NUTRITION OF *TENEBRIO MOLITOR*

HISTORY AND NOVELTIES FOR APPLIED RESEARCH IN INSECT INDUSTRY

Dr. Thomas Lefebvre
R&D Manager, Ÿnsect

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Summary

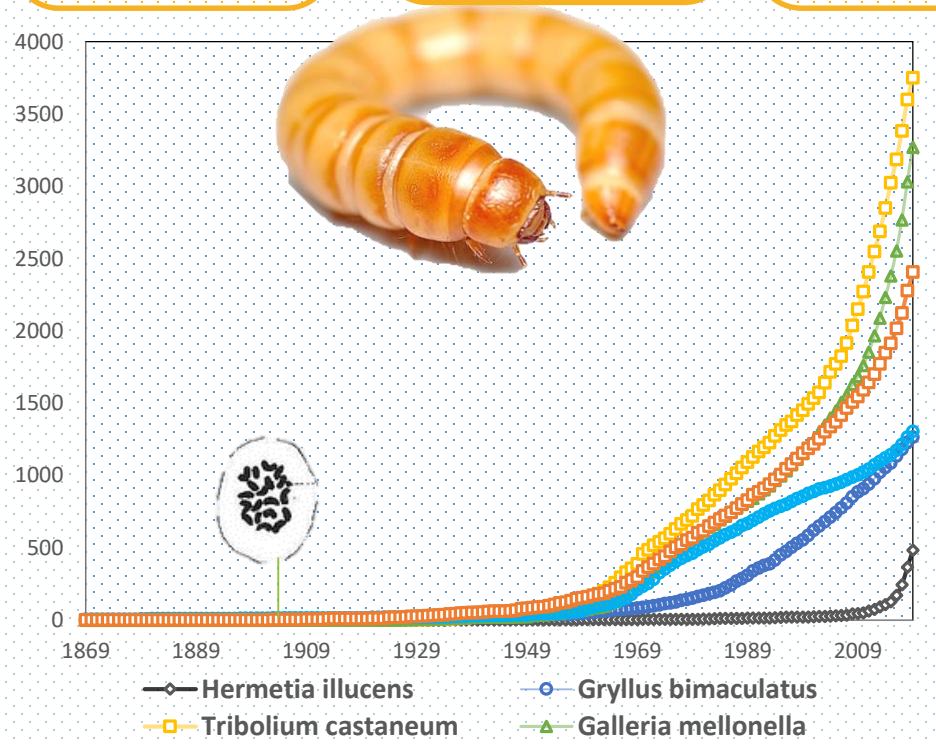
Tenebrio molitor : a model species

Mealworms are species of darkling beetles (Tenebrionidae), pests of stored cereals, model species in science, farmed for feed and food

Pest control
Genetics
Ecology
Immunity
Physiology
Nutrition

iBeetle-Base

A database of *Tribolium* RNAi phenotypes



Cumulative number of scientific publications related to mealworms and other insects (source: Dimensions)

The founders of *T. molitor*'s nutrition

Georges Tessier

Pioneer in *T. molitor* nutrition by publishing in 1939 with M. Lafon.

They showed that mealworms need :
< 3% lipids,
>40% carbs (starch preferentially),
10-15% proteins,
Yeasts as growth factors

Jean Leclercq

He initiated with GS Fraenkel a large study about *T. molitor* nutritional requirements and particularly their utilization of proteins. He proposed to class the protein value of plants in response to mealworms growth

Gottfried S Fraenkel

He published several major studies on *T. molitor* nutrition by finding the importance of vitamins (Complex B), fatty acids (linoleic acids) and sterols (cholesterol). And above all, he discovered the Carnitine and its role for *T. molitor.*

