Measurement of energy expenditure of yellow mealworms in a mass rearing context

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C. Montaurier[1]*, V. Ageorges[2], E. Poulhes[2], L. Tournier[2] and S. Crépieux[2]

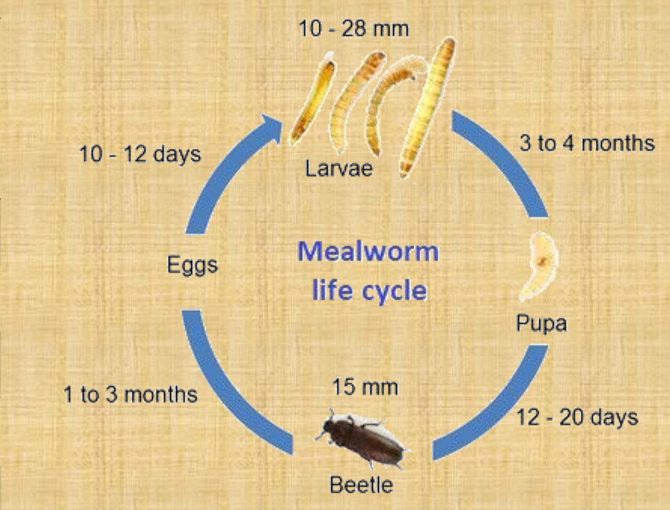
[1]INRAE, Unité de Nutrition Humaine (UNH), Université Clermont Auvergne, Clermont-Ferrand, France
[2]Invers, Champ de la Croix, 63720 Saint-Ignat, France
*christophe.montaurier@inrae.fr

Background: During the last decade, insects have received increasing interest as sources of protein for animal feed and human food. Yellow mealworm (*Tenebrio molitor*) is considered as one of the best options because is rich in protein, easy to breed and feed. This species of insect is commonly reared in crates containing agricultural by-products such as wheat bran. In a mass rearing context, an insect farm can contain thousands of these crates with different insect life stages. At the moment, there is only little data available concerning the heat generation of yellow mealworms in rearing conditions, making it hard to scale livestock houses.
In this context, the **goal of this study** was to measure the energy expenditure (EE) of insects at different life stages in normal rearing conditions (temperature, hygrometry, insect density, water supply) using calorimetric cages.

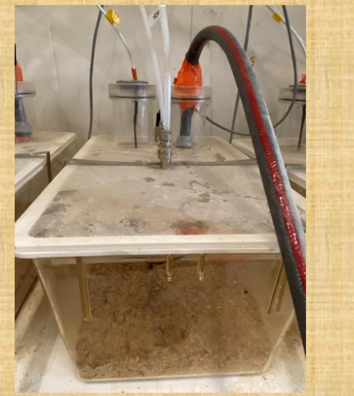
Material and methods:

We measured feed consumption, body mass, O_2 consumption, CO_2 production and temperature for 10 *Tenebrio molitor* life stages (i.e eggs, 7mg larvae, 16mg larvae, 29mg larvae, 50mg larvae, 60mg larvae, 79mg larvae, 98mg larvae, pupas and adults).

Stage	Mass per individual (mg)	Number of individuals per cage	Total mass of individuals per cage (g)
Egg	-	-	1 kg (powder)
Larva	7.1	7417	52.9
Larva	15.6	4679	73.0
Larva	29.1	4708	137.0
Larva	49.9	4699	234.7
Larva	60.5	4661	282.0
Larva	78.9	4697	370.5
Larva	97.9	4696	460.0
Pupa	106.9	540	57.8
Adult	106.7	660	70.5



The densities of individuals, for each phase, in the calorimetric cages were the same as those in the rearing tanks. In all cases 750 g of wheat bran was placed in each cage, except for the eggs for which 1 kg of powder was placed in each cage. This powder is the sieved mixture of eggs + wheat bran, from the adult egg-laying crates.



