A **citizen science**-based approach to promote **circular economy** in the context of a fast-growing **insect industry**

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Outline

1. Background
2. Motivation & Citizen Science
3. Workshops
   - For schools
   - For citizens
4. Conclusion

Background

Advantages of insect farming over traditional livestock

- Low water consumption
- Less land use due to verticalization
- Lower GHG emissions
- Higher feed conversion efficiency
- Higher percentage of digestible bodymass

Background

Prospects for insect mass-rearing

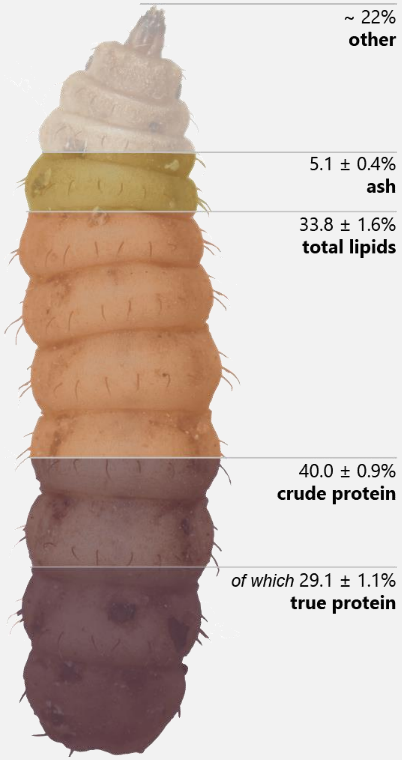
- Currently mainly for aquaculture, growing market for pet food. Approval for poultry and pigs ahead.
- Annual production of >5 million tons of insect protein by 2030
- Black soldier fly market predictions:
  - Annual growth of 35%
  - Market volume >$ 3 billion by 2030
- Exponential increase on scientific publications
  - >240 publications on the black soldier fly in 2020, compared to only 17 publications in 2015

Background

Black soldier fly (*Hermetia illucens*)

- Can grow on e.g.:
  - Agro-industrial side streams
  - Food wastes
  - Animal manure
  - Human excrements
- High protein and fat content
- Rearing residues for fertilization

Figure 1: Larval nutrient composition. (Liland *et al.* 2017)



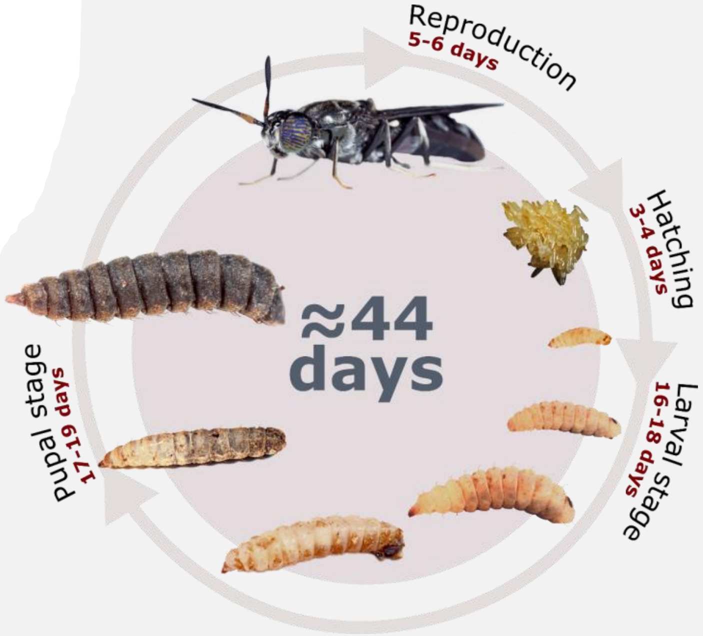


Figure 2: Life cycle in a lab-reared black soldier fly population.

