

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

**Thessaloniki2021**

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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

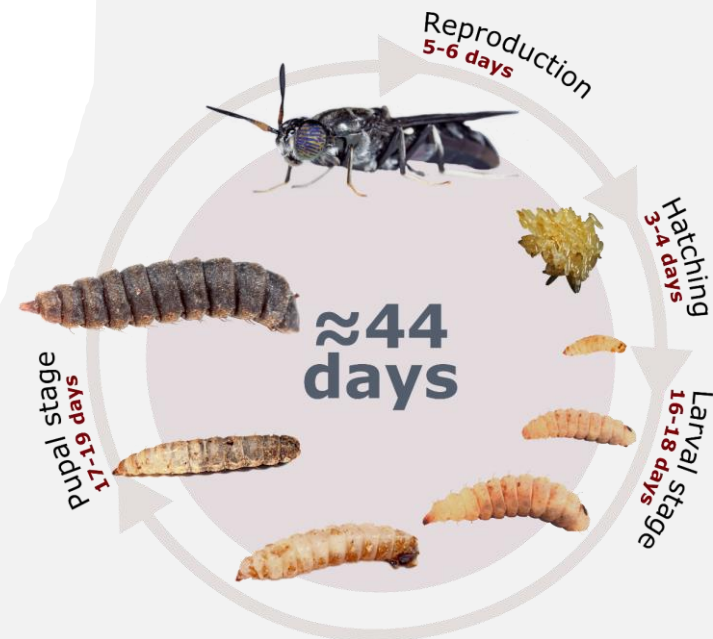
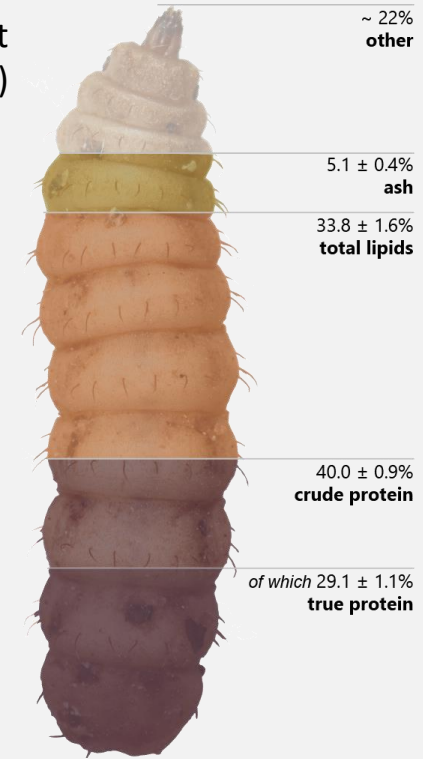
- Currently mainly for aquaculture, growing market for pet food. Approval for poultry and pigs ahead.
- Annual production of >5 million tons of insect protein by 2030
- Black soldier fly market predictions:
  - Annual growth of 35%
  - Market volume >\$ 3 billion by 2030
- Exponential increase on scientific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

