Black Soldier Fly (*Hermetia illucens*) Frass as Plant Fertilizer

T. Klammsteiner, V. Turan, S. Oberegger, H. Insam, M. Fernández-Delgado Juárez

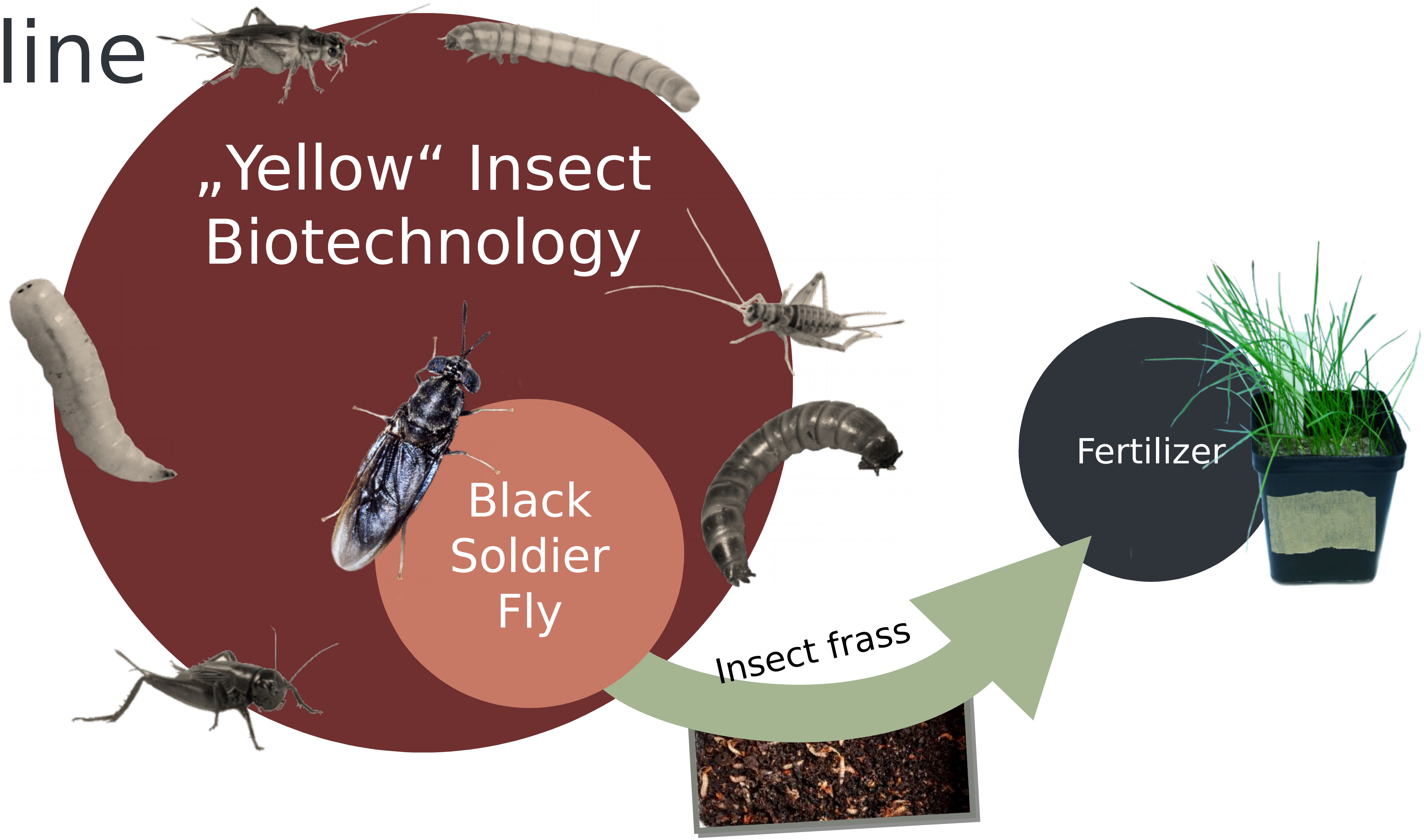
University of Innsbruck – Department of Microbiology

Email: thomas.klammsteiner@uibk.ac.at

Website: www.fromwastetofeed.wordpress.com

7th International Conference on Sustainable Solid Waste Management HERAKLION2019 - 26.06.2019

