Using insect larvae to upcycle waste organic residues to produce novel animal feed ingredients

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Novel applications of insect meals as '*new*' animal feed ingredients:

Aquaculture, 24 (1981) 103–109
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SOLDIER FLY LARVAE AS FEED IN COMMERCIAL FISH PRODUCTION

K. BONDARI and D.C. SHEPPARD

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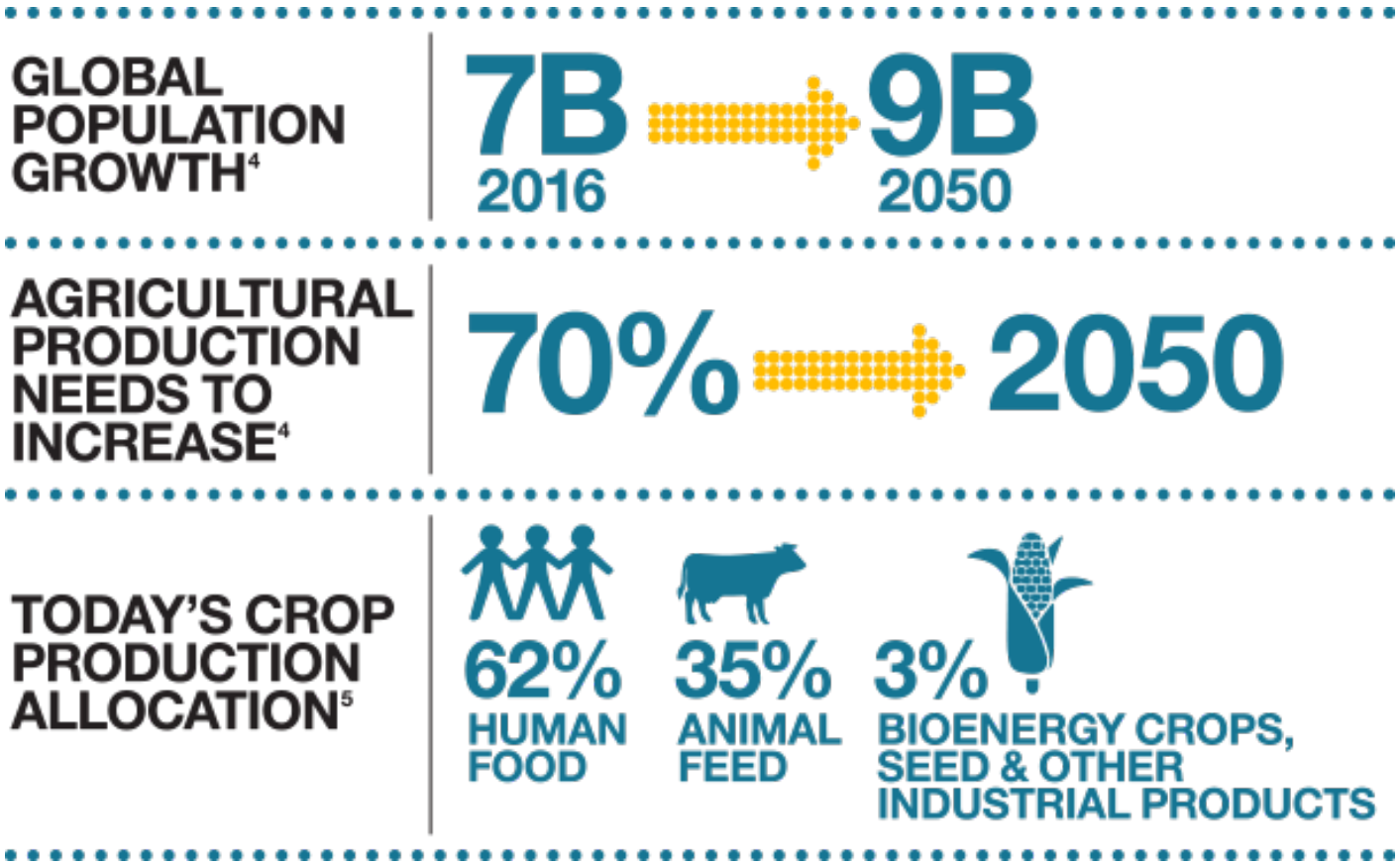
(Accepted 29 October 1980)

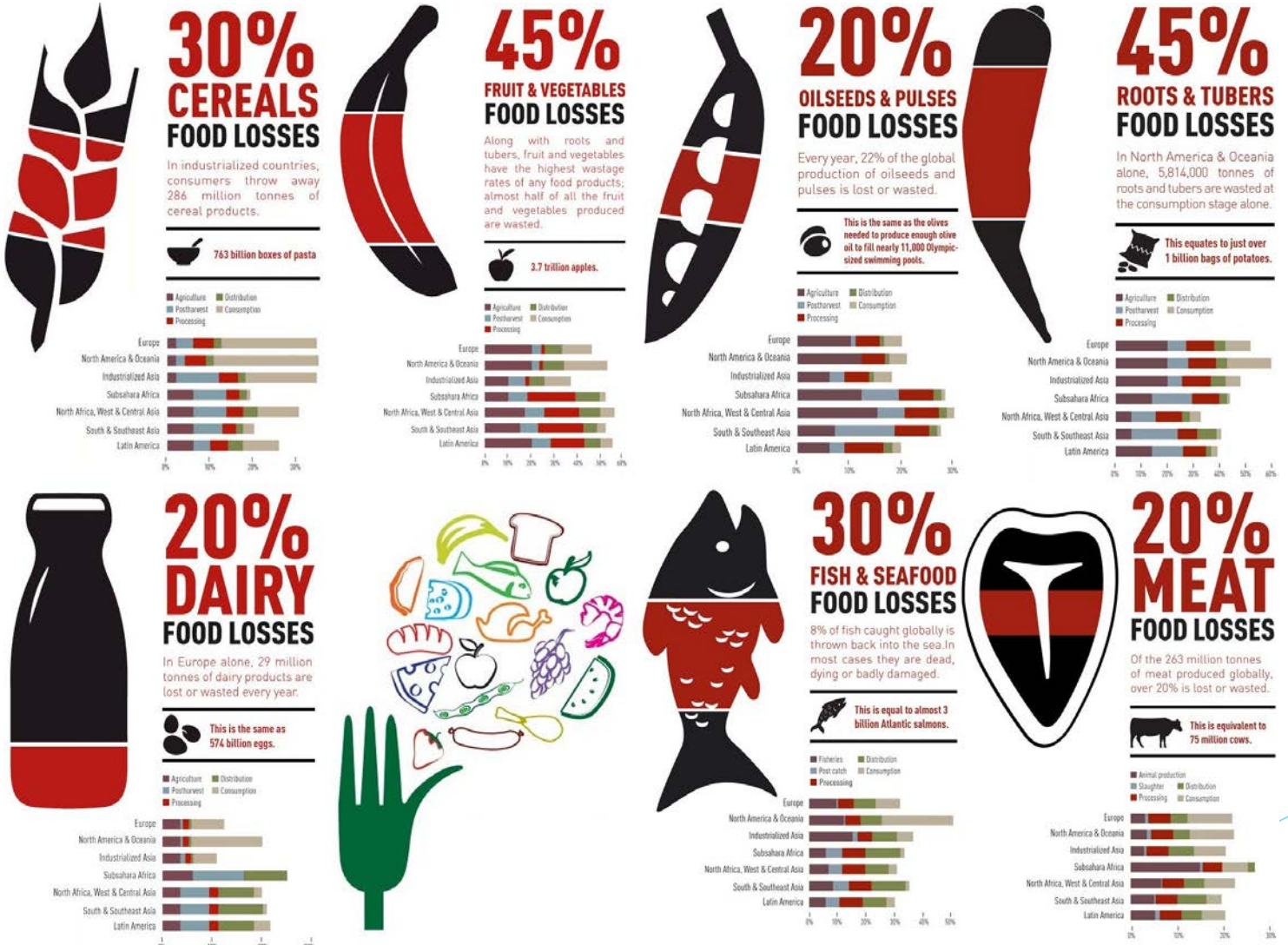
- So what has changed?