# Background

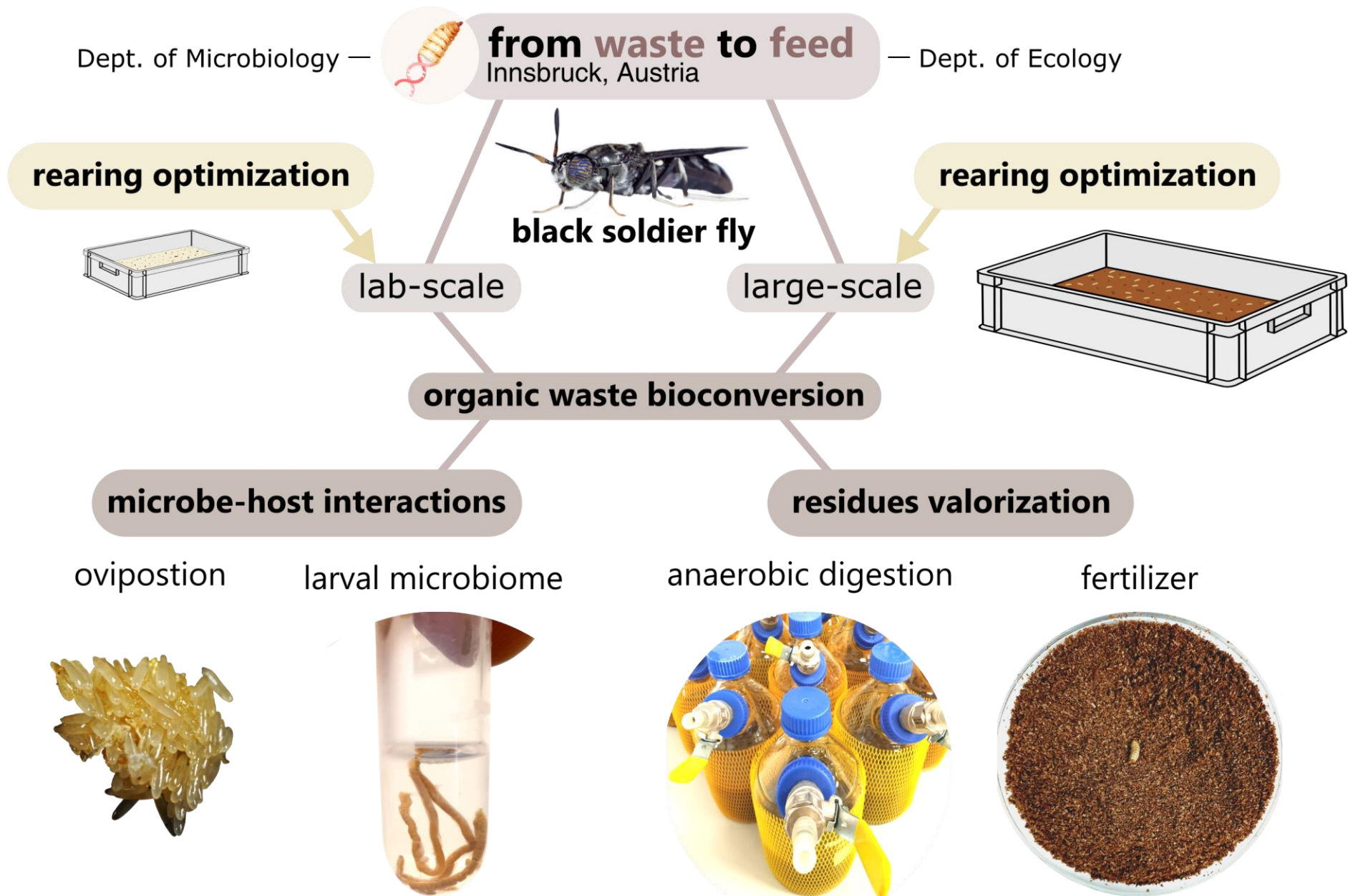
## Black soldier fly (*Hermetia illucens*)

- 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, increasing 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
- Preferably no meat
- If well-balanced, low on odour
- Approximate runtime 2-3 weeks depending on substrate