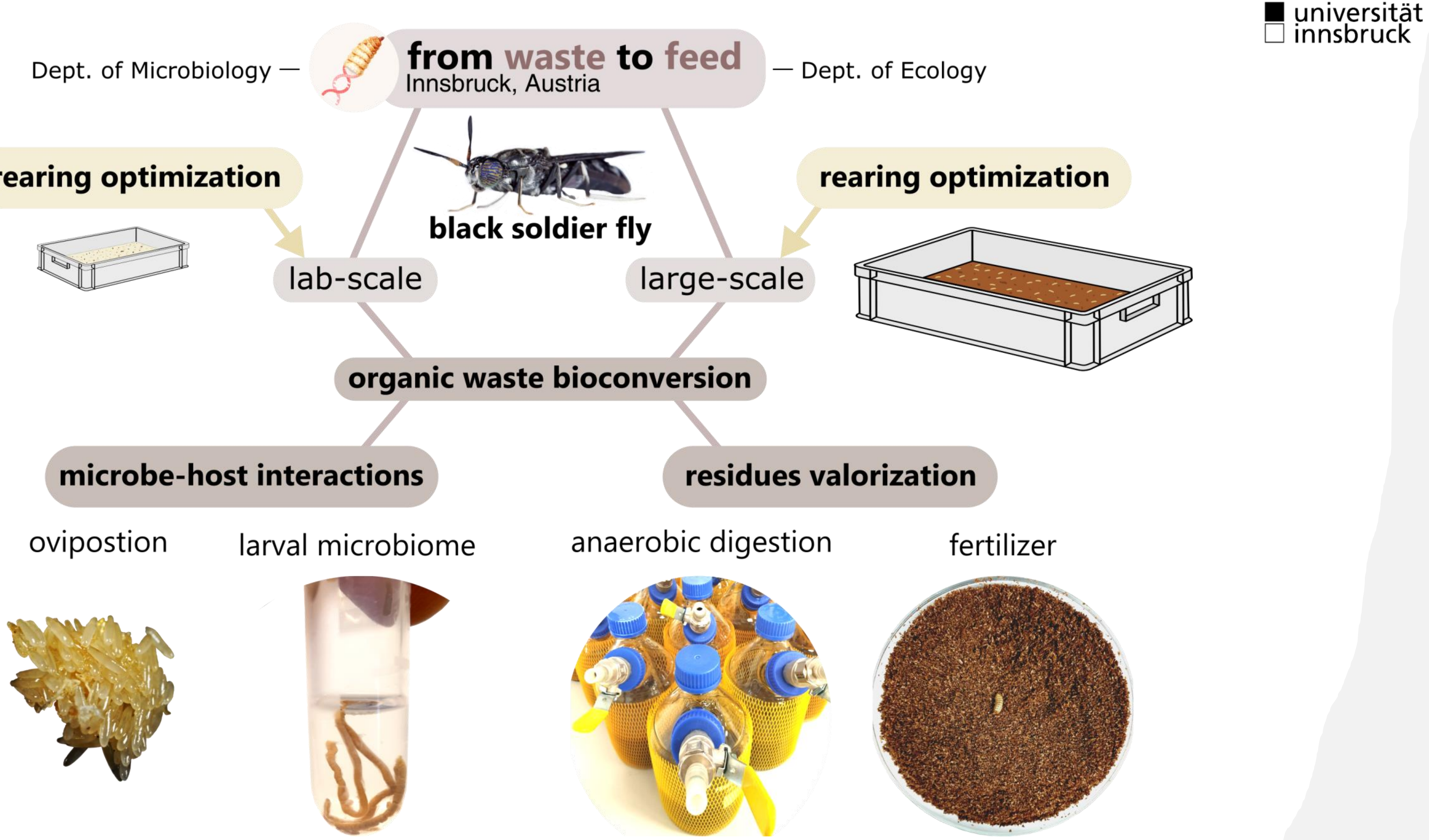


Figure 3: Overview on the insect-related research topics of our working group.

Motivation for this project

Social acceptance of insects as feed and food

- No recent history of entomophagy in Europe
- Aversion towards insects spreads to „insect eating cultures“
- Emerging industry, products are still expensive
- Westerners prefer indirect insect consumption:
  - traditional livestock fed with insects
- Stigmatization due to association with waste management

Citizen Science

- Growing interest since the 1990s
  - Started in the field of biology, ecology, and conservation
  - Recent studies engage citizens to tackle socio-ecological questions: e.g. food losses and food wastes
- Valuable complement to hypothesis-driven research
- Generation of large datasets by including large groups of citizens
- **Crucial**: Scientific support & standardization for data acquisition

Workshops

What was the goal of this project?

Raise awareness about socio-ecological problems

Keywords: excessive soy farming, increasnig fishmeal demand, environmental footprint of traditional livestock

Introduce people to the benefits of insect farming

Keywords: modularity, circular economy, investment opportunity,

Highlight the benefits of insect-based food & feed

Keywords: nutrient content, bioconversion efficiency, useable biomass, ethics

Counteract prejudice against insects

Keywords: hands-on experiences, spread knowledge, independent work

Figure 4: Citizen Scientists setting up their rearing system.

How does it work?

Our initial requirements:
- Easy to handle
- Reusable & sustainable
- Low-cost

What we ended up with:
- Appealing & functional system
- Dismountable
- Easy to repair
- Total costs: approx. 33 €
  - Includes precision scale, tweezers, lab journal
- **Most important**: suitable for the rearing of larvae

Figure 5: Rearing system for black soldier fly larvae.

How does it work?

