutritional aspects. In: Paoletti, M.G. Ecological Implications of Minilivestock - Potential of Insects, Rodents, Frogs and Snails. Science Publishers, Enfield.
4 European Commission (2005) Commission Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs. Official Journal of the European Union, L 388:1-26.

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The potential of black soldier fly (*Hermetia illucens* L.) as animal feed: Biological view

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Black Soldier Fly – BSF; *Hermetia illucens* L. (Diptera: Stratiomyidae) is a saprophagous species that can be used in manure management, to control other dipterans, and for the bioconversion of organic waste. BSF larvae feed on different decaying organic materials and, can convert these into high quality proteins and lipids. Its nutritional value depends on the quality and quantity of food ingested and has been reported to contain both high protein and fat content (37 – 57% and 13 – 35%, respectively). BSF has been used as feed for a variety of animals, including swine, chickens, and fish, and is being explored as an important ingredient for pet feed. There are some studies related to biology and nutrition of BSF, however, there are knowledge gaps that need to be filled. Particularly, to what extent inclusion of BSF in feedstuff contributes to a circular economy needs to be explored more thoroughly. Although there are some studies on the effects of abiotic and biotic factors on BSF rearing success, those did not address improvement of production performance and nutritional value. To judge its aptness as animal feed, detailed information on its biology, nutritional traits and economic aspects is required. In an ongoing project we perform experiments exploring how the density of BSF larvae and the dietary macronutrients affect lifetime performance and body elemental composition, and what are the possibilities to improve BSF yield and nutritional value for husbandry animals. The project's results will provide information on BSF physiology, performance and body composition that will allow a more efficient use of this species as animal feed.

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Development and marketing of new proteins; experienced impediments, solutions and tools

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The introduction of new proteins like proteins derived from insects or insect based ingredients on the EU food market is complex, time consuming and rather expensive. The most important impediments which companies experience in the development and marketing of new proteins are [1]: the complex and opaque procedures of the EU Regulation (EC) No 258/97 on novel foods and novel food ingredients; insufficient acceptance from consumers and producers.

To overcome the experienced complex procedures of the Novel Food Regulation tools have been developed in a research project for the Ministry of Economic Affairs and in a public private partnership project: a decision tree and a guideline. Producers of new proteins like those derived from insects, algae, sugar beet leaves and duck weed worked together with researchers to understand the complex procedures and to fill their application dossiers in an efficient way. Two tools were developed to support the compilation of a dossier. Also advises of researchers for filling of dossiers for specific proteins have been helpful for the involved companies.

The Decision Tree Novel Food [3] can be used by companies to determine whether a new product is a Novel Food and what kind of authorisation is needed: authorisation or notification. When it is clear a product is a novel food, a dossier should be compiled.

A guideline [2] was made to support companies in composing their dossiers. It is essential that companies tell a convincing story in the application dossier substantiating with sufficient data that the new protein is safe for human consumption. A dossier should contain all information which is necessary to prove this. The guideline describes in detail the items to be addressed in these application dossiers and gives references to guidance documents of competent authorities (CAs). Furthermore examples of already evaluated assessments and dossiers are provided. It also gives clue recommendations about what information for each item might be considered to be sufficient by CAs. However, for many items there are no clear-cut criteria. It should be stressed that each application dossier for a novel protein will have a different content due to specific product related characteristics. The opinion from member states' CAs or European Food Safety Authority (EFSA) cannot be predicted.

[1] Wagenberg, CPA van, Eppink, MM, Janssens, SRM, Van der Roest, J, Van der Sluis, AA, en Van der Spiegel, M (2012) Ontwikkeling en vermarkting van nieuwe eiwitten; Ervaren belemmeringen en oplossingen. LEI-rapport 2011-061.
[2] Wagenberg, CPA van, Janssens, B, Kalk, C, Van der Sluis, A, (2014) Guideline for making application dossiers for novel proteins; Novel food dossiers: from black box to tool box. in preparation.
[3] http://eiwitinnovaties.fbresearch.nl/page/decision-tree-novel-food

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Enabling the exploitation of insects as a sustainable source of protein for animal feed and human nutrition PROteINSECT