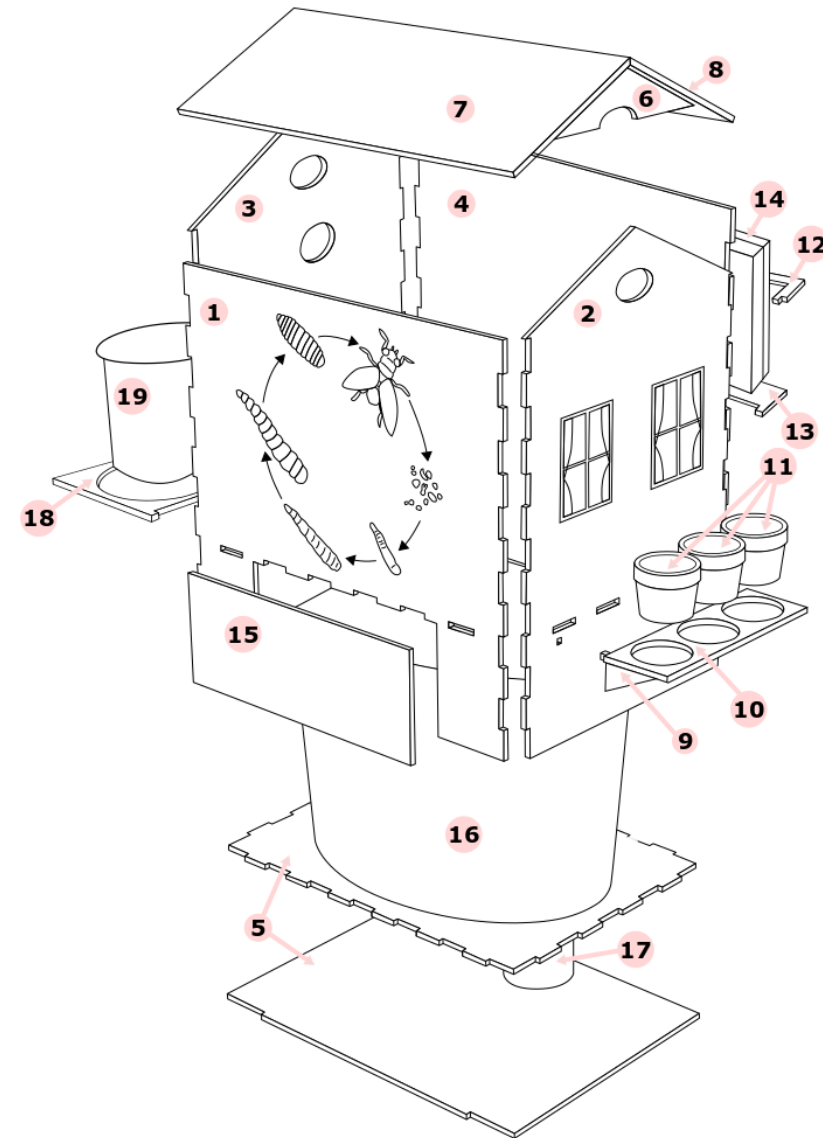


Figure 6: Exploded view of the rearing system.

# 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 <sup>1,\*†</sup> ,  Thomas Klammsteiner <sup>2,\*†</sup>  ,  Magdalena Gassner <sup>3</sup> ,  Carina Desirée Heussler <sup>2</sup> ,  Suzanne Kapelari <sup>3</sup> ,   
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*Sustainability* 2020, 12(22), 9574; <https://doi.org/10.3390/su12229574>

Received: 19 October 2020 / Revised: 13 November 2020 / Accepted: 14 November 2020 / Published: 17 November 2020

(This article belongs to the Collection [Sustainable Citizenship and Education](#))