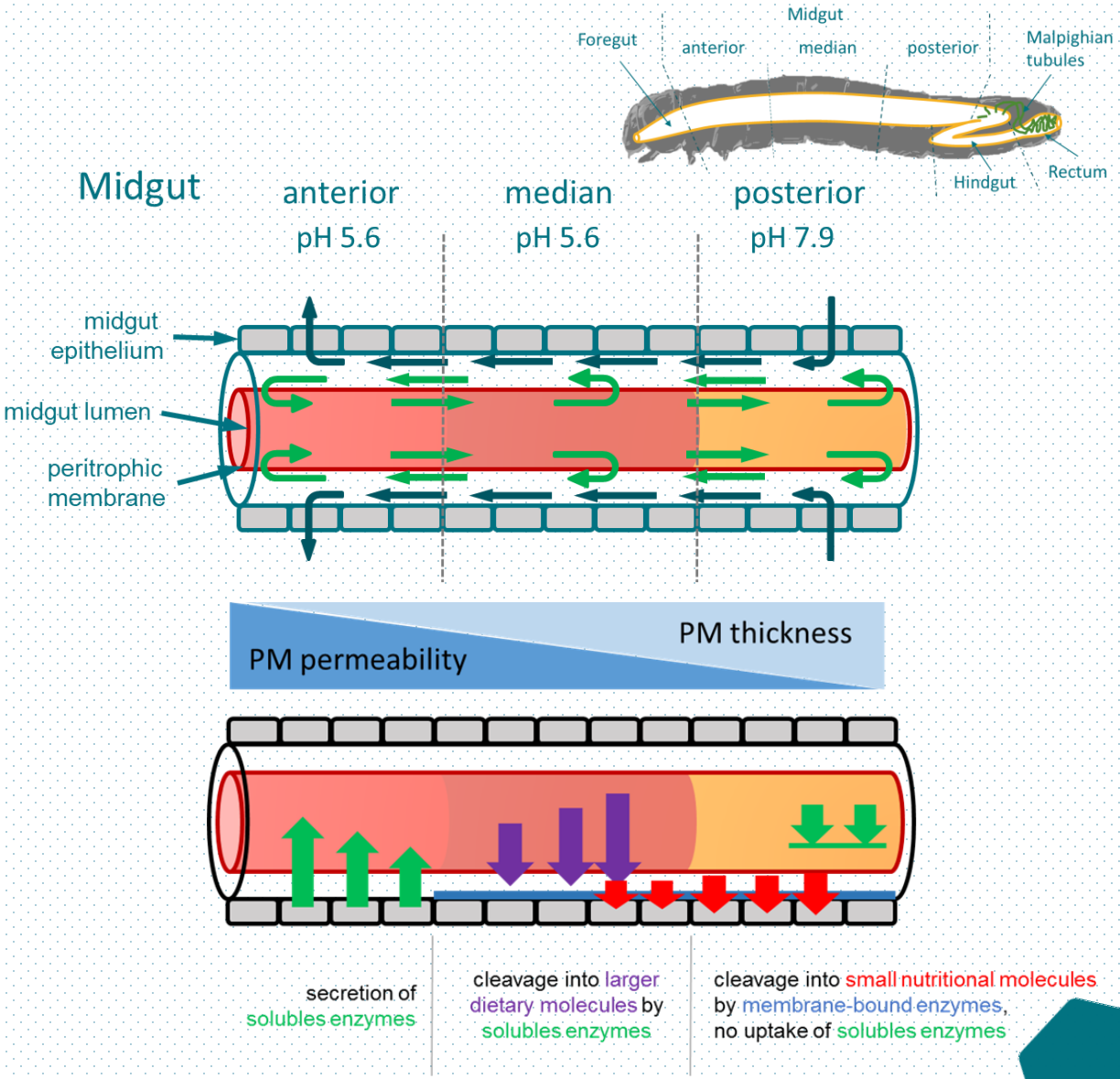
GRF Davis

Beginning as the student of J Leclercq, he dedicated most of his work to *T. molitor* nutritional requirements, especially the needs in proteins and amino acids. He was the most prolific author on this topic.

The physiology of mealworms gut

Walter R. Terra

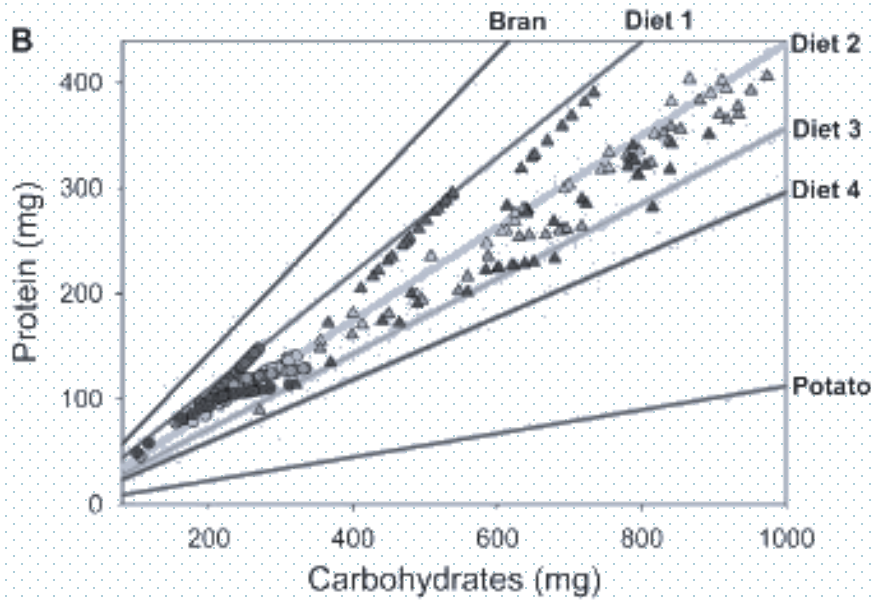
His research is mainly dedicated to the description of insects gut physiology (and especially the one of mealworms), their ecology and the digestive mechanisms involving enzymes and physiological regulations. He published a major article on transcriptomic analysis of the *T. molitor*'s midgut in March 2017.