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Food security is a global challenge. Within the overall increased demand for food, and particularly meat production, there is also an urgent need to increase supply of protein from sustainable sources. The principle objective of the international and multidisciplinary PROteINSECT consortium is to facilitate the exploitation of insects as an alternative protein source for animal and human nutrition. Advances have been made in rearing of insects for incorporation in animal feed in countries including China and Mali. The consortium brings together expertise in these countries together with European insect breeders and feed production companies in order to optimise systems and set up pilot scale production facilities in the EU. The project will demonstrate the feasibility of the use of insect-derived proteins in animal feed through trials with fish, poultry and pigs. Quality and safety along the food chain from insect protein itself, to incorporation in feed and ultimately human consumption of insect-protein reared livestock, will be evaluated. The use of waste streams that focus on animal rather than plant material for insect rearing will be examined. To optimise the economic viability of the use of insect proteins, uses for the residual flows from the production system will be determined. Life cycle analyses will enable the design of optimised and sustainable production systems suitable for adoption in both ICPC and European countries. Key to uptake is ensuring that a regulatory framework is in place and this will be encouraged by the preparation of a White Paper following consultation with key stakeholders, experts and consumers. PROteINSECT will build a pro-insect platform in Europe to encourage adoption of sustainable protein production technologies in order to reduce the reliance of the feed industry on plant/fish derived proteins in the short term, and promote the acceptance of insect protein as a direct component of human food in the longer term.

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Value added creation of eri silkworm (*Samia ricini* D.) pupa by cultivation of medicinal fungus (*Cordyceps militaris*) in Thailand

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This study aims to evaluate growth and development mainly of *Cordyceps militaris* isolates on eri silkworm (*Samia ricini* D.), an edible safety and high protein insect, using pupae and solid medium incorporated with pupa powder. Six isolates of *Cordyceps* spp. derived from nature (No.1 *Isaria tenuipes*; *C. takaomontana*) and commercial isolates (No.2-6 *C. militaris*) were inoculated on eri silkworm pupae and rice grain medium mixed with eri silkworm pupa powder (10% w/w) and mineral solution. The cultures were incubated in the continuous dark incubator at 20±1 ºC for 14 days until hyphae colonized fully on pupae or media and followed by incubation under light (2000 lux)/dark (12h/12h) at 20±2 ºC, 75-85 % (R.H.) to induce fructification. Results showed that 3 isolates, No. 1(Native isolate), No.3 and No.4 grew and developed stroma on eri pupae in 45 days after inoculation. On rice grain based artificial medium with eri pupa powder, 4 isolates (No.1, 3, 4 and 6) could produce stroma in 45-60 days. Morphological character of stroma depended on different fungal isolates. Our study suggests the exploitation and value added creation of eri silkworm pupa by cultivation of medicinal fungus (*C. militaris*) as source of amino acids and for large-scale cultivation in Thailand. Furthermore, larva stage and ecorace/variety of both eri silkworm and mulberry silkworm as growing media are ongoing research.

1 Jin, Y-Q, and Li, B (2013) Cultivation of eri-silkworm *Cordyceps militaris* and determination of its amino acid composition. Adv.Mat.Res. 796:21-24.
2 Shrestha, B, Zhang, W, Zhang, Y and Liu, X (2012) The medicinal fungus *Cordyceps militaris*: research and development. Mycol Progress DOI 10.1007/s11557-012-0825-y.

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Entomophagy at the New York Entomological Society 100th Anniversary celebration

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In May 1992, The New York Entomological Society celebrated its 100th Anniversary and the organizing committee decided on entomophagy as our theme. Our president was good friends with a well-known entomophagist, Gene DeFoliart, and invited him to be our keynote speaker. The committee had to secure meeting facilities, interview chefs and caterers, locate insects for consumption, and contact media outlets (not much of an Internet then - relied on phones and faxes) to publicize it. We opted for the brownstone ambience at the Explorer's Club. I knew various suppliers for crickets, mealworms, waxworms and other insects. We also settled on Kurrajong grubs from Australia which were shipped frozen. A colleague in Arizona was able to feed honeypot ants on apricot nectar and shipped repletes in a light olive oil (so they wouldn't burst). We interviewed 5 caterers and chefs and settled on one.