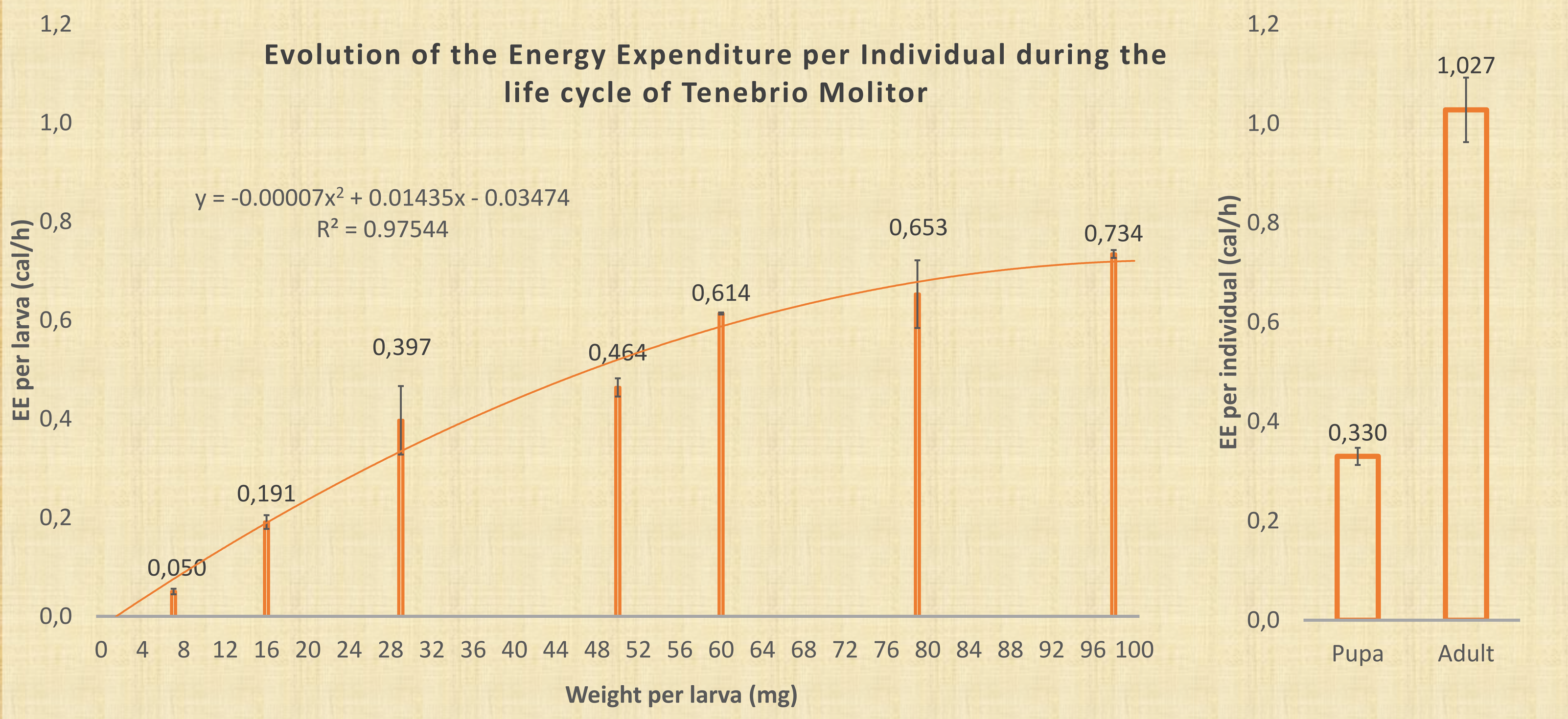
When necessary, water was sprayed into the cages, once or twice every 24 hours, to maintain the normal humidity level for rearing.

We carried out the measurements over 24 hours periods using four calorimetric cages with the PhenoMaster/LabMaster TSE system (Bad Homburg, Germany). The gas analysis system was checked and calibrated before each measurement period. Energy expenditure was calculated using Weir's equation:
$$EE\ (kcal) = (3.941 \times VO_2) + (1.106 \times VCO_2)$$
(Weir, 1949)

Results are given as mean ± standard deviation (sd).