- **Inside**: plastic bucket
- **Outside**: wooden structure
- **Ideal substrate**:
  - vegetable kitchen waste
  - processed food wastes
- Preferrably no meat
- If well-balanced, low on odour
- Approximate runtime 2-3 weeks depending on substrate

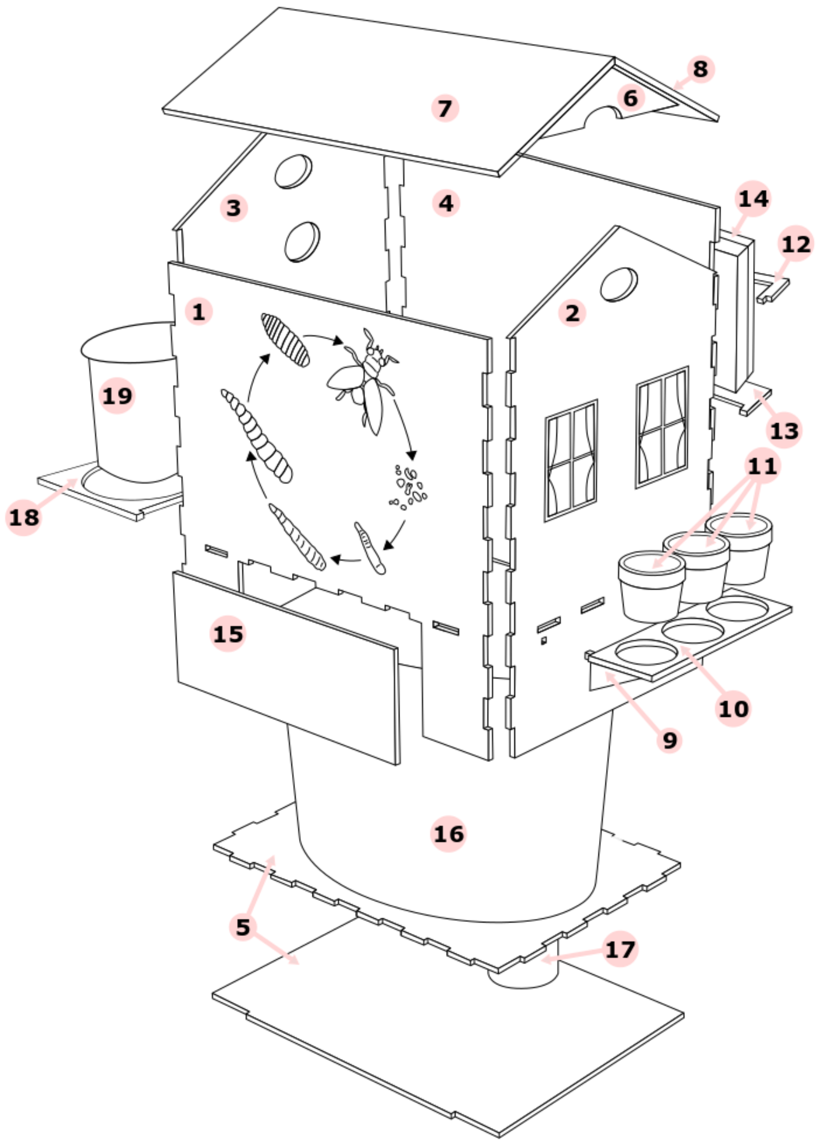


Figure 6: Exploded view of the rearing system.

How does it work?

- **Self-harvesting**: appropriately angled ramp for larval migration
- **Tightly sealable lid**: no unwanted escaping of larvae, net-covered holes for aeration
- **Drainage system**: hole at the bottom collects excess liquids in a detachable jar (can be used as fertilizer for plants = comparable to worm tea)

Figure 7: Inner bucket with ramp for larval self-harvesting.

Workshops

For schools

- Five classes (ages 13-18 years)
- Schools with different backgrounds and curricula
- >100 pupils

For public

- Four public workshops
- Multiple 1-on-1 trainings
- 28 three-week experiments by Citizen Scientists
- 3 control experiments under stable environmental conditions
- 3 control experiments under „household" conditions

School workshops

Open Access Article

Black Soldier Fly School Workshops as Means to Promote Circular Economy and Environmental Awareness

by Andreas Walter [1,*,†], Thomas Klammsteiner [2,*,†], Magdalena Gassner [3], Carina Desirée Heussler [2], Suzanne Kapelari [3], Markus Schermer [4] and Heribert Insam [2]

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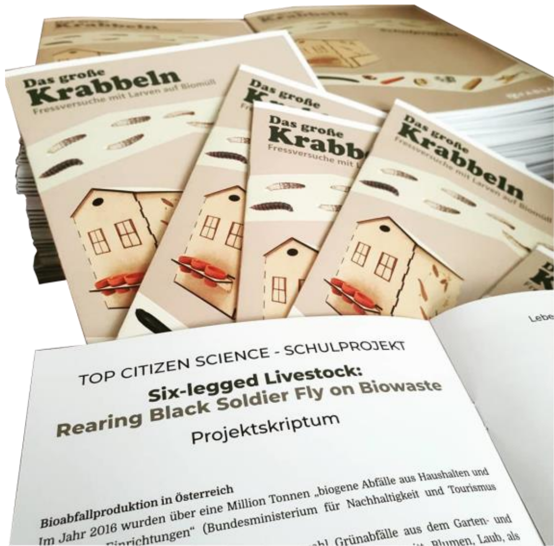


Figure 8: Booklets containing information on organic waste statistics, insect rearing and instructions for the experiments.