In addition to the banquet, we also featured insect-related materials including sculptures made of bronze and of wood, live insect displays and living table arrangement composed of tarantulas and flowers. Cricket chirping was part of the sound system.

Our centennial banquet was one of the first to Since this was something very new to the general American public, the media (at that time, newspapers, magazines, television and radio) scrambled to get a space at the banquet for their audience's enjoyment.

The presentation is via PowerPoint to illustrate the meeting décor, sculptures, live insects, butlered h'orderves, dinner, guests, media coverage including television, radio, printed materials.

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Feasibility of mass rearing of black soldier fly in Iceland

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In recent years, the prospect of rearing insects for feed and food has gained more interest. Iceland has no tradition of using insects neither as feed nor food. However, several trends contribute to the prospect of mass rearing being increasingly more attractive.

Aquaculture has steadily increased in recent years in Iceland, in particular of salmonids. The current procedures of producing feed are environmentally taxing [1] with transportation costs being high especially in the remote parts of Iceland where fish farming is most intense. World market prices for fish feed's biggest components has risen steadily in the past few years. At the same time, although great improvements have been realized recently, there are several underused waste streams. These include fish offal, manure and biological waste from food processing and households.

Iceland has relatively high wages, making automation in the whole rearing process important. The high wages contribute to the venture only being cost effective if conducted on an industrial scale.

The black soldier fly (*Hermetia illucens*) has been shown to possess a range of positive properties, such as high growth rate, pathogen reduction in substrate, self-harvesting nature, capability of ingesting a wide range of substrate, palatability for fish, high protein and lipid content, and a short life cycle [2]. For Icelandic conditions, the black soldier fly would have to be reared indoors in high temperature. If flies escape, they would not pose any infecting risks because they neither feed, bite or sting. Furthermore, in the frigid outdoors, its chance of survival is little.

Given that Iceland follows European feed legislation, the legislative framework of using animal by-products for rearing insects is quite restrictive, both in terms of what insects can be fed and how they can be integrated into feed for other animals. The legislative framework for fish feed is less strict than that for feeding land animals [3]. Reform will have to be made for insect products to safely but economically enter the diet for both animals and humans.

Our preliminary results indicate that combined, these factors make Iceland an exciting option for mass rearing of black soldier fly. Experiments with local waste streams will start in 2014 with the goal of further assessing the feasibility and cost-effectiveness of the effort.

1 Naylor LR, Goldburg RJ, Primavera JH, Kautsky N, Beveridge MCM et al. (2000) Effect of aquaculture on world fish supplies. *Nature,* 405, 1017-2024.
2 St-Hilaire S, Cranfill K, McGuire MA, Mosley EE, Tomberlin JK et al. (2007) Fish Offal Recycling by the Black Soldier Fly Produces a Foodstuff High in Omega-3 Fatty Acids. Journal of the world aquaculture society, 38, 309-313.
3 Smith R and Pryor R. (2013) Enabling the exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition. Work deliverable D5.1. PROteINSECT. Available online: http://www.proteinsect.eu/fileadmin/user_upload/deliverables/D5.1t-FINAL.pdf.

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Sustainable insect biorefinery

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Current protein production for human nutrition can't keep up with the increasing global protein demand. In Europe consumption of whole insects is controversial. Hence alternative uses (as a non-visible food ingredient) are a nice alternative.

This poster presents possible routes of the Biorefinery of insects and the possibility of the use of insects as a Biorefinery tool to upgrade side streams!

We separated proteins, fats and fibres out of insects. Based on analysis of the properties of these materials we have evaluated applications.

Furthermore we have identified some focus points of current research and Hurdles to be taken for application of insects in Food in the EU.