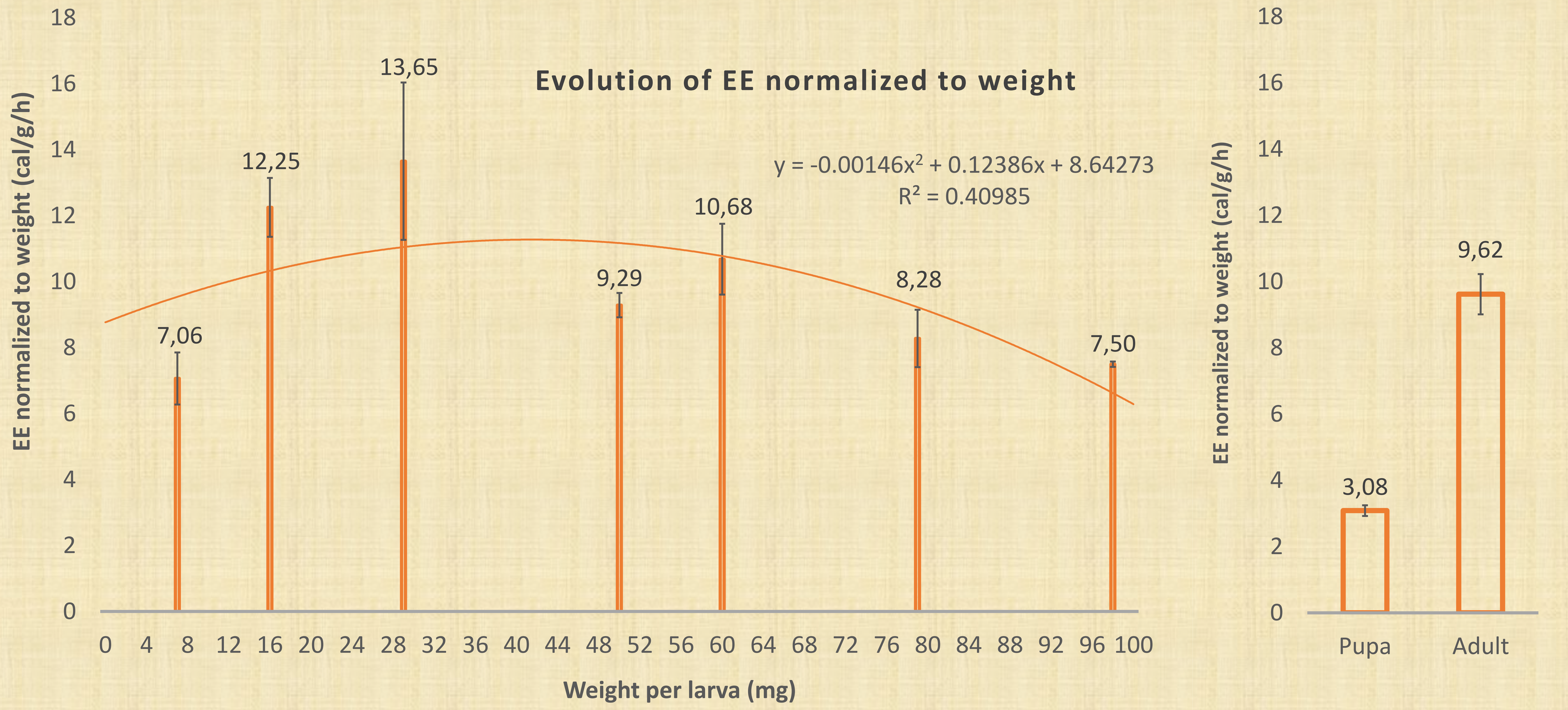
Results

The results we obtained illustrate for the first time the profile of EE for each insect life stage in mass rearing conditions. The EE per individual increased with weight gain for larvae from 7 to 60mg (EE from 0.050 ± 0.005 to 0.734 ± 0.008 cal/h).



EE tended to stabilize beyond 60mg (EE about 0.678 ± 0.064 cal/h). When the larvae became pupae, their EE decreased to 0.330 ± 0.017 cal/h per individual. Finally, adult mealworms had the highest EE with 1.027 ± 0.065 cal/h per individual. The EE of the eggs was very weak and the data were difficult to use.

EE normalized per g of body mass increased for larvae from 7 to 30 g (7.06 ± 0.79 to 13.65 ± 2.39 cal/g/h respectively), then they decreased to be at 7.50 ± 0.08 cal/g/h at the end of larval growth. This suggests that, at the end of growth, the larvae increased more their fat mass than their lean body mass. Adults had normalized EE equivalent to larvae of 50-60mg. Pupae had a normalized EE to 3.08 ± 0.16 cal/g/h.



From these results we can position the data of mealworm (larva 100mg) in relation to those typical of human, rat and mouse (data from our team). We compare normalized EE (cal/g/h) measured during 24 h.

 1.46 <  (rat) 5.38 <  7.50 <  (mouse) 19.42

From our results, we were also able to calculate the energy released by the production of larvae in a rearing shed of 700 m²:

2250 trays * 300g/tray of 15mg larvae : 6 Kw/h
2250 trays * 600g/ tray of 30mg larvae : 15 Kw/h
2250 trays * 1Kg/ tray of 50mg larvae : 18 Kw/h
2250 trays * 2Kg/ tray of 100mg larvae : 30 Kw/h

= 70 Kw/hour

= 700 people in a 700m² building

Conclusions: In addition to improving knowledge of EE of the *Tenebrio molitor* during the different phases of its life, these results will also make it possible to size the temperature regulation of rearing sheds.
These observations suggest a good calorific potential for advanced larval stages and adults.
Further studies will be realized on the complete life cycle of *Tenebrio molitor* and will include the impact of the photoperiod, the observation of body composition to explain the asymptote of EE progression during growth, the measurement on a greater amount of eggs to make the data usable. Taken together, these data could provide a key knowledge for the scaling and sizing of new yellow mealworm farms.