Outline


„Yellow“ Insect Biotechnology
Black Soldier Fly
Insect frass
Fertilizer

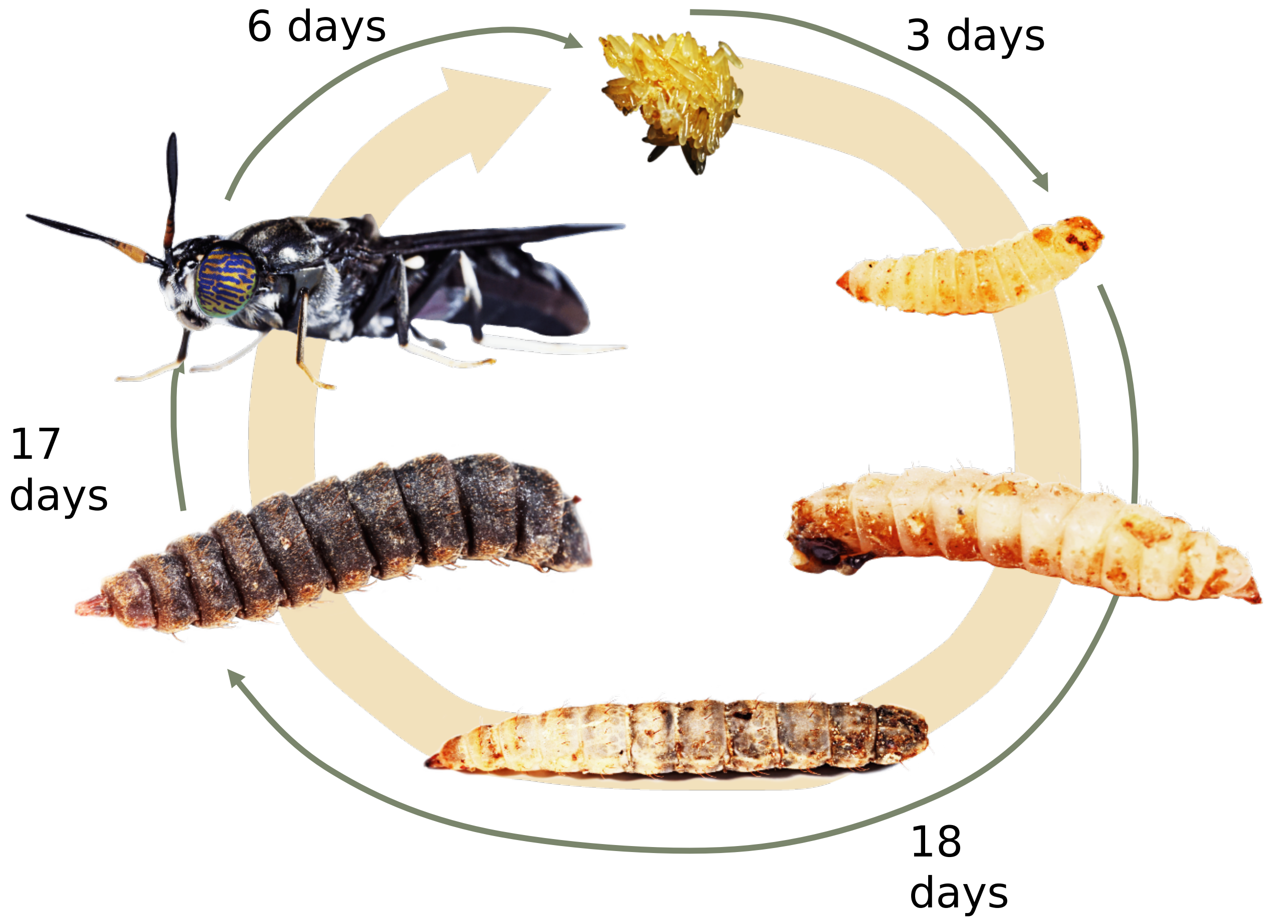
The Black Soldier Fly

- Native in the Neotropics, but spread across all continents
- Ideal habitat: 27 °C and 60% relative humidity
- Up to two centimetres in length
- No pest or vector of diseases, mainly acts as decomposer

(Diener et al., 2009)
(Hauser and Woodley, 2015)
(Mertenat et al., 2019)

The Black Soldier Fly

- 44 days from egg to adult fly
- Adult fly lays up to 600 eggs
- Five moults between six instars



(Nakamura et al., 2016)
(Wang and Shelomi, 2017)

The Black Soldier Fly

Focus point: Larvae

- Able to degrade broad spectrum of organics
- Increasingly used as waste valorisation agent
- Up to 35% fat and 40% protein (<220 mg biomass/larva)
- Larvae inhibit growth of pathogens (e.g. *E. coli*, *Salmonella* sp.)