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Alternative protein production technology for animal feed in the UK

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Development of alternative sources of protein for incorporation into animal feeds is required to meet the needs of the UK feed industry. Insects, or more specifically insect larvae, comprise a new source of protein that has the advantage over traditional sources in that several species can be reared upon a wide range of low value organic materials to produce high quality protein with minimum land footprint. A three year project, joint-funded by the Technology Strategy Board and ABN, aims to develop a method for the mass-production of fly larvae on organic waste materials, analyse the nutritional value of the protein derived from insects and determine the safety and risks associated with insect protein in animal feed. The nutritional value of insect-derived protein will be assessed in feeding trials with chickens, which have been chosen as poultry are naturally insectivorous. The ultimate aim of the project will be to enable the commercial production of a protein feed material of known value suitable for incorporation into animal feed.

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Trends in USA edible insect businesses

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Despite questionable widespread consumer acceptance among Western cultures, many new enterprises safely producing edible insects for consumption by humans and other animals have recently opened for business in the United States. At the same time, the US population has shifted from being primarily of Euro-American origin to a majority of the US population being primarily from other ethnic origins, such as Asian, Pacific Islander, and Hispanic, cultures that do have a strong current use of edible insects. Approximately half of the federally recognized Native American tribes in the US do have a history and/or current use of edible insects. Little to no research has been published that examines trends in new edible insect businesses in the US. We tested the hypothesis that there has been a significant increase in the number of edible insect businesses in the US in the past 10 years. We compared the number of currently operating edible insect businesses by the year they opened for business. The average start date of enterprises currently producing farmed insects for human food and animal feed is 2010. Our study excluded novelty insect products like candies. The number of these insect production businesses were graphed by year of founding and a linear regression analysis was applied to these data. We found a significant increase in the number of businesses producing food and feed containing edible insects as a major ingredient in the United States. Companies producing products featuring edible insects now outnumber those producing insects for feed.

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Mass rearing of *Hermetia illucens* (Diptera: Stratiomyidae): Identifying bottlenecks in egg production

Gobbi, P.[1,2], Martínez-Sánchez, A.[1,2] and Rojo, S.

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Hermetia illucens or the Black Soldier Fly (BSF) is an insect of great economic importance at larval stage, due to its potential of bio-conversion a wide variety of organic streams (including wastes and by-products). This biotransformation results in highly nutritious larval biomass for feeding a wide variety of animals (aquaculture, livestock, pets) and potentially as human food. It is know that food ingested by BSF larvae determines both the physiological and morphological development of the adults (Gobbi et al., 2013). This contribution provides information about some of the main bottlenecks related with BSF mass production at industrial scale, i.e. biological parameters related with egg production without use of artificial light. On the one hand, density/housing colony experiment was carried out, comparing four adult density treatments (1000/2000 flies in 40x40x40 cm rearing box, vs 1000/2000 flies in 80x60x80 cm rearing box). On the other hand, egg production was compared with four treatments in the rearing boxes: a) no periodic introduction of pupae, b) fortnightly introduction of pupae, c) weekly introduction of pupae and d) weekly introduction of pupae twice as much as in treatment c). In all experiments abiotic conditions, such as solar radiation, temperature, relative humidity, were important to obtain an optimal development of BSF. A continuous supply of fertile BSF eggs is a key factor to develop a true mass-production of larval biomass as alternative source of proteins for animal feed industry.

1 Gobbi, P, Martínez-Sánchez, A and Rojo, S (2013) The effects of larval diet on adult life-history traits of the black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae). European Journal of Entomology, 110(3): 461–468.

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Macrotermes gilvus (Hagen) the mound building termite : A food supplement

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Macrotermes gilvus (Hagen), a mound building termite is one of the very few insects consumed as a delicacy in certain parts of Tamil Nadu, India. In general, the alates that emerge for their nuptial flight following rain or slight drizzling in the late evenings between 18 and 20 hours are collected and consumed either raw or roasted. The nutrient composition of the termites was measured using standard techniques. The results revealed the presence of major nutrients like proteins (28 ± 0.08 gm%), sugar (17.8 ± 0.23 gm%), lipids (17 ± 0.83 gm%) and minerals like sodium (9 ± 0.21 mM /l), potassium (5.2 ± 0.32 mM/l), calcium (0.86 ± 0.70 mg%) and iron (126.81 ± 0.34 µg%). In addition, following monsoon, the mushroom *Termitomyces schimperi* grows around the mound located under the shades of trees rich in humus and decomposing plant matter. This mushroom is not only cherished as a delicacy but also is treasured for its rich protein content and immense therapeutic value in traditional medication. The mound appears semispherical to irregular and cone shaped with an utmost elevation of about 30 to 60 cm. Each mound is formed of a combination of 15 to 20 rounded chambers of varying sizes covering a total circumference of about 4 to 6 feet. The living chambers of the mound have an inner width varying from 8 to 28 cms, at a profundity of about 10 to 30 cm, containing eggs to adult termites. The thick walls, nests and termites inhibit the growth of microbes including a few human pathogenic bacteria. If efforts are taken to culture these termites in large numbers under controlled conditions, delicious low-cost supplementary diets can be made available to the public as an antidote to the prevailing malnutrition and anemia.