School workshops

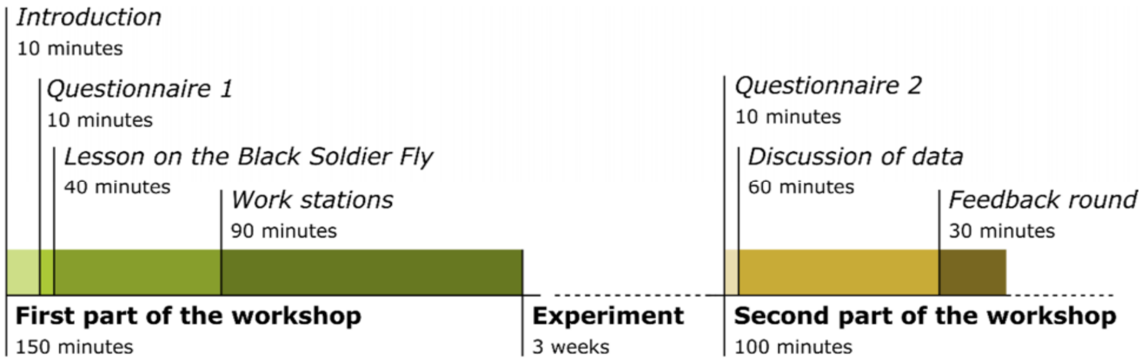


Figure 9: Structure of a school workshop

- Specifically tailored programm
- Elaborated together with teachers
- Lectures were streamlined with school curricula
- Pre-Workshop lecture vs. Post-Workshop lecture
- Independent research carried out by pupils
- Change in mindset observable between workshops

Figure 10: Provided materials ready for assembly.

School workshops

Results

- All students sticked to the sampling scheme
- Good larval growth across all school experiments
- Mostly fruit wastes were used as feed

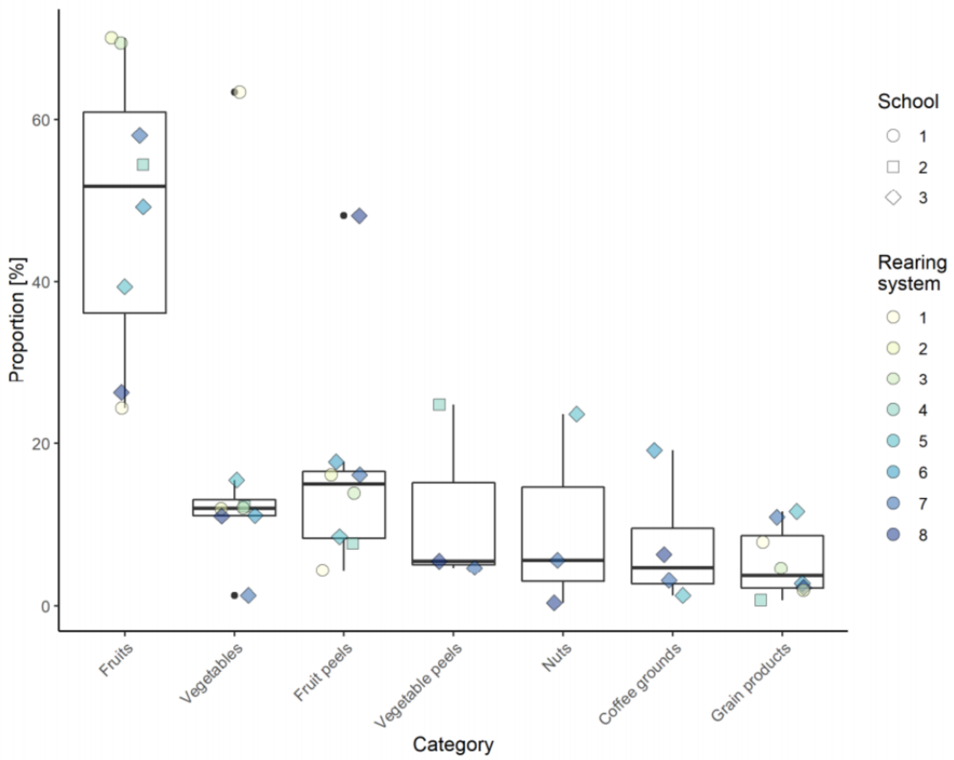


Figure 11: Overview on the different types and amounts of organic wastes used within the school experiments.