Agrifood sector: Our collective challenge…

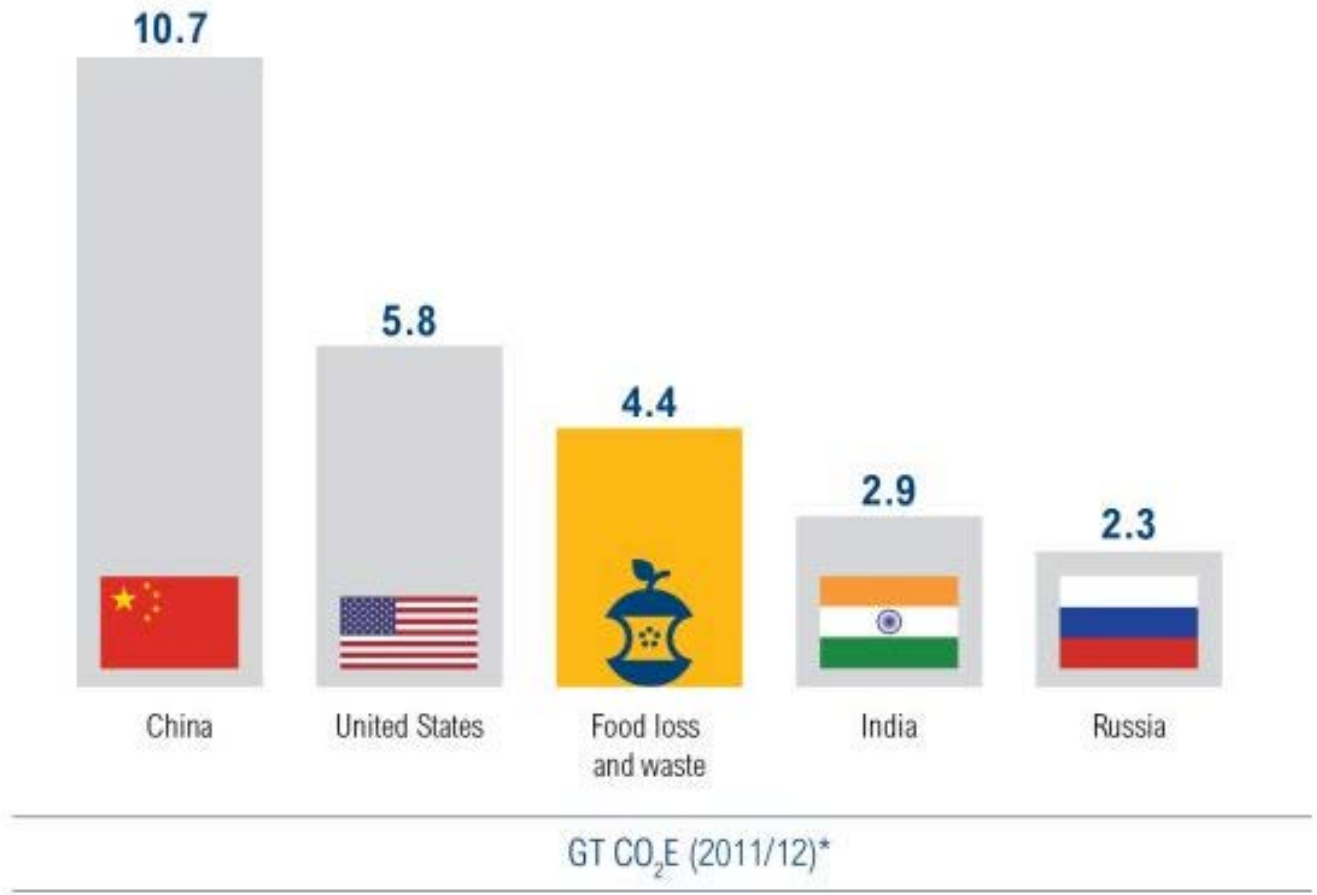


- Need to find ways to produce more with less…

Food Waste: Previously an issue largely ignored…



Food waste and GHG emissions

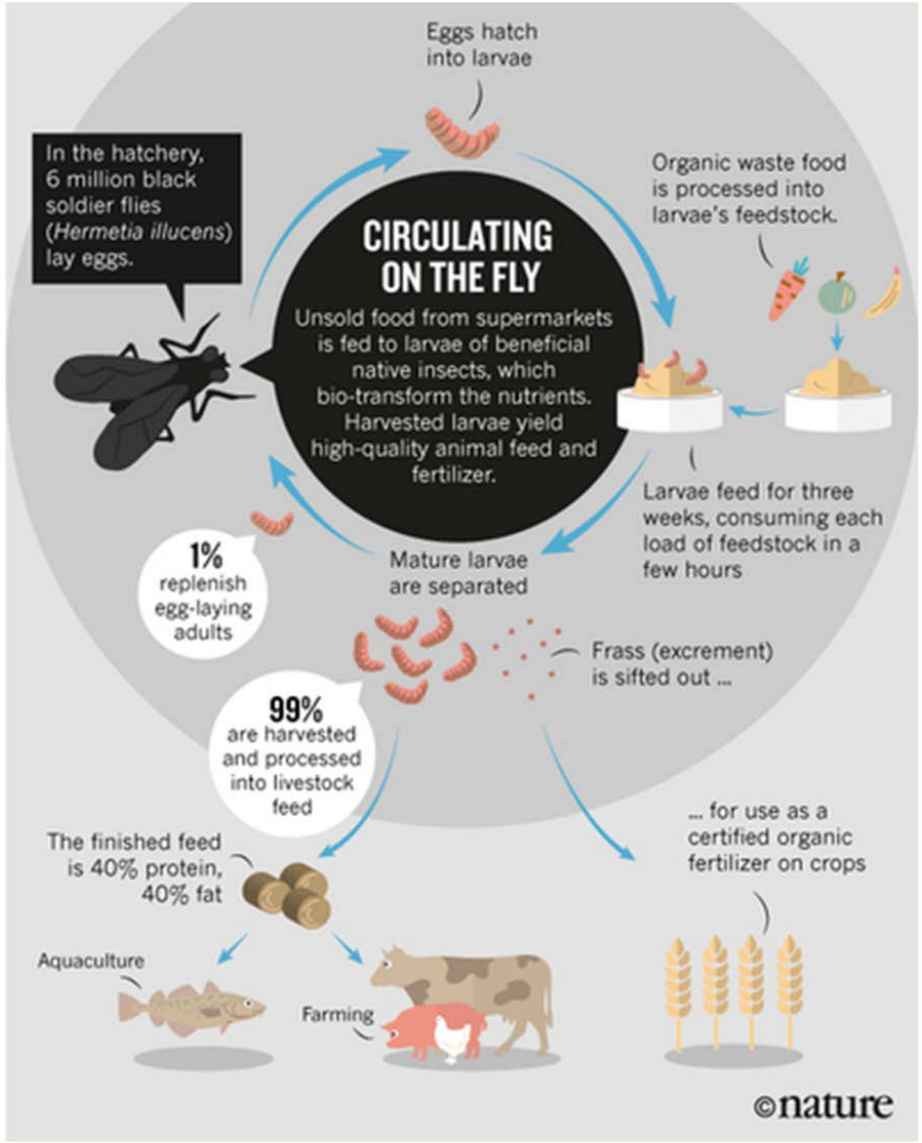


* Figures reflect all six anthropogenic greenhouse gas emissions, including those from land use, land-use change, and forestry (LULUCF). Country data is for 2012 while the food loss and waste data is for 2011 (the most recent data available). To avoid double counting, the food loss and waste emissions figure should not be added to the country figures.