(Choi et al., 2012)
(Tomberlin et al., 2002)

Yellow Biotechnology

"Biotechnological methods for exploiting insects or insect-derived molecules, cells, organs or microorganisms"

- 1.1 million species described, up to 10 million species estimated
- Large variety of molecules interesting to the bioeconomy
  - E.g. attractants, repellants, defensive compounds, antimicrobial peptides
- Products from the Black Soldier Fly:
  1. Protein & Fat: stored in larval biomass
  2. **Chitin: exoskeleton of pupae and shavings**
  3. **Residues (Frass): excretions, undigested substrate**

(Rumpold et al., 2017)
(Vilcinskas, 2014)

Yellow Biotechnology

"Biotechnological methods for exploiting insects or insect-derived molecules, cells, organs or microorganisms"

1. Protein & Fat: stored in larval biomass
   - As supplement for feedstuff production
   - Lipids used for producing biofuels
   - Fats used in cosmetic industry

EnviroFlight® - EnviroOil™

(Wang et al., 2017)

Yellow Biotechnology

"Biotechnological methods for exploiting insects or insect-derived molecules, cells, organs or microorganisms"

2. Chitin: exoskeleton from pupae and shavings

- Chitosan = plant available form of chitin
- Application in medicine, agriculture, food/non-food use
- Plants:
  - Promotes synthesis of >20 resistance proteins
  - Production of hydrolases, chitinase, glucanase

CHITIN

Chitinase

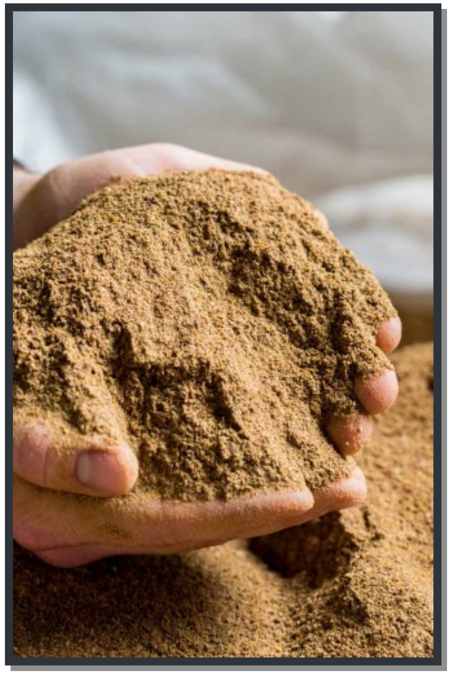
CHITOSAN

(Tharanathan and Kittur, 2003)

Yellow Biotechnology

"Biotechnological methods for exploiting insects or insect-derived molecules, cells, organs or microorganisms"

3. **Residues (Frass): excretions, undigested substrates**
   - Varying consistency, depending on water content
   - Pelletized and direct use as fertilizer
   - Co-substrates in anaerobic digestion
   - Composting or use in vermicomposting