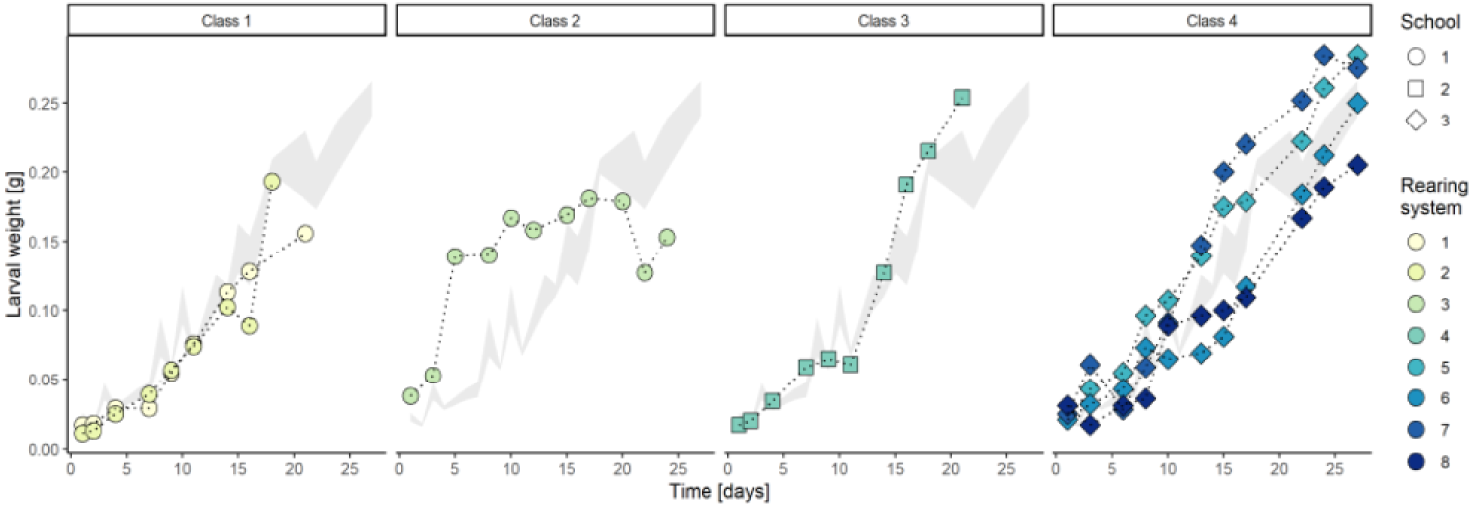


Figure 12: Larval biomass gain separated by school classes. The grey background represents the average biomass gain across all experiments (± standard error).

Public workshops

- Broad range of ages: 23 years to 72 years
- All backgrounds
- 64% female vs. 36% male participants
- Average duration of experiments: 23 ± 1.5 days
- Garden, balcony, kitchen, living room, basement