Source: CAIT. 2015; FAO. 2015. *Food wastage footprint & climate change*. Rome: FAO.

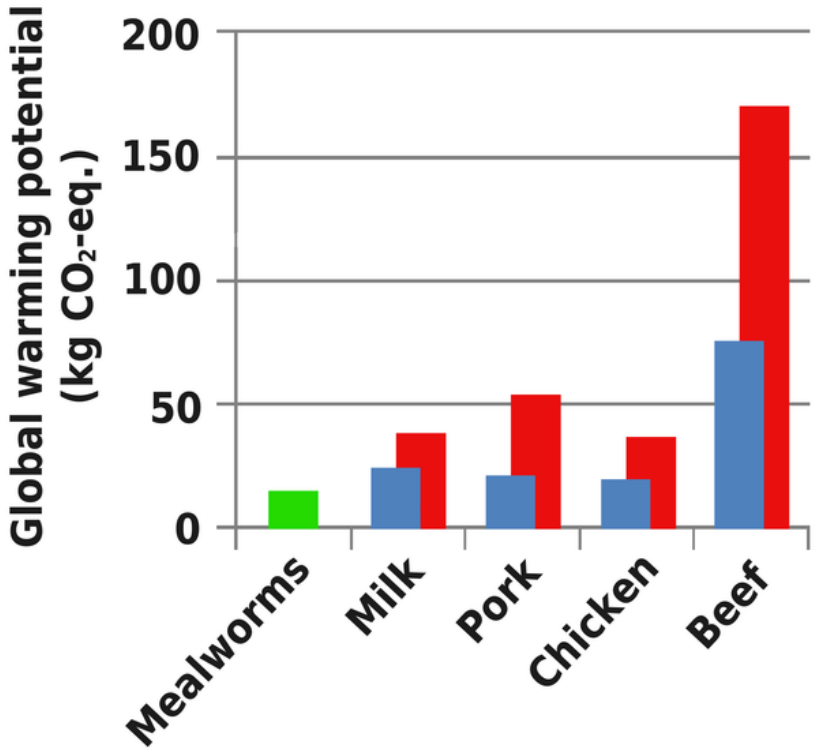
WORLD RESOURCES INSTITUTE

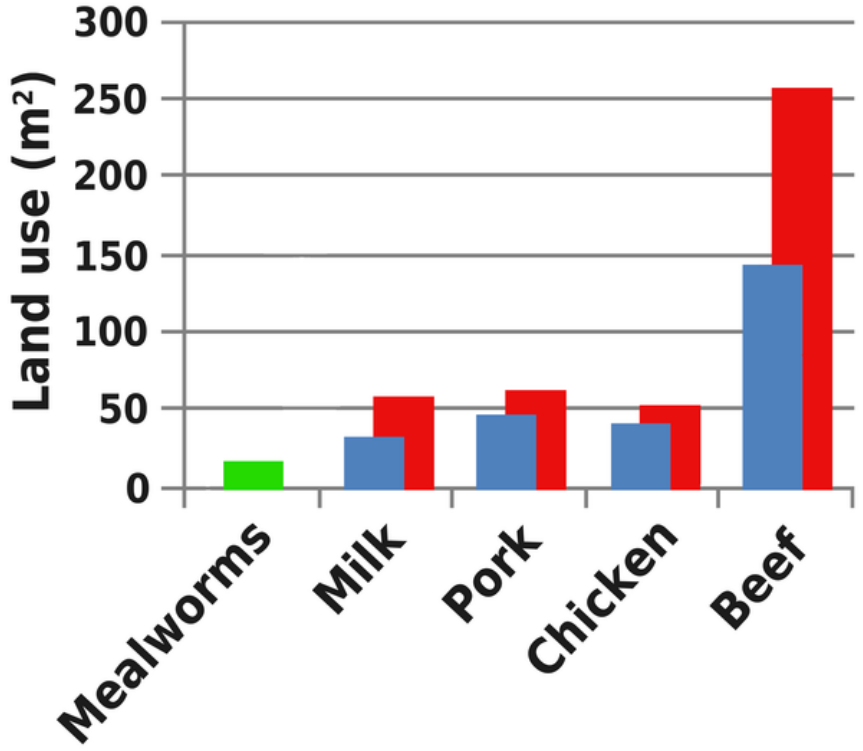
Exploiting the ecological services of insect larvae to upcycle wastes



www.nature.com

Environmental impact of mealworms vs. other animal products: Life Cycle Analysis





Oonincx DGAB, de Boer IJM (2012) Environmental Impact of the Production of Mealworms as a Protein Source for Humans – A Life Cycle Assessment. PLOS ONE 7(12): e51145. https://doi.org/10.1371/journal.pone.0051145
https://journals.plos.org/plosone/artiwcle?id=10.1371/journal.pone.0051145