Link to publication



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

# School workshops

- 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

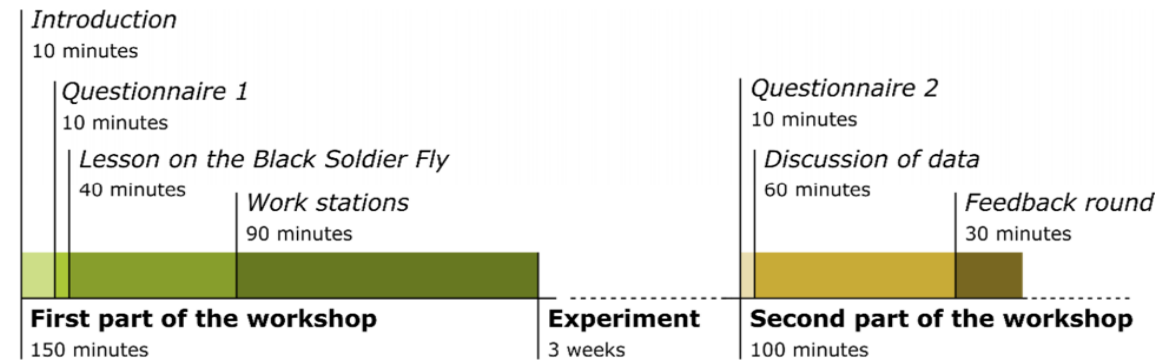


Figure 9: Structure of a school workshop

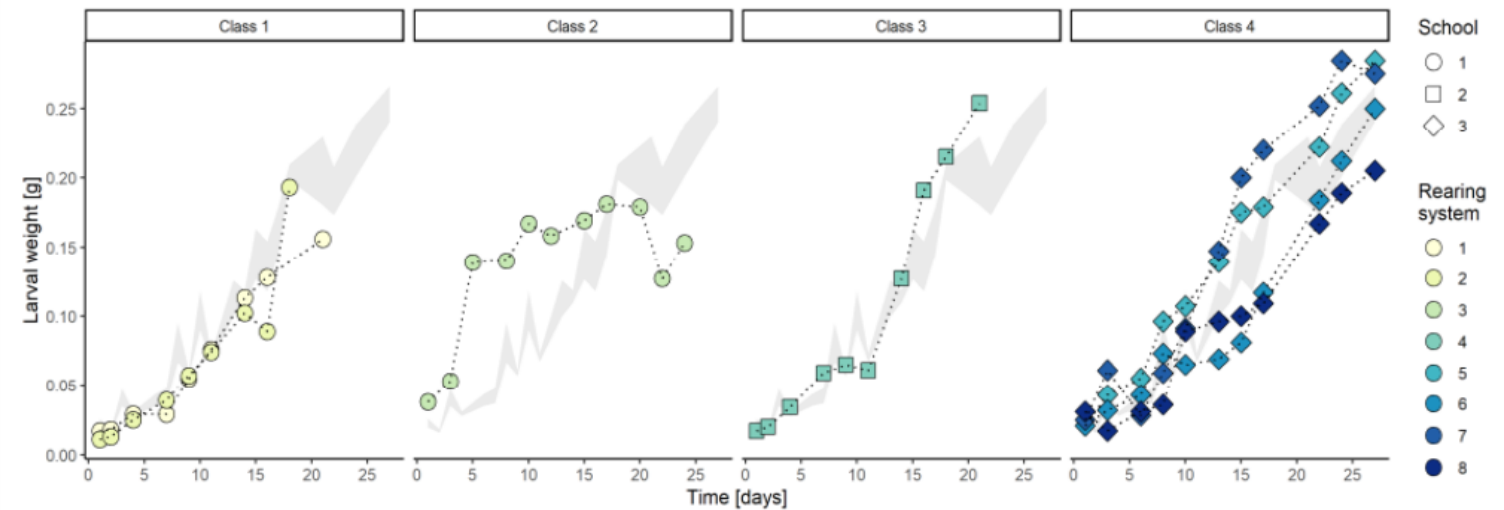
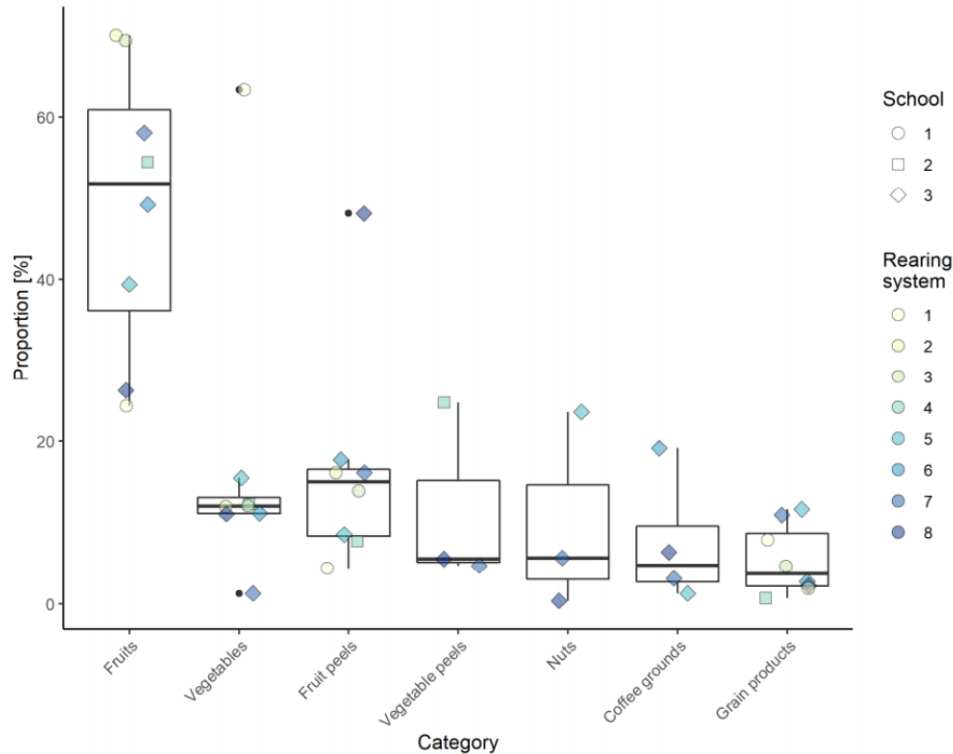