Public workshops

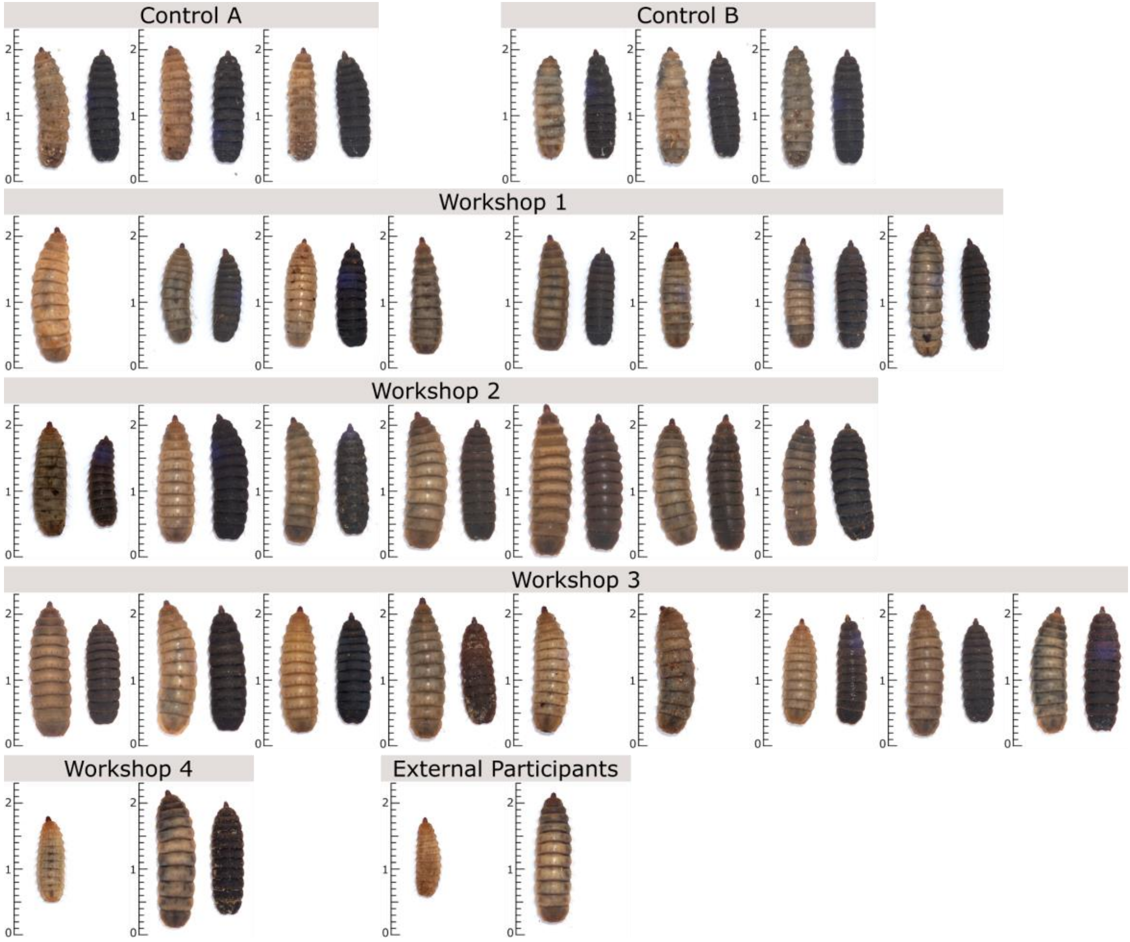


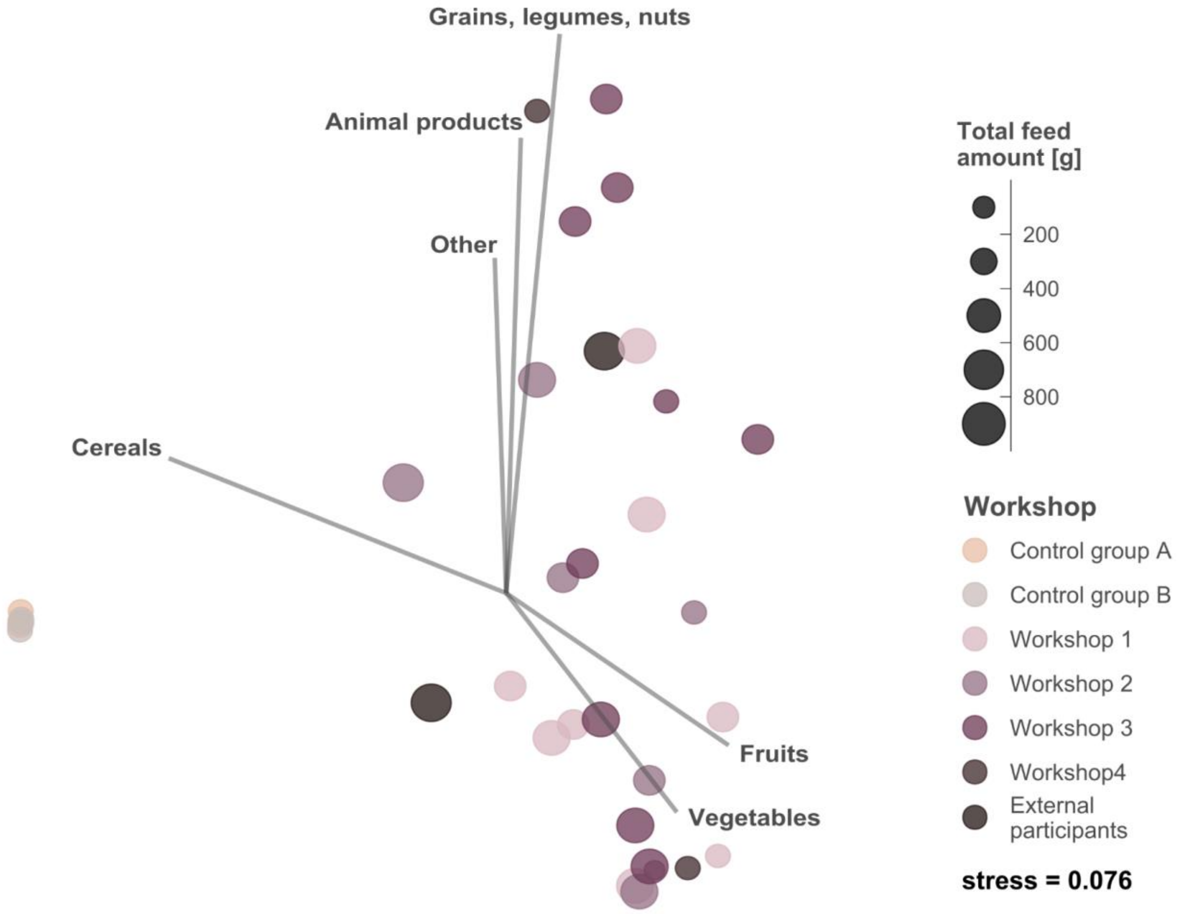
Figure 13: Overview on the larval rearing success.