PLOS ONE

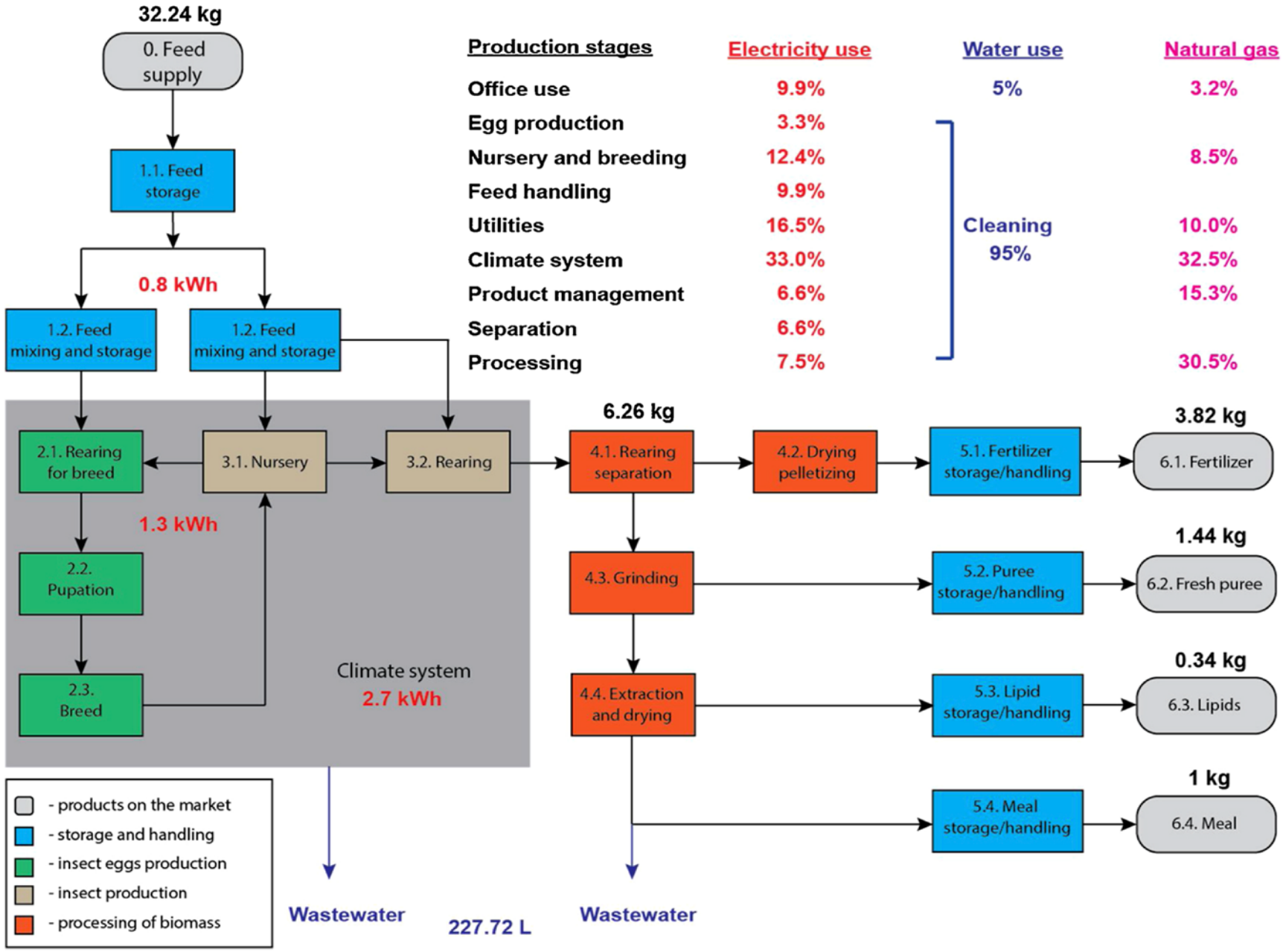


Fig. 1. System boundaries of the study (attributional modelling) including inputs distribution and relative mass flows.

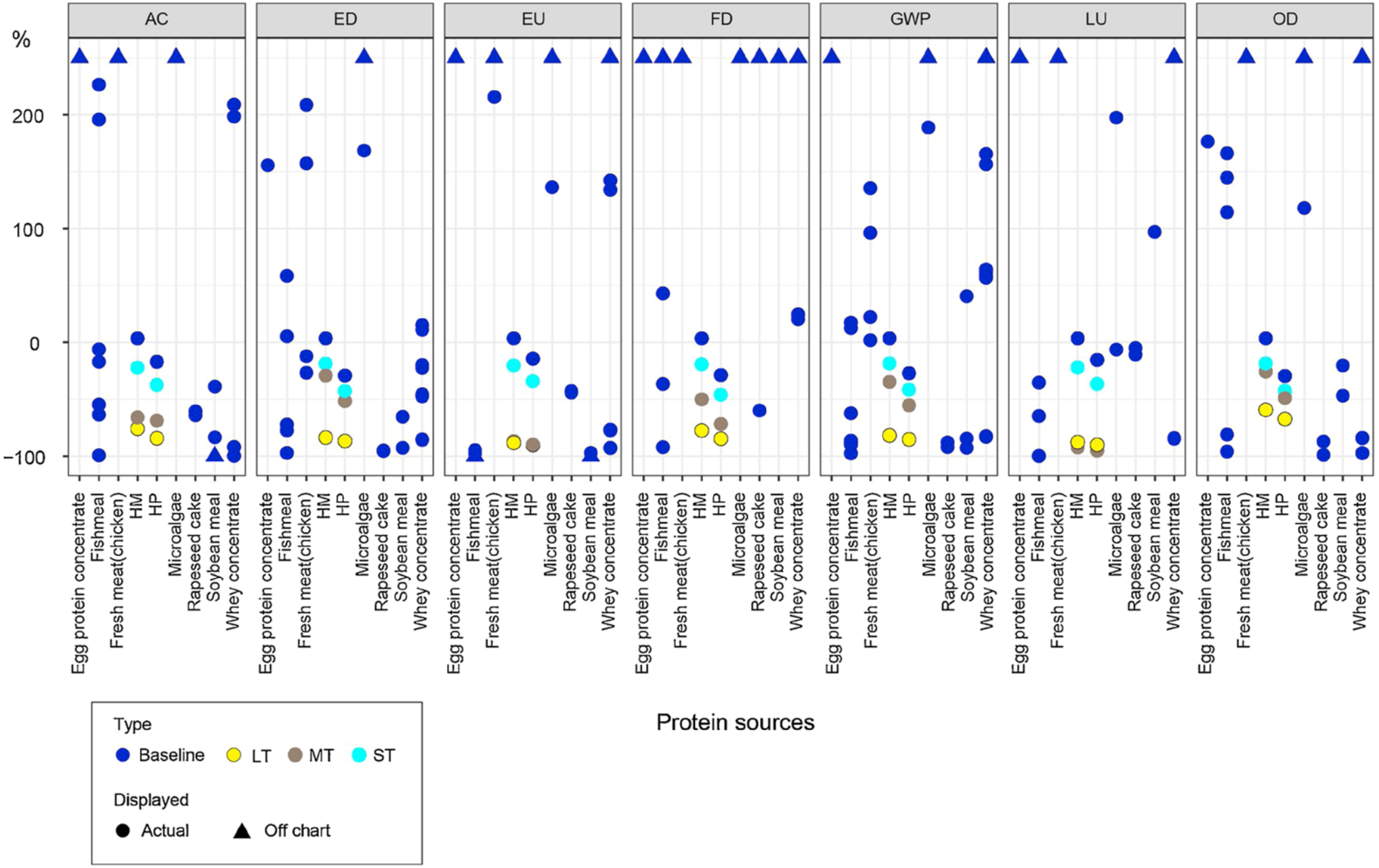


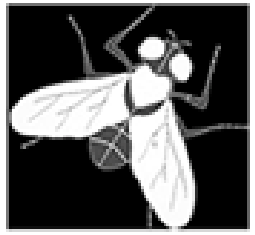
Fig. 3. Environmental impacts of different sources of proteins (dry matter basis) weighted against HM, GWP – global warming potential; OD – ozone depletion; AC – acidification; EU – eutrophication; ED – energy demand; FD – freshwater depletion; LU – land use, relative impacts are censored at -100% and 250% to maintain the readability of the plot and as triangles at these limiting values, references for the analysis of environmental impacts are in Table A.2.