Figure 10: Provided materials ready for assembly.

# School workshops

## Results

- All students stuck 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 ( $\pm$  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:  $23 \pm 1.5$  days
- Garden, balcony, kitchen, living room, basement

# Public workshops

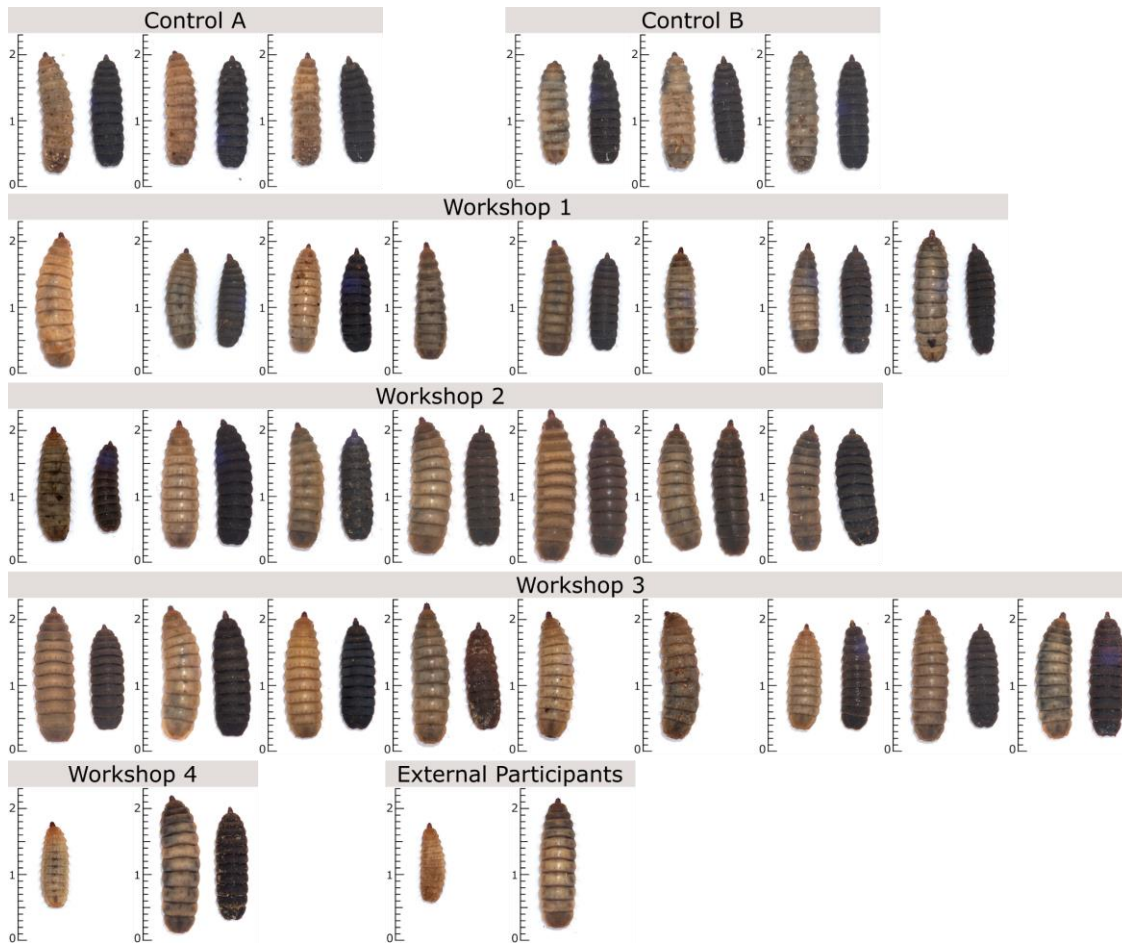


Figure 13: Overview on the larval rearing success.

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

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

$W$ ...total amount of organic material (feed amount)