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Optimisation of the composition of *Hermetia* meal as a potential feedstuff for broiler and fish

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Concerning the necessary protection of fish resources worldwide, animal nutritionists are eager to find alternative protein sources as a substitute for fish meal. A promising possibility is the utilisation of an insect meal produced from larvae of the Black Soldier Fly (BSF) *Hermetia illucens* that can be used as a proportionate replacement for fish meal in diets for fish in aquaculture and poultry. The aim of this study was to produce a high total yield of BSF larvae with high crude protein and reduced crude fat content to approximate the high feed value of fish meal. Further objectives were to examine the influence of different growing substrates on the nutrient contents of BSF larvae and to investigate the possibility of fat content reduction in BSF larvae with mechanical pressure.

Primarily, a feeding trial with three different growing substrates was conducted: 1) a mixture of middlings (Control group), 2) dried distillers’ grains with solubles (Protein group), and 3) dried sugar beet pulp (Fibre group). After a 15-day growth period, the total larvae yield, the individual larvae mass, and survival rate were determined and the chemical composition of the larvae was analysed. The Control group showed the significantly highest total larvae yield (0.43 kg/kg growing substrate) with the lowest substrate consumption (2.1 kg dry matter (DM) per kg larvae). While the larvae of the fibre group featured a high crude protein and the lowest crude fat contents, their development has been hindered so that the total larvae yield was very low. Despite relatively low methionine contents when comparing BSF larvae meal to fish meal, it shows a high overall protein quality. The BSF meal contained only one third of the phosphorus content of fish meal.

Secondarily, in a compression trial with different parameters (pressure, temperature, duration), the largest reduction in fat content of the Control group larvae (from 30.9 % to 16.6 % in DM) was achieved with a trial regime of 250 bar, 50 °C, and 30 min. Only the parameters pressure and temperature had a significant influence on the fat reduction.

This study showed that the total yields and the composition of BSF larvae are highly dependent on the type and quality of the growing substrate. This was true for the crude nutrient and the mineral content. Regarding its composition, a BSF meal in diets could crucially contribute to meet the protein and energy requirements of poultry and fish.

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A research framework for pro-poor commercial scale insect-based transformation of organic wastes in Ghana

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Rapidly urbanizing Ghana is challenged with meeting the growing demand for animal source foods, ensuring sanitary waste disposal and creating livelihood opportunities for the poor [1]. Transforming wastes through insects can provide a mechanism for producing inputs valuable for both livestock and crop production. As livestock and fish production intensifies, the requirement for quality feeds is also growing [2]. Similarly, production of nutrient-dense vegetables, usually by women smallholder farmers, is constrained by nutrient scarcity. Insect larvae can substitute for high quality imported feed ingredients (i.e. fishmeal, soybean meal) that constitute a major proportion of total costs [3]. The left-over, 'treated' biomass can be used as biofertilisers, substituting for conventional fertilisers. This paper outlines a research frame-work for promoting pro-poor 'insect value-chains' based on knowledge transfer and adaptive co-management of black soldier fly (*Hermetia illucens*) technology production pioneered in China [4] . The research will evaluate commercial scale production systems co-located with appropriate waste-streams for their technical, environmental, economic and social performance/acceptability and the use of the outputs by women smallholder farmers. A Public health impact assessment (PHIA) will incorporate local environmental/ occupational health and global environmental impact assessments (the latter through life-cycle analysis: LCA); comparing insect production to existing waste remediation/ disposal and co-product production methods [5]. The research complements and builds on outcomes of earlier pilot-scale work evaluating the use of soldier fly larvae as an aqua-feed ingredient.