More recent articles on P:C requirements

Juan Morales-Ramos

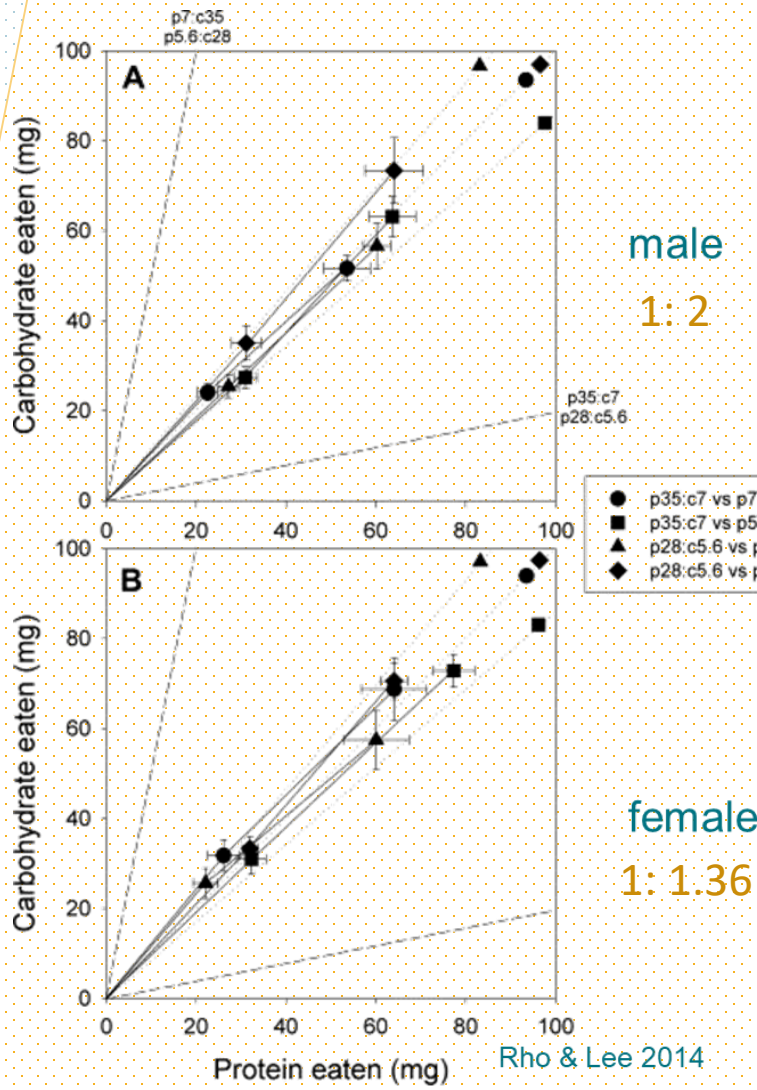
He published several articles these last years on *Tenebrio molitor's* physiology, and notably conducted a study about the optimal nutrient balance of mealworms determined by the self selection method



Geometric framework plot of digestible carbohydrate versus protein in experimental diet mixtures