- Average survival: 93%
- Biomass gain:
  - Minimum: 515%
  - Maximum: 1962%
- Waste reduction index:
  - Minimum: 0.69
  - Maximum: 3.75

$$WRI = \frac{D}{t} \times 100 \qquad D = \frac{W - R}{R}$$

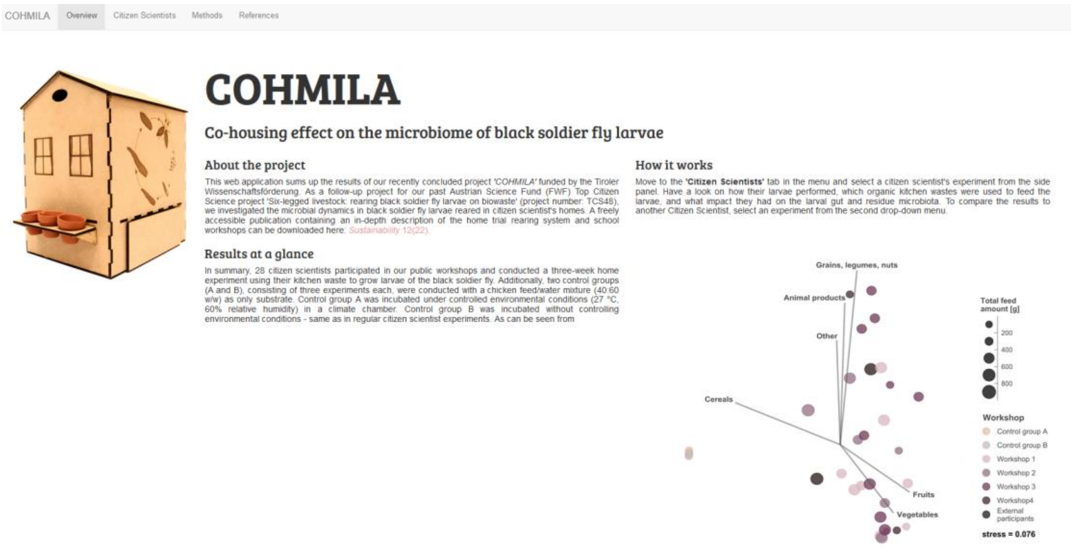
W…total amount of organic material (feed amount)
t…duration of the experiment
R…residue after time *t*
High WRI = good reduction efficiency

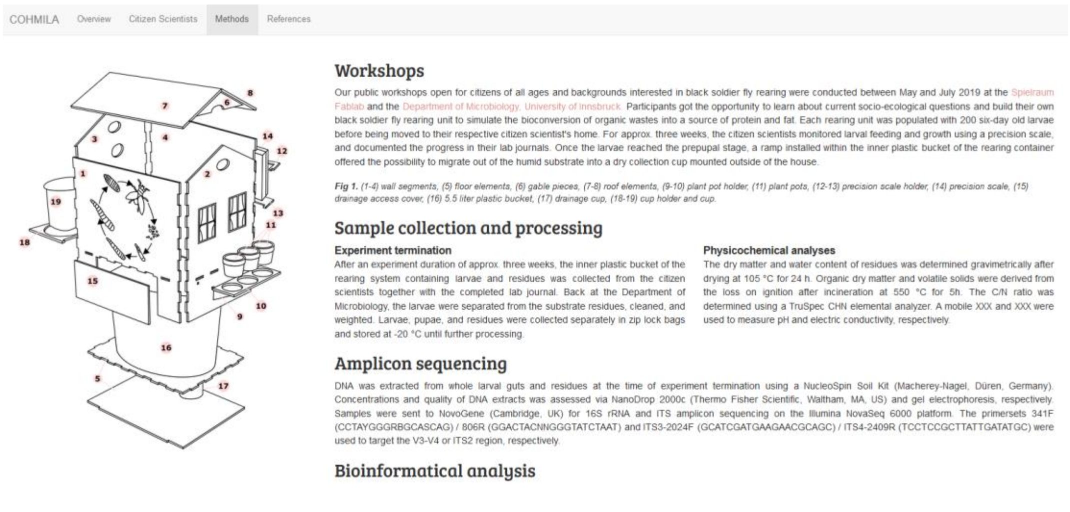
Public workshops



- High diversity in organic waste composition
  - 89 different products
- Large spread of total feed amounts
  - 197 – 854 g