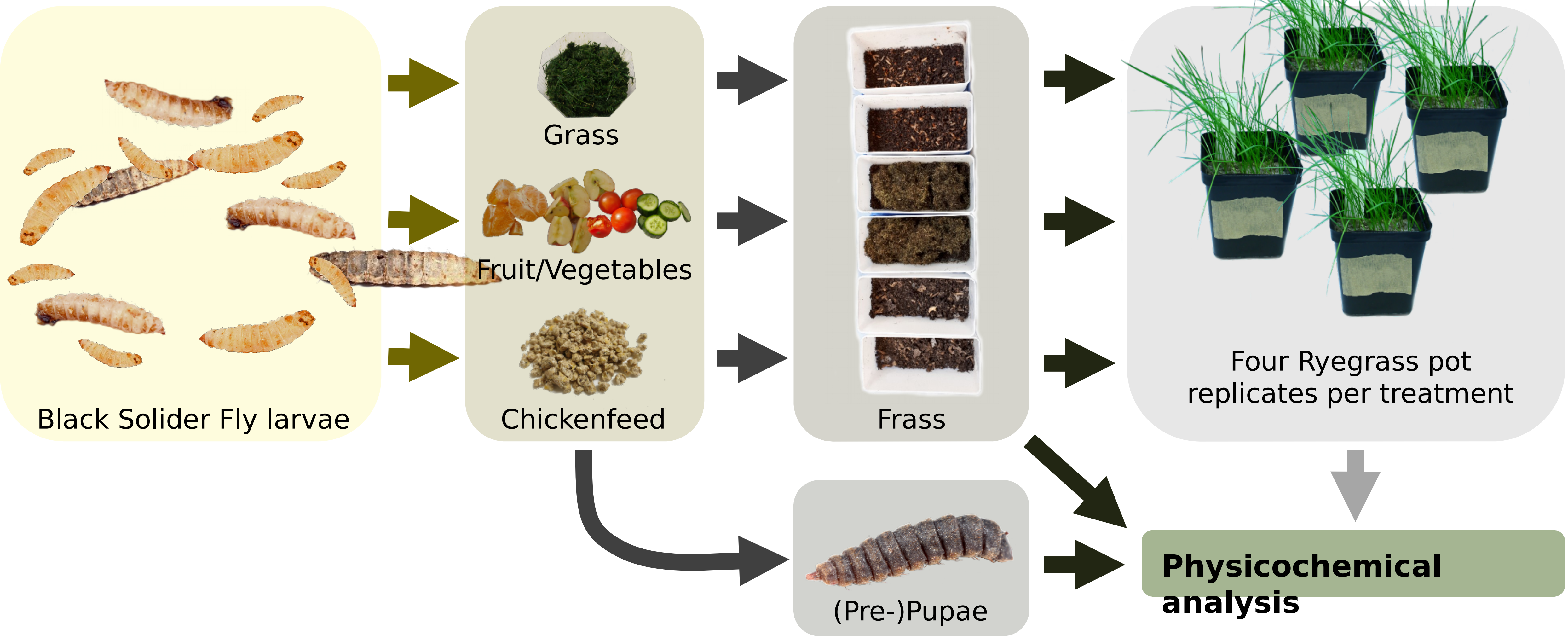
EnviroFlight® - EnviroFrass™

(Dortmans et al., 2017)

Insect Frass

- Frass = inconsistent description of insect faeces of various forms
- Mainly consists of excrements, shavings (exoskeletons) and residues
- Manifold ecological functions
  - Structure material, feed for offspring, disguise against