Current species of interest:

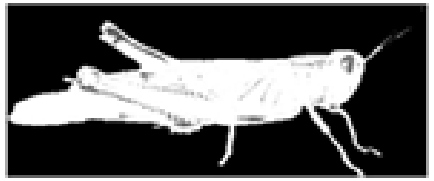
50%

8%

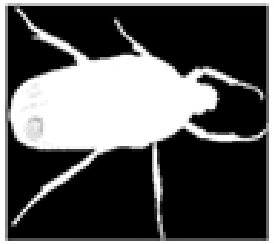
O. Diptera



O. Orthoptera

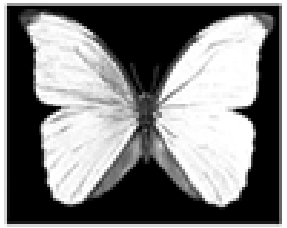


O. Coleoptera



11%

O. Lepidoptera



29%

Sanchez-Muros et al., 2015

Emerging opportunities: Insect meals vs. fish & soy meals





Constituents	Black soldier fly larvae	Housefly maggot meal	Mealworm	Fishmeal	Soymeal
Crude protein	42.1 (56.9)*	50.4 (62.1)	52.8 (82.6)	70.6	51.8
Lipids	26.0	18.9	36.1	9.9	2.0
Calcium	7.56	0.47	0.27	4.34	0.39
Phosphorus	0.90	1.60	0.78	2.79	0.69
Ca:P ratio	8.4	0.29	0.35	1.56	0.57

Adapted from Tran et al. 2015

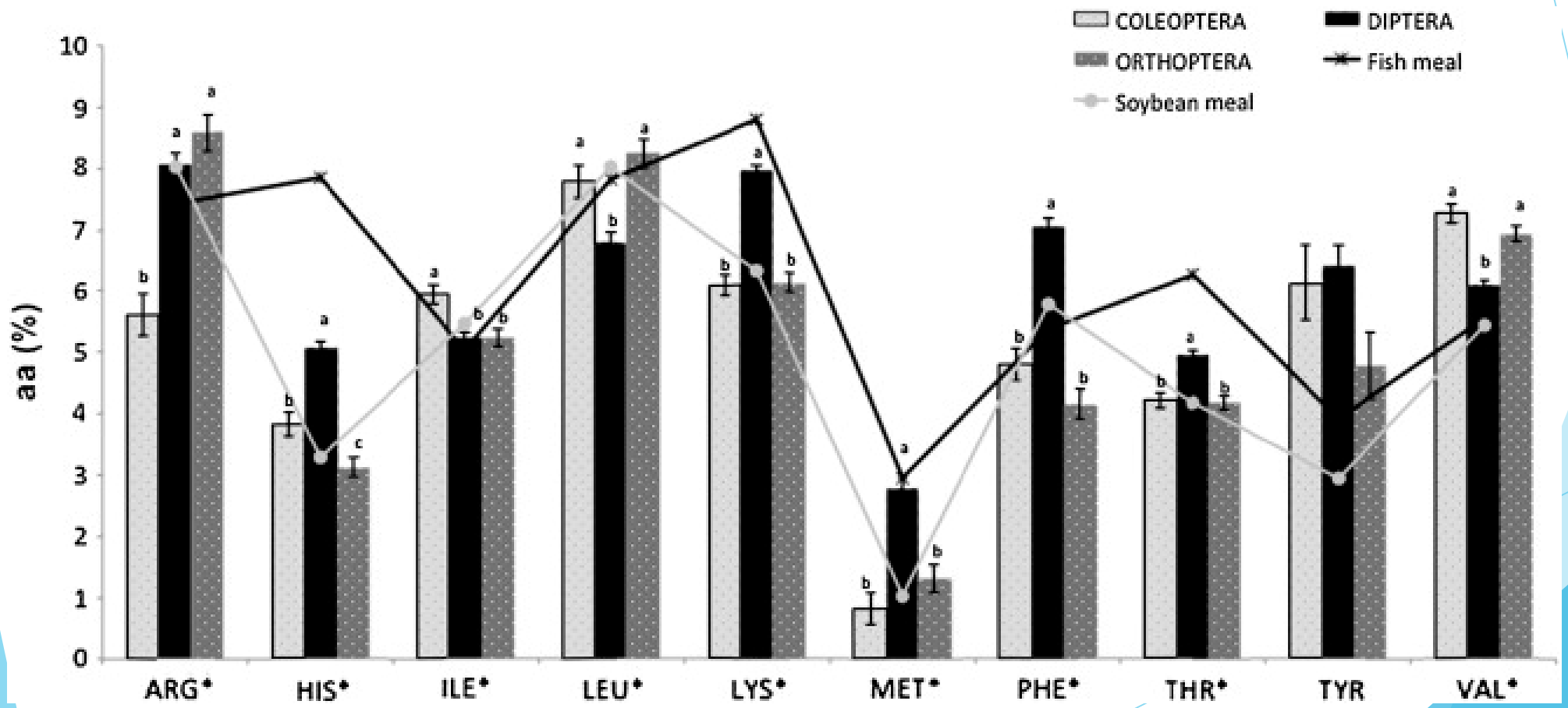
Fishmeal replacement: not only restricted to aquaculture

3 - 5 % chick **5- 7.5% piglet** **5-30%**

- High-priced commodity, qty/price fluxuations, sustainability issues

Amino acid profiles vs fish meal

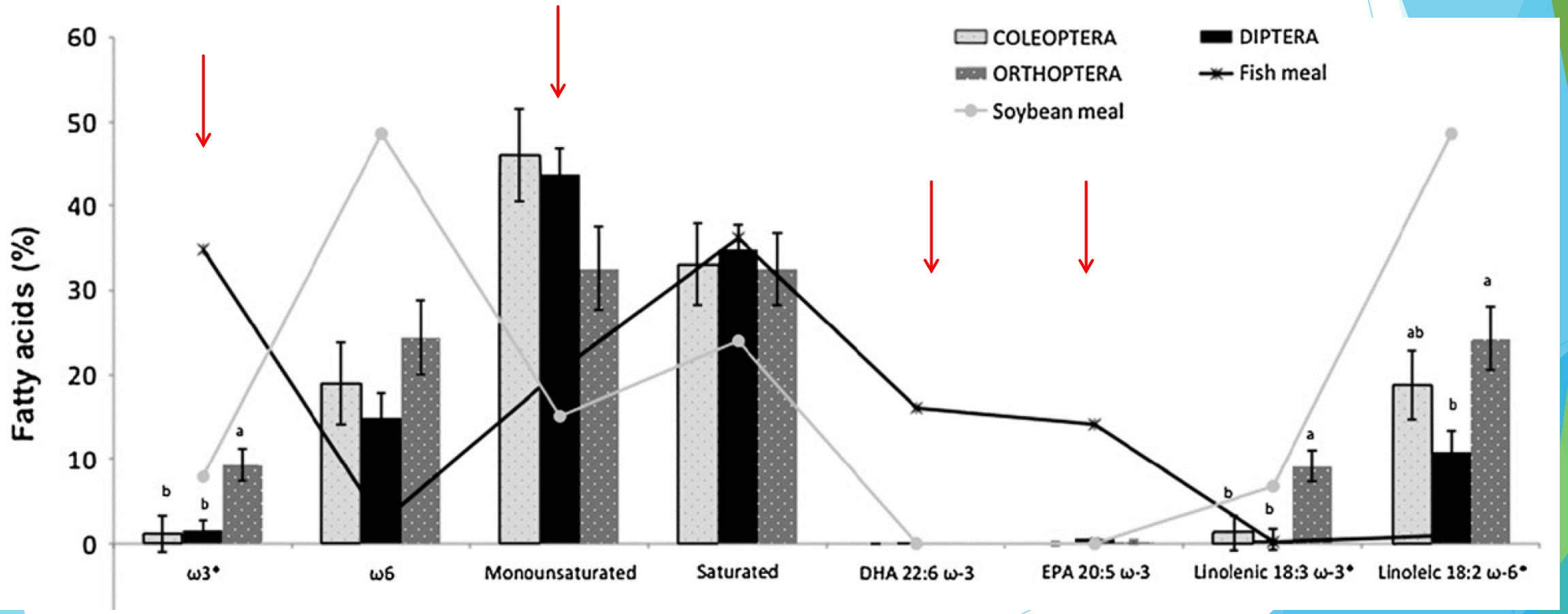
Profile of dipteres (*Hermetia* et *Musca*) in essential amino acides are very similar to that of fish meal



Barroso et al., 2014

Fatty acid profiles vs fish meal

Fatty acid profiles are very different from fish meal



Barroso et al., 2014

animals

MDPI

Review

Animals Fed Insect-Based Diets: State-of-the-Art on Digestibility, Performance and Product Quality

Laura Gasco [1,*], Ilaria Biasato [1], Sihem Dabbou [2], Achille Schiavone [2] and Francesco Gai [3]

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check for updates

Table 2. Dietary insect meal inclusion in avian diets and related effects on apparent digestibility coefficients in comparison with the control diet used in the different trials.