Morales-Ramos et al. 2011

Rho and Lee conducted a similar study on *Tenebrio molitor's* adults



male

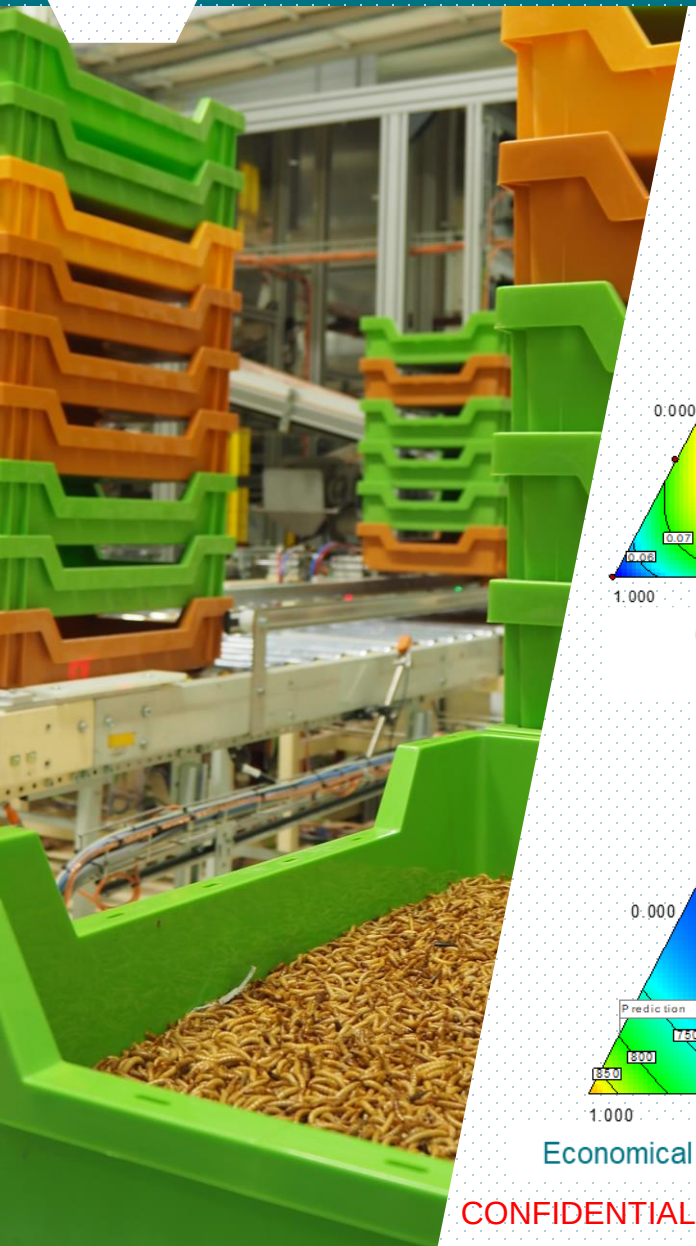
1: 2

female

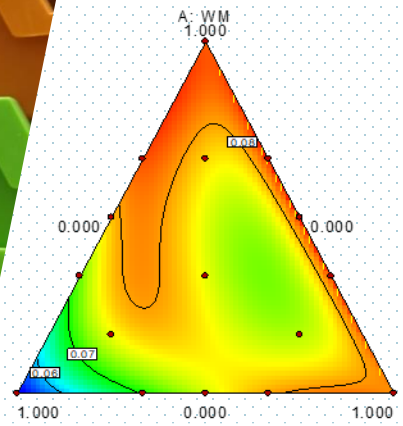
1: 1.36

Rho & Lee 2014

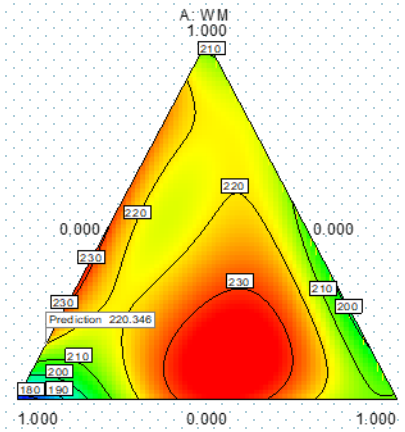
Diet optimization for industrial application



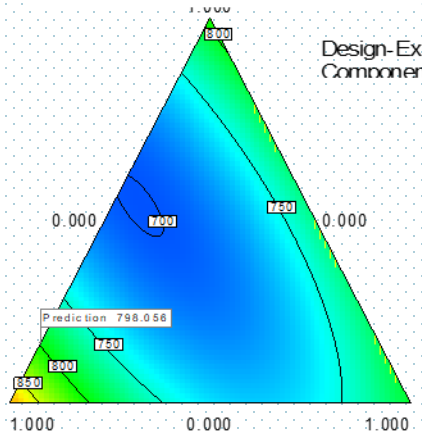
Diet formulation using *n*-factors mixture design and formulation software