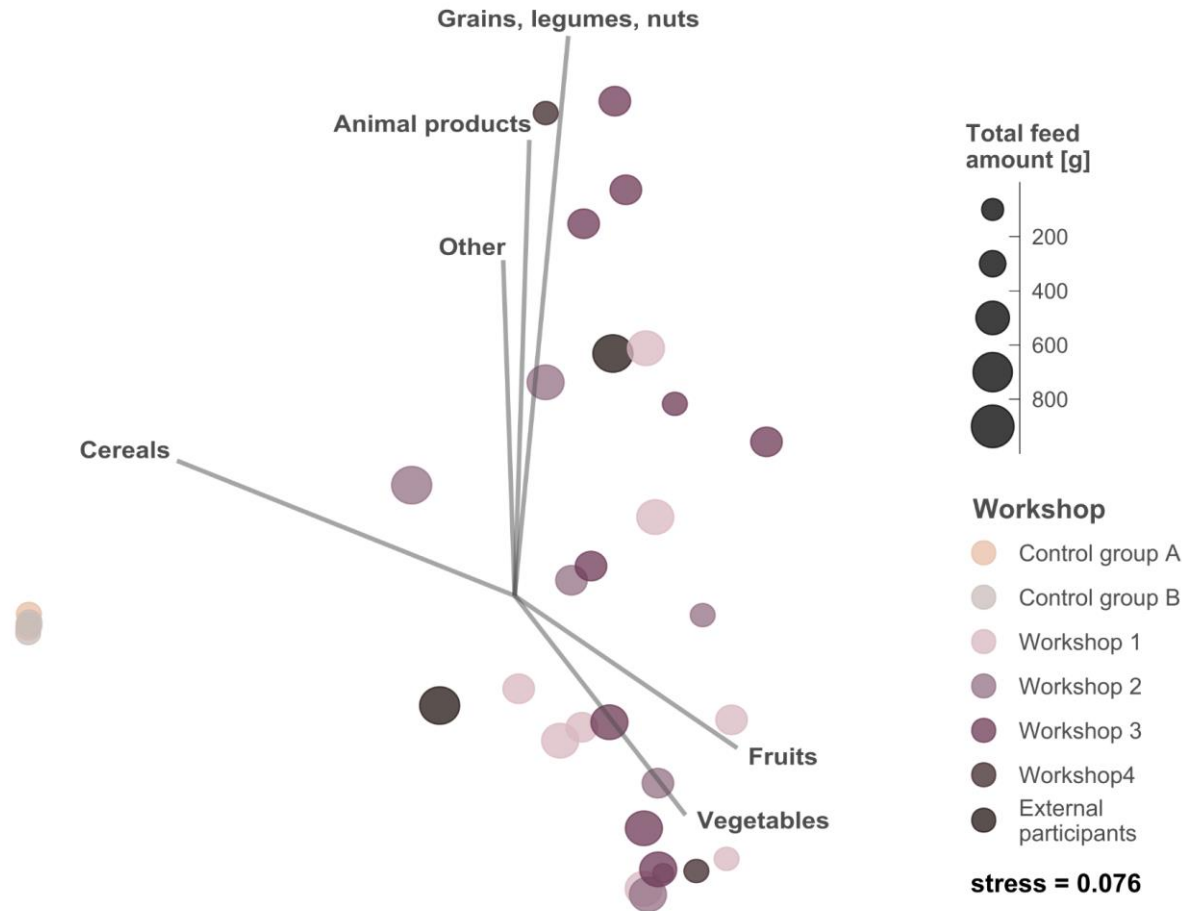
$t$ ...duration of the experiment

$R$ ...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

COHMILA Overview Citizen Scientists Methods References



## COHMILA

### Co-housing effect on the microbiome of black soldier fly larvae

#### About the project

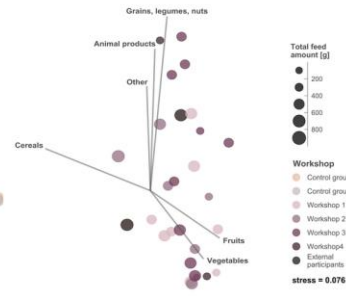
This web application sums up the results of our recently concluded project 'COHMILA' funded by the Tiroler Wissenschaftsförderung. As a follow-up project for our past Austrian Science Fund (FWF) Top Citizen Science project 'Bio-eggart livestock: rearing black soldier fly larvae on bio-waste' (project number: T0248), we investigated the microbial dynamics in black soldier fly larvae reared in citizen scientists' homes. A freely accessible publication containing an in-depth description of the home trial rearing system and school workshops can be downloaded here: [Sustainability 12\(202\)](#).

#### Results at a glance

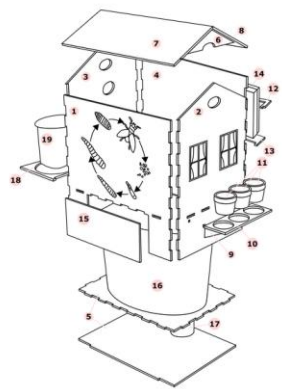
In summary, 28 citizen scientists participated in our public workshops and conducted a three-week home experiment using their kitchen wastes to grow larvae of the black soldier fly. Additionally, two control groups (A and B), consisting of three experiments each, were conducted with a chicken feed/water mixture (40:60 w/w) as only substrate. Control group A was incubated under controlled environmental conditions (27 °C, 60% relative humidity) in a climate chamber. Control group B was incubated without controlling environmental conditions - same as in regular citizen scientist experiments. As can be seen from