Avian Specie	Insect Species	Insect Form	% Insect Inclusion	Days of Feeding	Impact on Nutrient Digestibility	Reference
Broiler chickens	Full-fat TM and HI	Larva meal	25%	9	No influence on the CTTAD of the nutrients, except for the CTTAD of the EE: HI more digestible than TM. Higher AIDC in the TM group than in the HI.	[19]
	• HI dried (100 °C) • HI dried (65 °C) • Defatted HI dried (65 °C)	Pre-pupa meal	50% 50% 40%	7	Higher CTTAD values for the nutrients in the defatted HI pre-pupae meal dried at 65 °C diet than the control and the diets with HI pre-pupae meals dried at 65 °C.	[22]
	• Partially defatted HI • Highly defatted HI	Larva meal	25%	9	Influence on the CTTAD of the EE and GE, which were more digestible in the HI partially defatted group than the HI totally defatted. No effect on the AA digestibility except for the glutamic acid, proline and serine that were more digestible in the HI highly defatted.	[21]
	• Dry-rendered HI • Extruded HI • Full-fat HI	Larva meal	50%	5	Higher CTTAD of the CP, EE, ash and CF in the dry-rendered larvae diet than the other groups.	[23]
	Full fat TM		29.65%	32	Decrease in the ADC of the DM, CP and OM.	[26]
	TM	Oil	5%	28	Increase in the CTTAD of the EE.	[31]
	MD	Larva meal	30%	7	Increase in the ADC of the CP and AA.	[29]
Broiler quails	Defatted HI	Larva meal	10% and 15%	11	Higher CTTAD of EE in the 10% group than the other groups. No significant effect on the CTTAD of the DM, OM and CP.	[24]
	HI1 (reared on layer mash) HI2 (reared on 50:50 layer mash and fish offal)	Larva meal	10%	15	Higher AME for the HI-fed quails than the control diet. HI2: higher CTTAD for the DM and OM than the HI1.	[25]
Broiler ducks	Defatted HI	Larva meal	3%, 6% and 9%	47	Lower CTTAD of the CP during the starter period with the inclusion of 9% HI than the other diets. Higher CTTAD of the EE during the grower and finisher periods than the control diet.	[30]
Laying hens	Partiallydefatted HI	Larva meal	7.3% and 14.6%	140	Decrease in the AIDC of the DM, OM and CP.	[27]
	Highly defatted HI	Larva meal	17%	147	Decrease in the AIDC of the DM, OM and CP.	[28]

Note: HI: *Hemetia illucens*; TM: *Tenebrio molitor*; MD: *Musca domestica*; CTTAD: apparent digestibility coefficients of the total tract; AIDC: apparent ileal digestibility coefficients; ADC: apparent digestibility coefficient; DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; CF: crude fiber.

Rapidly growing database of feeding insects to farmed animal species

Salmonids

Tilapia

Shrimp

Grower and finishing pigs

Layer

- **Substitution of fishmeal: 7.5 to 100%**
- **From no impact to documented issues (species dependant):**
  - **Palatability**
    Feed intake
  - **Growth performance**
    Weight gain
    FCR
    Protein efficiency
  - **Product quality**
    ↓ Lipid
    ↓ HUFA n-3
    Δ Colour
  - **Immune system stimulation (chitin)**

- Juvenile rainbow trout (180 g);
- Inclusion of 0, 25%, 50% black soldier fly (HI) larvae meal;
- Growth, digestibility, nutrient budgets, carcass composition, intestinal morphology.

Renna *et al. Journal of Animal Science and Biotechnology* (2017) 8:57
DOI 10.1186/s40104-017-0191-3

Journal of Animal Science and Biotechnology

RESEARCH Open Access

Evaluation of the suitability of a partially defatted black soldier fly (*Hermetia illucens* L.) larvae meal as ingredient for rainbow trout (*Oncorhynchus mykiss* Walbaum) diets

M. Renna[1], A. Schiavone[2,3], F. Gai[3*], S. Dabbou[2], C. Lussiana[1], V. Malfatto[1], M. Prearo[4], M. T. Capucchio[2], I. Biasato[2], E. Biasibetti[2], M. De Marco[2], A. Brugiapaglia[1], I. Zoccarato[1] and L. Gasco[1,3]

- Juvenile rainbow trout (45 g);
- Inclusion of 0, 6.6%, 13.2%, 26.4% black soldier fly (HI) larvae meal;
- Growth, digestibility, nutrient budgets, carcass composition metabolic impacts.

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aquaculture

The oil fraction and partially defatted meal of black soldier fly larvae (*Hermetia illucens*) affect differently growth performance, feed efficiency, nutrient deposition, blood glucose and lipid digestibility of rainbow trout (*Oncorhynchus mykiss*)

André Dumas[a,*], Thiago Raggi[a], Justin Barkhouse[a], Elizabeth Lewis[b], Erika Weltzien[c]

Growth performance

Items	HI0	HI25	HI50	SEM	*P*-value
Survival,%	97.4	98.3	100.0	0.681	0.298
IBW,g	178.9	178.8	179.1	0.099	0.579
FBW,g	539.3	545.4	538.0	5.098	0.849
WG,g	360.5	366.5	358.9	5.079	0.840
SGR,%/d	1.40	1.42	1.41	0.013	0.935
FCR	0.90	0.88	0.90	0.009	0.739
PER	2.46	2.52	2.47	0.024	0.579
FR,%/d	1.33	1.32	1.33	0.005	0.442

Diet	IBW (g/fish)	FBW (g/fish)	WG (g/fish)	TGC (g⅓/°C*d)	FI (g/fish)	FCR**
A HI 0	47.8 (1.9)	341.5 (6.0)[a]	293.7 (4.9)[a]	0.289 (0.005)[a]	232.7 (3.5)	0.78 (0.01)[d]
B HI 6.6	45.5 (1.2)	325.7 (11.6)[a]	280.2 (10.5)[a]	0.286 (0.004)[a]	225.8 (8.5)	0.81 (0.02)[c]
C HI 13.2	46.6 (0.8)	319.2 (5.5)[a]	272.6 (4.7)[a]	0.279 (0.004)[a]	229.7 (9.9)	0.84 (0.01)[b]
D HI 26.4	45.9 (0.1)	286.6 (12.1)[b]	240.6 (2.1)[b]	0.260 (0.010)[b]	219.7 (13.0)	0.91 (0.00)[a]

Insect meal for feeding animals: many questions remain…

- Despite positive tendancies, many uncontrolled variables in animal feeding studies:
  - Biological differences (fish size/age, duration, dietary effects, etc);
  - Effects of insect matrix:
    - Provenance, age, growing medium, processing;

Requires standardized methodologies for insect rearing and animal studies.