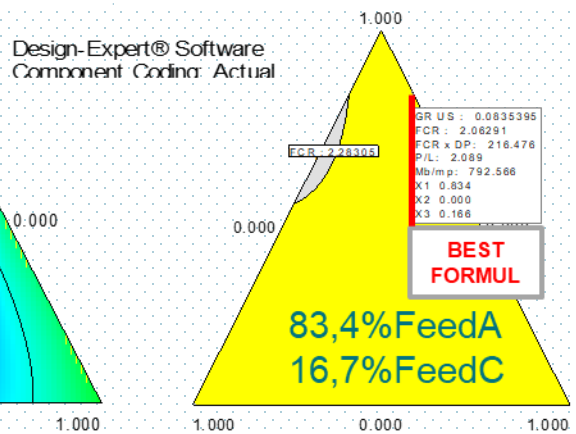
Growth indicator



FCR x Diet Price (Cost indicator)



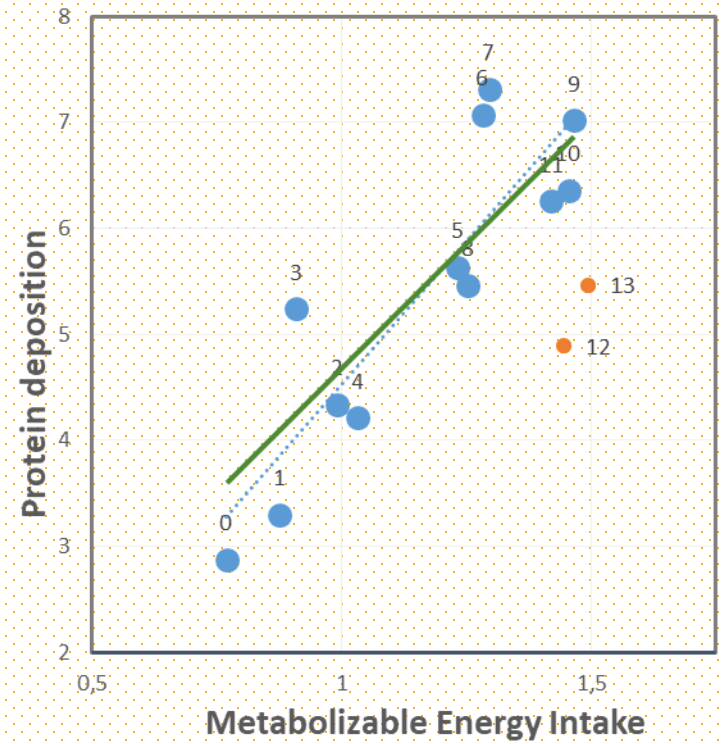
Economical factor (Margin indicator)

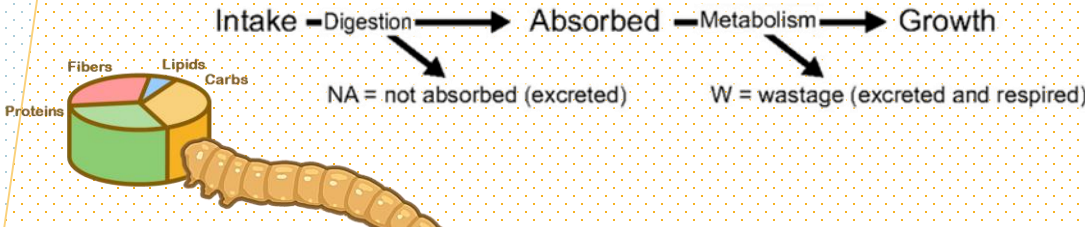


Optimization

CONFIDENTIAL AND PROPRIETARY

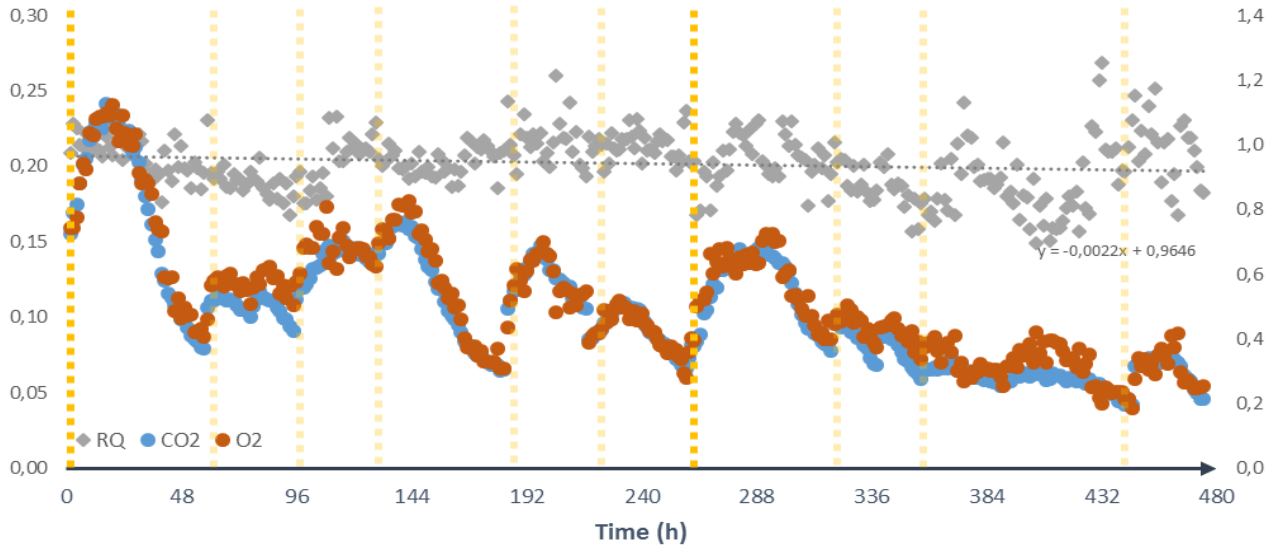
Definition of optimal P:C ratio based on digestible proteins and metabolizable energy