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Superworm farming: stable supply as human and animal food, organic fertilizer and medical use materials

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People are increasingly concerned about the food supply and food safety, in particular now the world population increases and the availability of arable land decreases. Extreme weather conditions affect many countries around the world. The pollution is getting worse. There are many diseases found in different animals. Many factors are affecting the food supply and the food quality. The food problem will be a big topic around the world. Edible insects will be a solution to the above problem.

If edible insects are the solution, we then need to face how to maintain a stable supply of it and how to maintain the quality of the supply. By introducing a standardized and automation system on feeding and rearing the insects, we can improve the output and the quality of the production, and enhance the occupational safety and operational efficiency.

The next step is how we can make use of the insect and put it into practical use. The specific insect we will focus in this article will be *Zophobas morio*. The raw materials extracted from the insects consist of proteins, trace elements rich organic fertilizer, oils, chitin and enzymes. These were used in the food, animal feed, medical use and agricultural industry.

It can be used as direct food for humans, or as feed for animals. Also, the extracted materials can be used for medical purposes. Research has proven that some amino acids in the insects can help to cure some diseases. Furthermore, when used as organic fertilizer, it can help to increase the output of the farmland and improve the soil quality. Being organic, it is environmental friendly. By doing more studies, we may find some new uses of the insects in different areas.

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Effect of replacing wheat bran feed with *Flammulina velutipes* cultivation media wastes on the growth of mealworm (*Tenebrio molitor*)

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For centuries, insects have been used as food due to their availability and easiness in raising that is much less burdensome for environment than animal husbandry breeding. Mealworm (*Tenebrio molitor*) is a store-pest of which larvae are grown in farm and considered more profitable for human than traditional meat food. Valuable feed substitute which allows easy balancing of feed rations, and provides the lowest cost per unit of obtaining meal products remained a concern. The aim of the present wok was to evaluate the effect of replacing wheat bran feed with *Flammulina velutipes* cultivation media wastes on the growth performance of mealworm. The experiment was carried out for 168 days (24 weeks) on 100 mealworm larvae. The weights of larvae after 8 weeks growth are similar in all treatments with control except in the treatment of 100% of cultivation waste replaced. Growth rate of larvae was almost the same, and pupation rate in all treatments showed lower than control group, but replacing 20 to 50% of waste culture medium group showed no significant differences. Pupal weights in the 60 to 80% of treatment group showed higher performance than control group. Hence, on studying the effect of replacing conventional mealworm feed with waste media from mushroom culture, it was found that *Flammulina velutipes* cultivation media wastes could replace the wheat bran feed by the ratio of 20 to 50% for the large-scale farming resulting in economic advantage and dietary equivalency.

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Developmental characteristic of *Tenebrio molitor* (Coleoptera: Tenebrionidae) at different temperatures and photoperiods

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As demand for *Tenebrio molitor* increases in the animal feed market, improvement of indoor mass-rearing systems becomes crucial. This study is aimed at establishing the technology for conserving genetic resource of *Tenebrio molitor*, and increasing the technology utilization. This year, in advance, this experiment was designed for examining the developmental characteristics of eggs and larvae. To research the developmental characteristics under different temperatures, eggs, larvae and papae were treated at 17.5, 20, 22.5, 25, 27.5 and 30°C. At 25°C, larvae were exposed to various photoperiod conditions, L:D 14:10, 12:12, and 10:14. The results show that the temperature range which affected hatching was 15~32.5°C. To achieve 70 percent or higher hatching rate 17.5~27.5°C was required. Furthermore, hatching occurred within 10 days, when the eggs were treated in 22.5~27.5°C. With regard to larval development, shorter developmental period, and higher pupation and eclosion rates were observed in 25~27.5°C. The shortest larval period was recorded at 14L:10D. At 10L:14D, in contrast, pupae showed the lowest chance of eclosion. Overall, larval development was optimal in long-day condition.

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