Journal of Insects as Food and Feed, 2018; 4(1): 1-4

Can diets containing insects promote animal health?

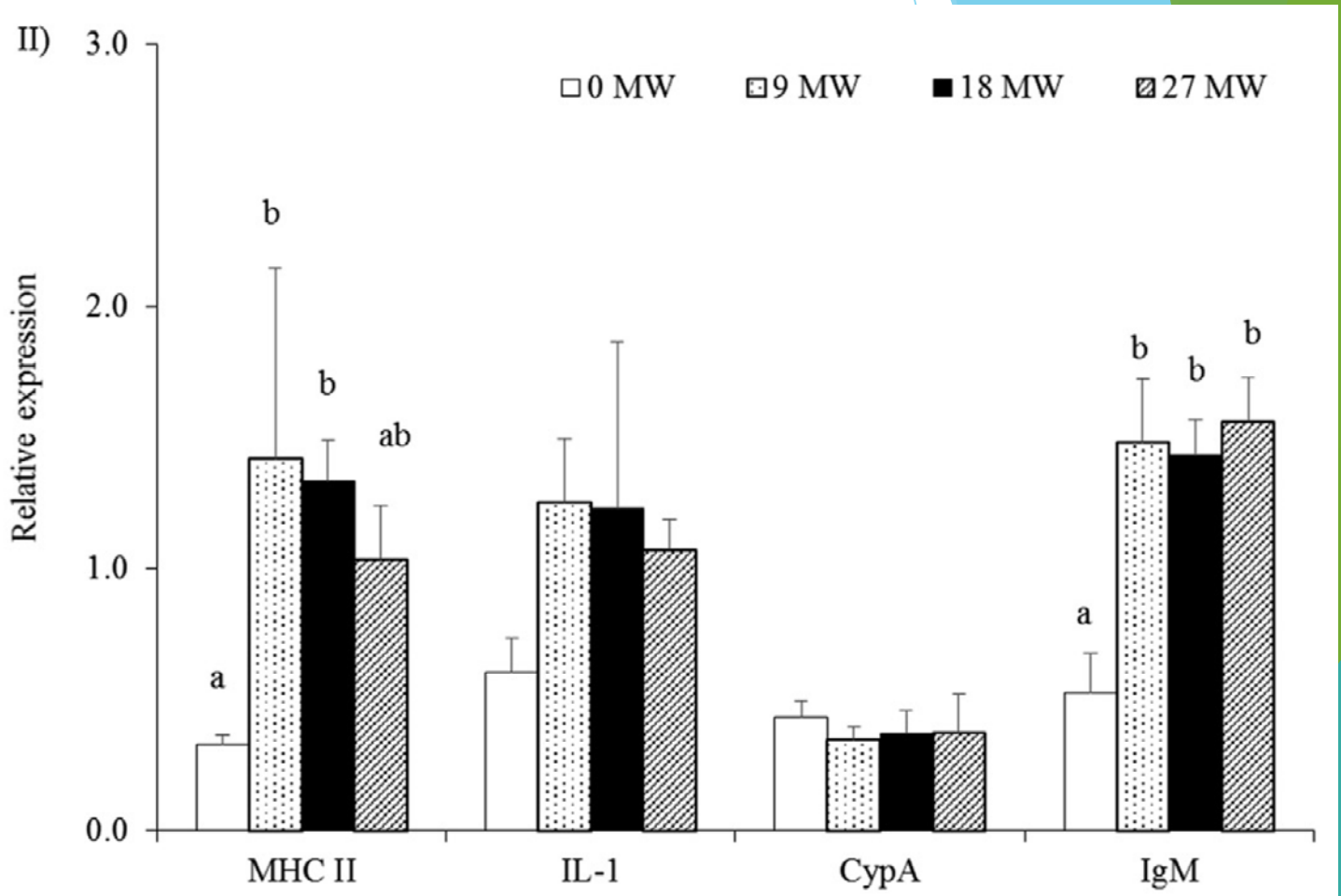
L. Gasco[1], M. Finke[2] and A. van Huis[3]*

[1]Department of Agricultural, Forest, and Food Sciences (DISAFA), University of Turin, Largo Paolo Br Grugliasco, Italy; [2]Mark Finke LLC, 17028 E Wildcat Dr, Rio Verde, AZ 85263, USA; [3]Laboratory of Entomol University & Research, P.O. Box 16, 6700 AA Wageningen, the Netherlands; editor-in-chief@insectsasfooa