Estimation of energy expenditure

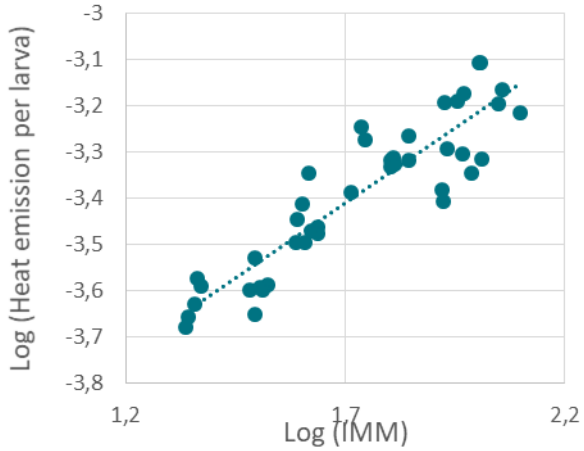
- Estimation of mealworms **heat emission** (Brouwer's formula $M = \alpha V_{O_2} + \beta V_{CO_2} + \gamma N + \delta V_G$)



02 consumption and CO2 production of mealworms on Wheat Bran diet

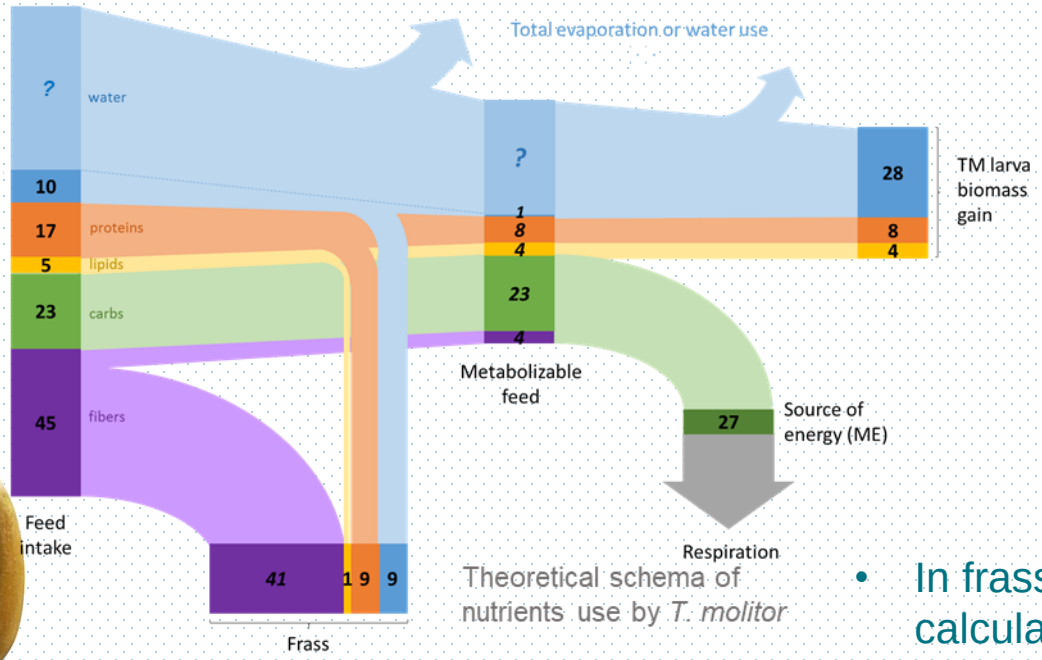
- Estimation of the **allometric coefficient of the metabolic weight**