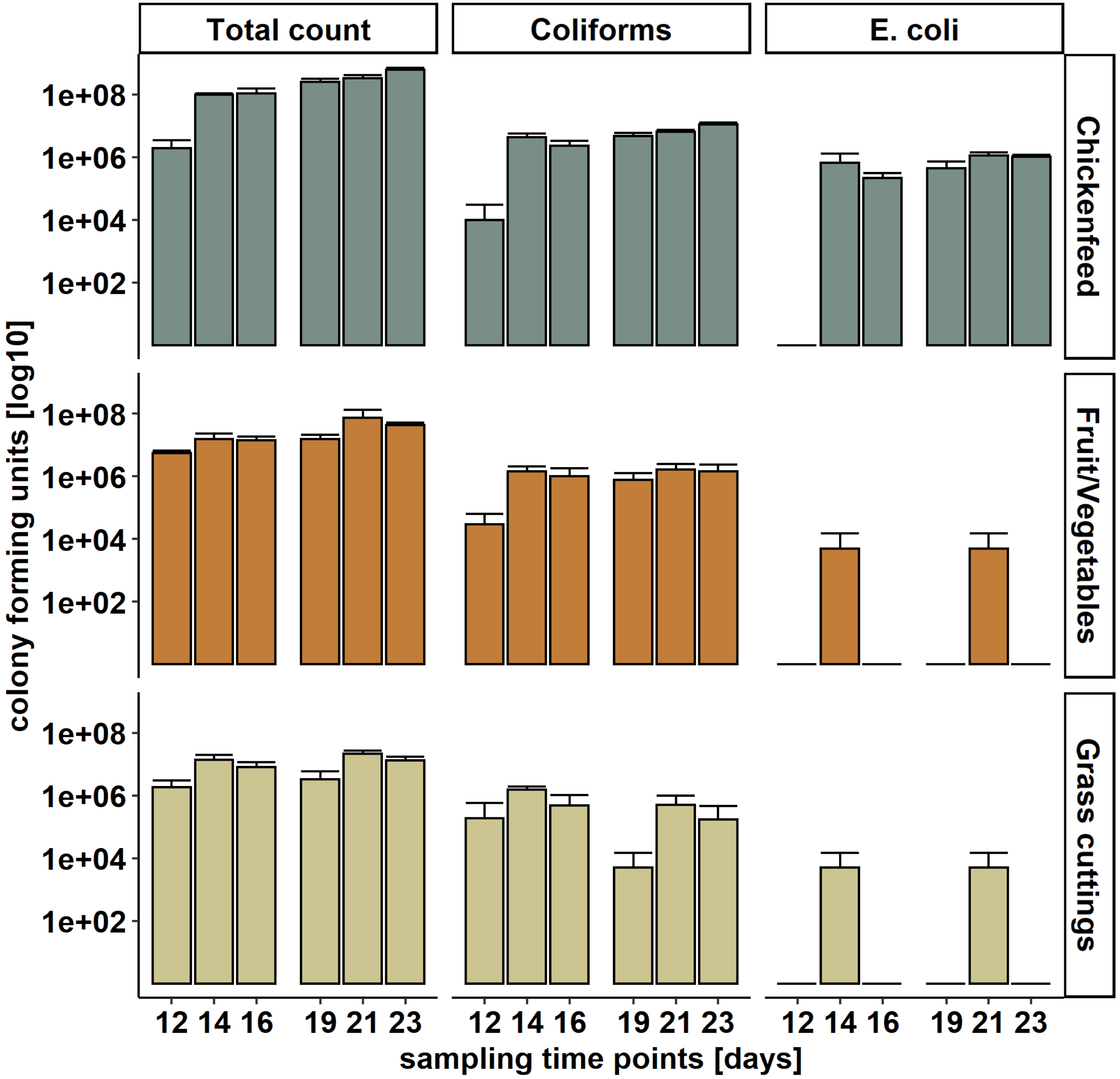
Experimental Design



Microbial Load on Larvae

- Comparable overall load
- Chickenfeed favors growth of *E. coli* (>10^6 CFU ml^{-1})

- No *Salmonella* sp. detected



Frass Characteristics

- Similar properties of frass from different treatments
- On average $6.4 \times 10^{7} \pm 6.6 \times 10^{6}$ CFU ml^{-1} *E. coli* in chickenfeed (CF) frass
- No *E. coli* in frass from grass-cuttings (GC) and fruit/vegetable (FV)

Table 1 – Physicochemical characteristics of frass

	GC-Frass	FV-Frass	CF-Frass
pH	5.40 ± 0.03	5.58 ± 0.01	6.22 ± 0.14
EC [mS cm^{-1}]	3.06 ± 0.03	2.36 ± 0.11	5.67 ± 0.27
C_{tot} [g kg^{-1}]	443 ± 6	488 ± 4	479 ± 8
N_{tot} [g kg^{-1}]	24.4 ± 0.2	18.3 ± 1.2	25.9 ± 0.9
C:N ratio	18.2 ± 0.4	26.6 ± 1.7	18.5 ± 0.3
VS [g kg^{-1}]	825 ± 9	873 ± 4	910 ± 7

Greenhouse experiment

- Ryegrass (*Lolium perenne*) planted for trials
- Control with standard NH_4NO_3 fertilizer
- Each treatment equalized to contain 40 mg N kg^{-1}
- Incubation for 28 days at 20 °C

Greenhouse experiment

- Neither *E. coli* nor *Salmonella* sp. detected in frass amended soils
- Strong decrease of coliforms to $1.7 \times 10^3 \pm 1.1 \times 10^3$ CFU ml^{-1} in soil
- No significant difference in plant biomass, soil total carbon, soil total nitrogen content between treatment and control

Greenhouse experiment

- 10% higher phosphorus bioavailability in frass (77±5%)
- Nitrate and dissolved nitrogen higher in control group
  - Frass might act similar to compost/organic amendments, releasing nutrients at a slower pace than nitrogen fertilizer