Web application





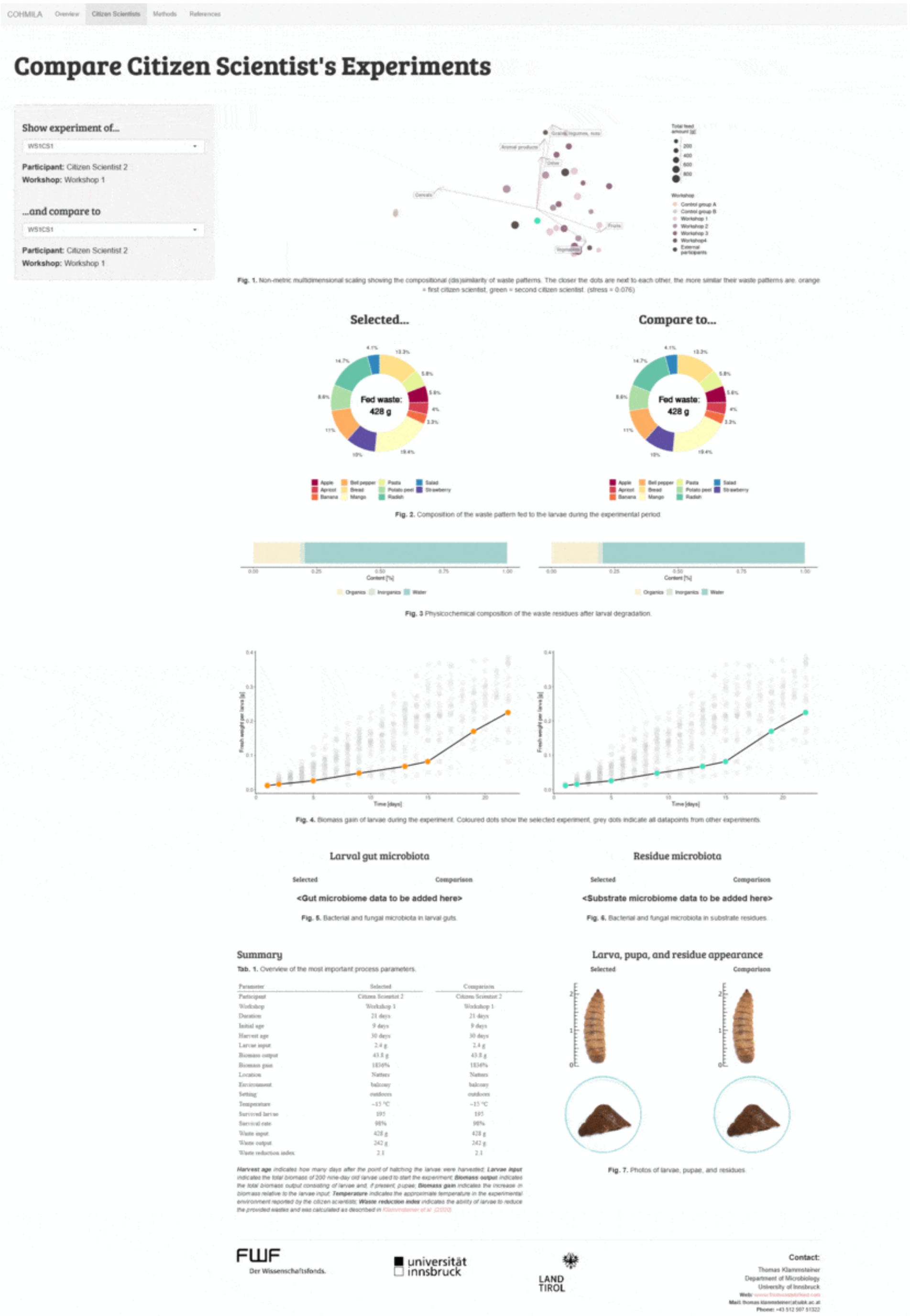


Figure X: COHMILA web application for the exploration of Citizen Scientist experimental results.

Conclusion

- Citizen science is a helpfull tool when applied accordingly
  - Scientific supervision & standardized data acquisition
- Industrially exploited insects in classrooms:
  - Provide hands-on experience
  - Low maintenance – high value
  - Easy to implement in school curricula
- Success for small-scale rearing system
  - Black soldier fly resilient and undemanding model organism
  - High survival, high efficiency, fast development stimulates interest

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