Energy expenditure and basal metabolic rate depend on the amount of metabolically active tissue in the body, rather than on total body weight. The coefficient 0.75 is generally used to calculate the weight of active tissue. But is lower in *Tenebrio molitor.*

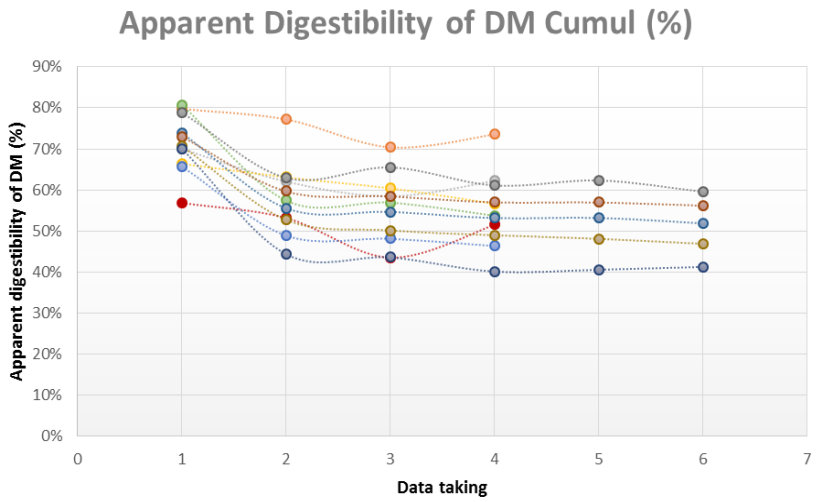


Assessment of feed digestibility

- Development of a **standard methodology** to estimate feed digestibility specific to Tenebrio molitor, which is essential for diet formulation



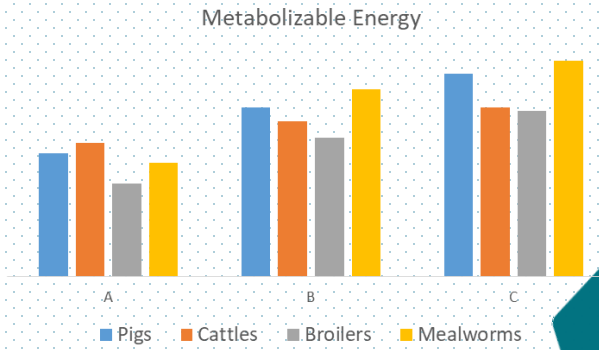
Theoretical schema of nutrients use by *T. molitor*



- In frass, there are metabolic wastes, that is why the calculation gives an **Approximate Digestibility** (Waldbauer 1968)

Observation of the frass (315µm) by microscopy

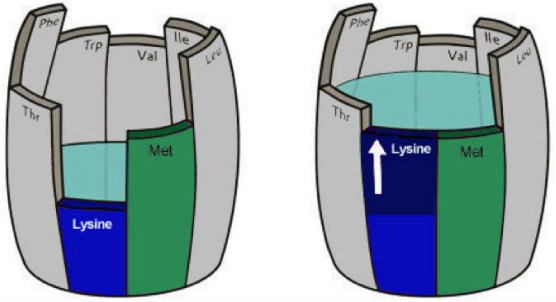
- Energy metabolizability of 3 cereal by-products appears relatively closer to pigs and generally better than other animals (firsts results)