#### How it works

Move to the 'Citizen Scientists' tab in the menu and select a citizen scientist's experiment from the side panel. Have a look on how their larvae performed, which organic kitchen wastes were used to feed the larvae, and what impact they had on the larval gut and residue microbiota. To compare the results to another Citizen Scientist, select an experiment from the second drop-down menu.



COHMILA Overview Citizen Scientists Methods References



### Workshops

Our public workshops open for citizens of all ages and backgrounds interested in black soldier fly rearing were conducted between May and July 2019 at the *Spielraum Fabrik* and the *Department of Microbiology, University of Innsbruck*. Participants got the opportunity to learn about current socio-ecological questions and build their own black soldier fly rearing unit to simulate the bioconversion of organic wastes into a source of protein and fat. Each rearing unit was populated with 200 six-day old larvae before being moved to their respective citizen scientist's home. For approx. three weeks, the citizen scientists monitored larval feeding and growth using a precision scale, and documented the progress in their lab journals. Once the larvae reached the prepupal stage, a ramp installed within the inner plastic bucket of the rearing container offered the possibility to migrate out of the humid substrate into a dry collection cup mounted outside of the house.

Fig. 1. (1-4) wall segments, (5) floor elements, (6) gable pieces, (7-8) roof elements, (9-10) plant pot holder, (11) plant pots, (12-13) precision scale holder, (14) precision scale, (15) drainage access cover, (16) 5.5 liter plastic bucket, (17) drainage cup, (18-19) cup holder and cup.