Take-home Message

- Larval Frass is not superior to standard soil conditioner, but can be used as equal alternative
- Complete removal of *E. coli* during application of frass as soil amendment
- High phosphorous bioavailability
- By-product from insect industry that contributes to a circular economy
- Similar properties of frass irrespective of insect's substrate

People

University of Innsbruck

- *Department of Microbiology*
  - Heribert Insam
  - Marina Fernández-Delgado Juárez
  - Andreas Walter
  - Wolfgang Dibiasi (Photos)
- *Department of Ecology*
  - Carina D. Heussler
  - Florian M. Steiner
  - Birgit C. Schlick-Steiner
  - Wolfgang Arthofer

University of Bingöl

- *Department of Soil Science*
  - Veysel Turan

BioApp
Biointeractions - from basics to application

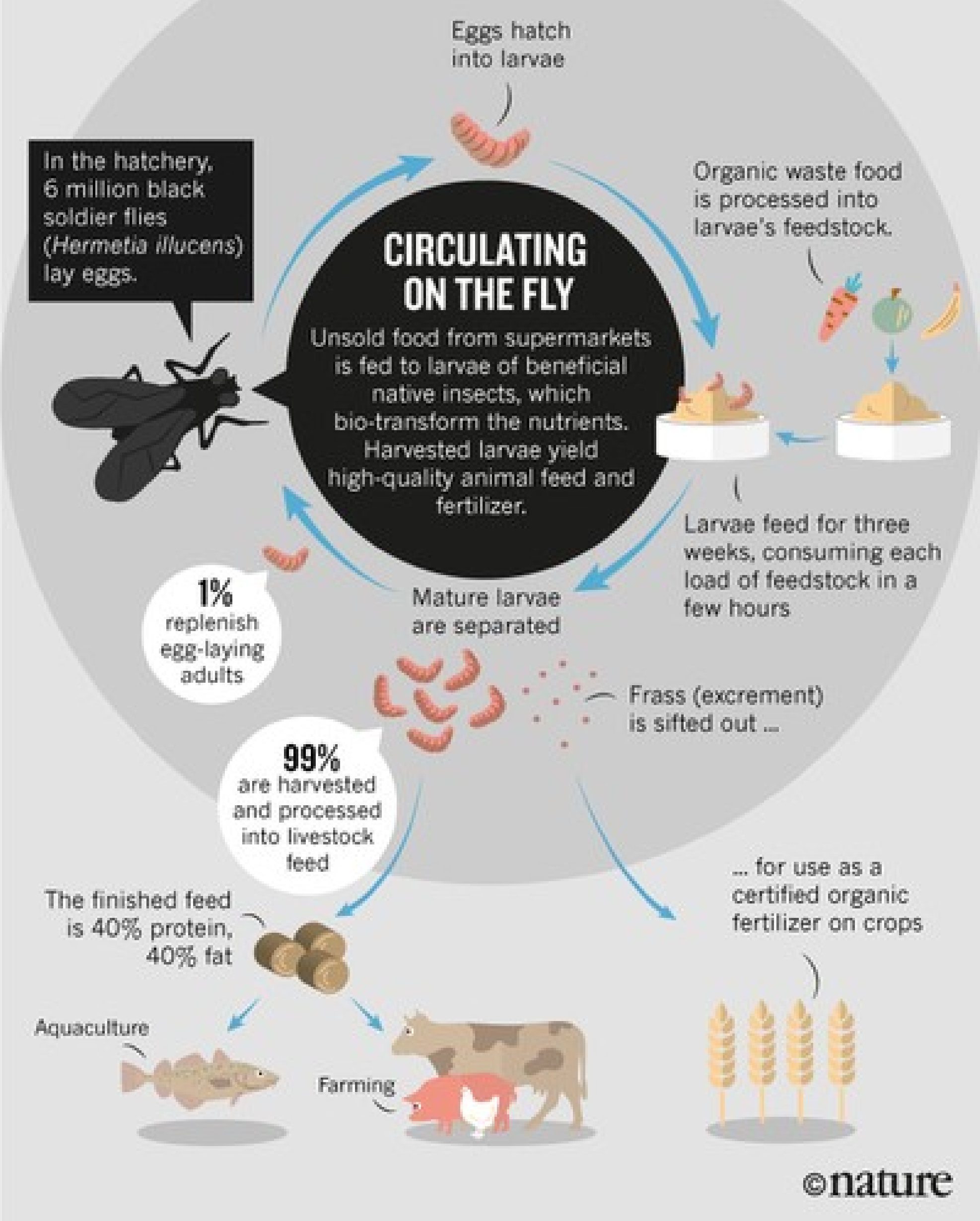
FWF
Der Wissenschaftsfonds.