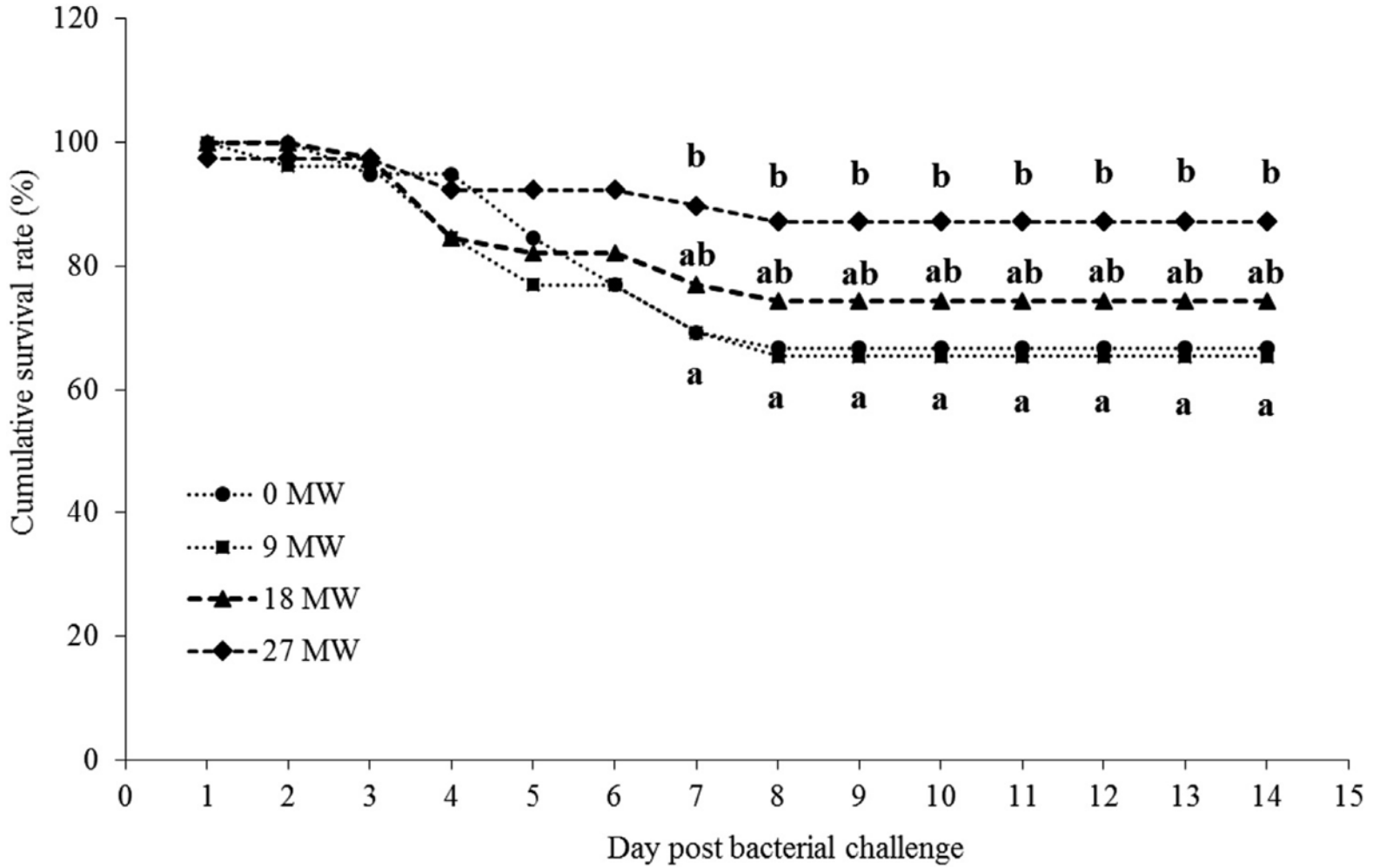
Beyond protein replacement

Mealworm replacement: enhanced gene expression of immune system

- Gene up-regulation
  - Specific/non-specifique
- Intestinal ‘health’
  - Mucosal histology
  - Microbiote/diversity



In vivo bacterial challenge: improved survival



Insect-based diets: animal welfare
The case for poultry:

- Control diet: Commercial mash diets
- Test diet: Soy-free mash diets + live larvae

1. Production performance was unchanged
2. Egg quality was unchanged
3. Improvement in feather score was observed

(Protix: Schmitt and Paul, pers comm)

Major challenges: Scale-up

Multi-faceted, complex systems and opportunities

- The opportunity for the agrifood sector is enormous; from waste organic upcycling the range of livestock species;
- Challenge: will require multidisciplinary efforts to address a range of issues (biology, engineering, regulatory etc.)

Regulatory appovals: Canada as a leader

The Globe and Mail – CFIA approves farmed maggots as chicken feed in North American first

POSTED ON JULY 28,

By Ann Hui The G
Last updated Thu
Inspection Agenc
the first time a fe
of insect...

New proteins

News | 14 Dec 2016 | 11059 views | 2 comments

EU agrees on insect protein for aquafeed

**IPIFF, the Europea
sect Production se
EU Member States**

News Release – Enterra Receives CFIA Approval to Sell Insect Larvae to Aquaculture Industry

POSTED ON FEBRUARY 15, 2017 BY VICTORIA LEUNG

February 15, 2017 10:00 ET Enterra Receives CFIA Approval to Sell Insect Larvae to Aquaculture Industry LANGLEY, BC--(Marketwired - February 15, 2017) - Enterra Feed Corporation has received approval from the Canadian Food Inspection Agency (CFIA) to sell its Whole Dried Black Soldier Fly Larvae as a feed ingredient for salmonids, including farmed salmon, trout...

Pet food, urban agriculture

- High-value applications
- Lower quantities required versus Big Ag applications

Niche applications: aquarium, reptiles

Protix: commercializing in-house brand eggs

Insect-based fish feeds: coming to a fish counter chez vous!!

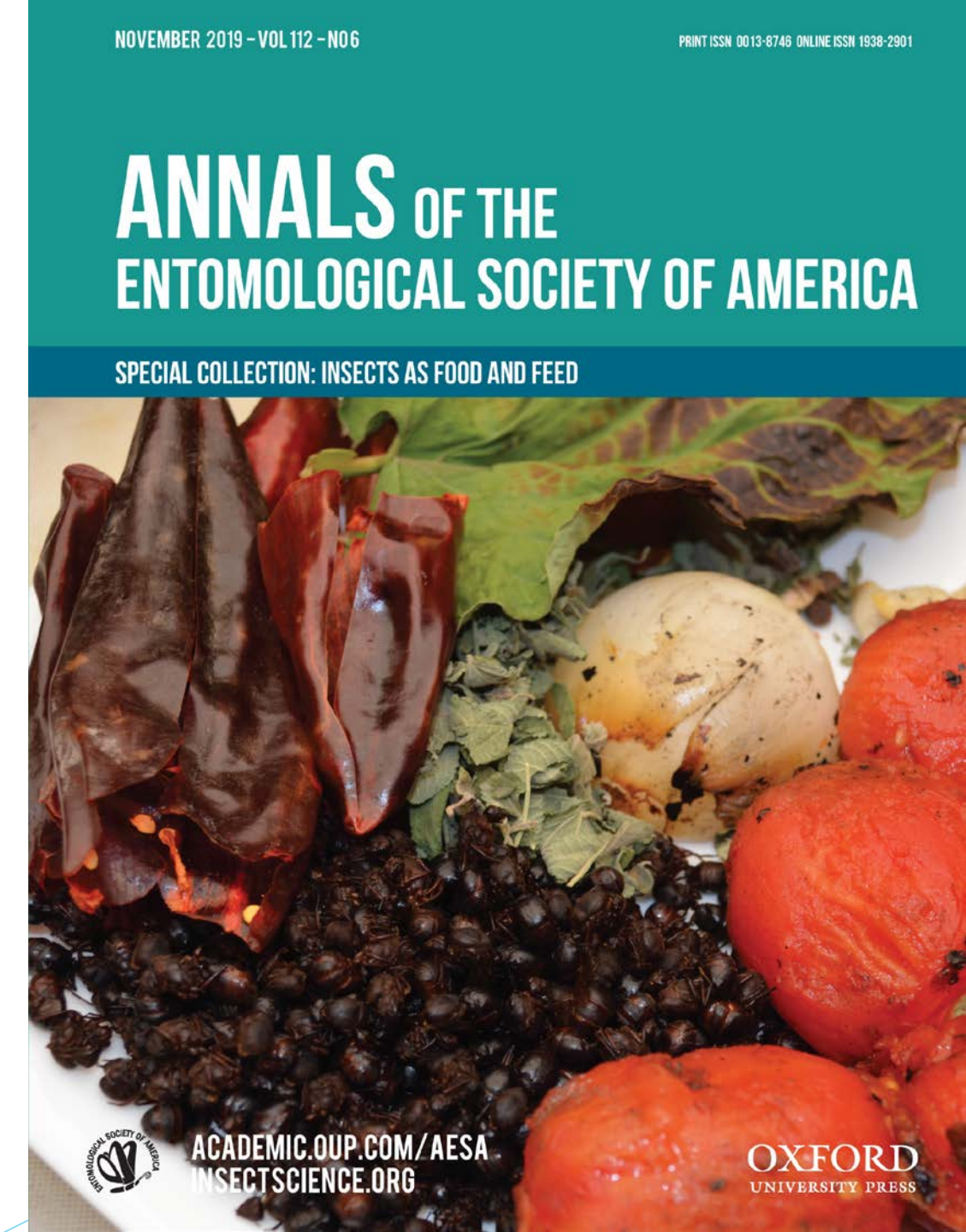
Thanks to our students, collaborators and partners

Fondation
David
Suzuki

Call for collaboration

146 yrs of experience!!

- Developing field needs multidisciplinary teams;
- Insect biology & physiology;
  - Reproduction
  - Nutrition & development
  - Health, disease, pathology
  - Genetic improvement




QUÉBEC CITY, CANADA
INTERNATIONAL CONFERENCE INSECTS TO FEED THE WORLD 2020
A *Rendez-Vous* in Québec City, Canada

Using insect larvae to upcycle waste organic residues to produce novel animal feed ingredients

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