### Sample collection and processing

#### Experiment termination

After an experiment duration of approx. three weeks, the inner plastic bucket of the rearing system containing larvae and residues was collected from the citizen scientists together with the completed lab journal. Back at the Department of Microbiology, the larvae were separated from the substrate residues, cleaned, and weighed. Larvae, pupae, and residues were collected separately in zip lock bags and stored at -20 °C until further processing.

#### Physicochemical analyses

The dry matter and water content of residues was determined gravimetrically after drying at 105 °C for 24 h. Organic dry matter and volatile solids were derived from the loss on ignition after incineration at 550 °C for 5h. The CN ratio was determined using a TruSpec CHN elemental analyzer. A mobile XXX and XXX were used to measure pH and electric conductivity, respectively.

### Amplicon sequencing

DNA was extracted from whole larval guts and residues at the time of experiment termination using a NucleoSpin Soil Kit (Machery-Nagel, Düren, Germany). Concentrations and quality of DNA extracts was assessed via NanoDrop 2000c (Thermo Fisher Scientific, Waltham, MA, US) and gel electrophoresis, respectively. Samples were sent to Novogene (Cambridge, UK) for 16S rRNA and ITS amplicon sequencing on the Illumina NovaSeq 6000 platform. The primers 341F (CCTATGGGRBGCASCAG) / 806R (GGACTACNCGGTATCTAAT) and ITS3-2024F (GCATCGATGAAGAACGCAGC) / ITS4-2409R (TCTCCGCTATTGATGTC) were used to target the V3-V4 or ITS2 region, respectively.

### Bioinformatical analysis

## Compare Citizen Scientist's Experiments

Show experiment of...  
 WSC11  
 Participant: Citizen Scientist 2  
 Workshop: Workshop 1

...and compare to...  
 WSC11  
 Participant: Citizen Scientist 2  
 Workshop: Workshop 1




Fig. 1. Non-metric multidimensional scaling showing the compositional dissimilarity of waste patterns. The closer the dots are next to each other, the more similar their waste patterns are. orange = first citizen scientist, green = second citizen scientist. (stress = 0.076)

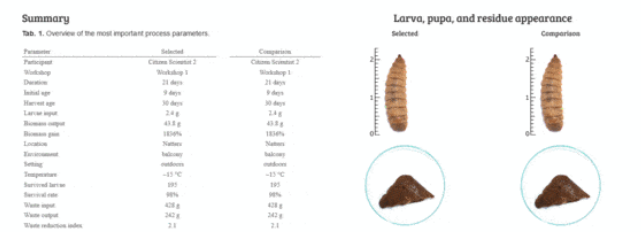
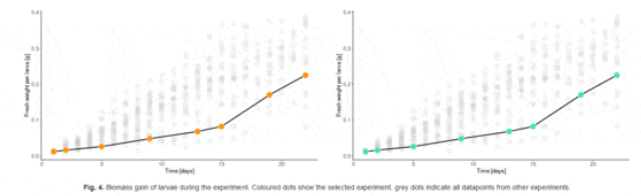
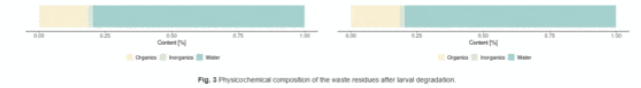
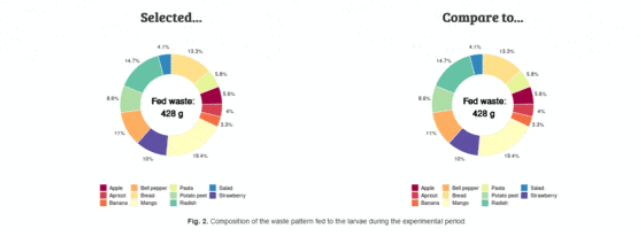


Figure X: COHMILA web application for the exploration of Citizen Scientist experimental results.

# Conclusion

- Citizen science is a helpful 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

# Contact

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