universität innsbruck
Institut für Mikrobiologie

References

- **Choi, W.H., Yun, J.H., Chu, J.P., Chu, K.B.**, 2012. Antibacterial effect of extracts of hermetia illucens (diptera: stratiomyidae) larvae against gram-negative bacteria. Entomological Research 42, 219–226. https://doi.org/10.1111/j.1748-5967.2012.00465.x
- **Diener, S., Zurbrügg, C., Tockner, K.**, 2009. Conversion of organic material by Black Soldier Fly larvae: establishing optimal feeding rates. Waste Management & Research 27, 603–610. https://doi.org/10.1177/0734242X09103838
- **Dortmans, B., Diener, S., Verstappen, B., Zurbrügg, C.**, 2017. Black Soldier Fly Biowaste Processing. Eawag - Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland.
- **Hauser, M., Woodley, M.**, 2015. The historical spread of the Black Soldier Fly, Hermetia illucens (L.) (Diptera, Stratiomyidae, Hermetiinae), and its establishment in Canada. Journal of the Kansas Entomological Society 146, 51–54.
- **Mertenat, A., Diener, S., Zurbrügg, C.**, 2019. Black Soldier Fly biowaste treatment – Assessment of global warming potential. Waste Management 84, 173–181. https://doi.org/10.1016/j.wasman.2018.11.040
- **Nakamura, S., Ichiki, R.T., Shimoda, M., Morioka, S.**, 2016. Small-scale rearing of the black soldier fly, hermetia illucens (diptera: stratiomyidae), in the laboratory: low-cost and year-round rearing. Applied Entomology and Zoology 51, 161–166. https://doi.org/10.1007/s13355-015-0376-1
- **Rumpold, B.A., Klocke, M., Schluter, O.**, 2017. Insect biodiversity: underutilized bioresource for sustainable applications in life sciences. Regional Environmental Change 17, 1445–1454. https://doi.org/10.1007/s10113-016-0967-6
- **Tharanathan, R.N., Kittur, F.S.**, 2003. Chitin — The Undisputed Biomolecule of Great Potential. Critical Reviews in Food Science and Nutrition 43, 61–87. https://doi.org/10.1080/10408690390826455
- **Tomberlin, J.K., Sheppard, D.C., Joyce, J.A.**, 2002. Selected life-history traits of Black Soldier Flies (diptera: stratiomyidae) reared on three artificial diets. Annals of the Entomological Society of America 95, 379–386. https://doi.org/Doi 10.1603/0013-8746(2002)095[0379:Slhtob]2.0.Co;2
- **Vilcinskas, A.**, 2014. Yellow Biotechnology II: Insect Biotechnology in Plant Protection and Industry. Springer.
- **Wang, H., Rehman, K. ur, Liu, X., Yang, Q., Zheng, L., Li, W., Cai, M., Li, Q., Zhang, J., Yu, Z.**, 2017. Insect biorefinery: a green approach for conversion of crop residues into biodiesel and protein. Biotechnol Biofuels 10. https://doi.org/10.1186/s13068-017-0986-7
- **Wang, Y.S., Shelomi, M.**, 2017. Review of black soldier fly (hermetia illucens) as animal feed and human food. Foods 6. https://doi.org/10.3390/foods6100091

Supplement


Eggs hatch into larvae
In the hatchery, 6 million black soldier flies (*Hermetia illucens*) lay eggs.
Organic waste food is processed into larvae's feedstock.
CIRCULATING ON THE FLY
Unsold food from supermarkets is fed to larvae of beneficial native insects, which bio-transform the nutrients. Harvested larvae yield high-quality animal feed and fertilizer.
Larvae feed for three weeks, consuming each load of feedstock in a few hours
Mature larvae are separated
1% replenish egg-laying adults
Frass (excrement) is sifted out ...
99% are harvested and processed into livestock feed
... for use as a certified organic fertilizer on crops
The finished feed is 40% protein, 40% fat
Aquaculture
Farming
©nature