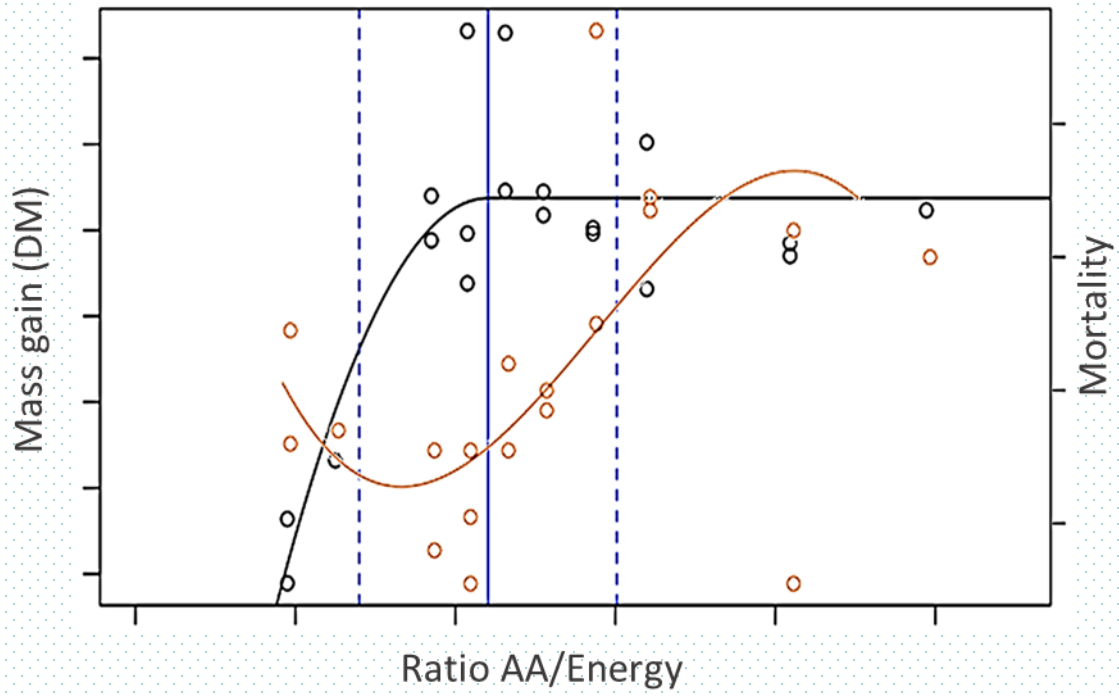


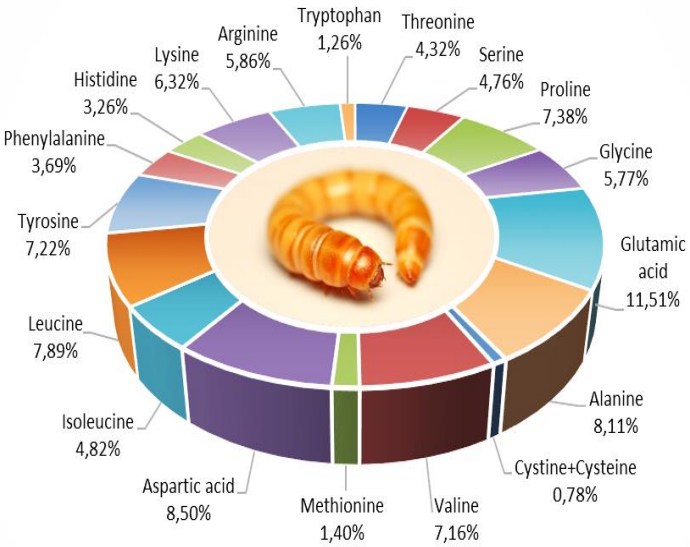
New advances in micronutrition

- Definition of the **first limiting amino acids**

Estimation of its **minimal value** (on isoenergetic and isoproteic diets) to compensate deficiency







- Supplementation in minerals and vitamins with **specific premixes** formulated according to scientific literature

Complete overview of R&D H&N activities

- Sourcing / Cartography
- Market analysis
- Nutritional composition
- Digestibility
- Quality control
- Pretreatment
- Storage

RAW MATERIALS

- Formulation
- Preparation /Industrial process
- Texture
- Water sources
- Vitamins and mineral Premix supplementation
- Specific diets (Starter, Grower, Finisher, Adult, ...)

DIET

- Nutritional requirements
  - Water (WTR)
  - Macronutrition (Prot., Energy)
  - Micronutrition (AAs)
- Resources allocation
- Digestive enzymes
- Feeding regulation
- Genetics

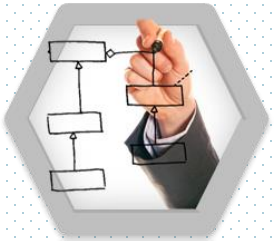
INSECT

- Evaluation of physiological and economical performances
  - Growth
  - Feed Conversion Ratio
  - Profitability
  - Fertility
  - ...
- Final body composition
- Feeding frequency
- Feed rationing
- Sanitary risk management
- Scalability

PRODUCTION

- Standardization of protocol and methods
- Indicators
- Quality procedures
- Database

METHODS



ŸNSECT's future developments

- European project **#FARMŸNG** to build the first and largest fully automated industrial unit specialized in the production of high quality insect proteins. Co-financed by European Commission and Bio-based Industries Joint Undertaking (BBI JU) for 20 M€

- Fund-raising of 125 M$ in Series C funding in the largest early-stage agritech funding deal on record in Europe. Construction of Ÿnfarm in Amiens (France) to produce max 20,000 tonnes of insect protein a year.

Ynsect

Thank ÿou !

ANY QUESTIONS?