Maximizing performances of *Hermetia illucens* larvae by optimizing protein and carbohydrates content in semi-industrial diets

Jacques de Montigny (1, 2), Chloé Brouzes (1), François-Xavier Boulanger (1)

(1) Agronutris, R&D Department, 18 Rue du Négoce, 31650 Saint-Orens-de-Gameville, France
(2) Université Paris-Saclay, AgroParisTech, 22 place de l'Agronomie, 91120 Palaiseau, France

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 Jacques de Montigny Jacques.demontigny@agronutris.com

To speak the same language…

Acronyms used in this presentation

- P = Protein
- C= Carbohydrates
- C:P = Carbohydrates:Protein ratio
- C+P = Carbohydrates + protein content (expr. as %DM)
- FCR = Feed conversion ratio
- BSFL = Black soldier fly larvae
- DOL = Days-old larvae

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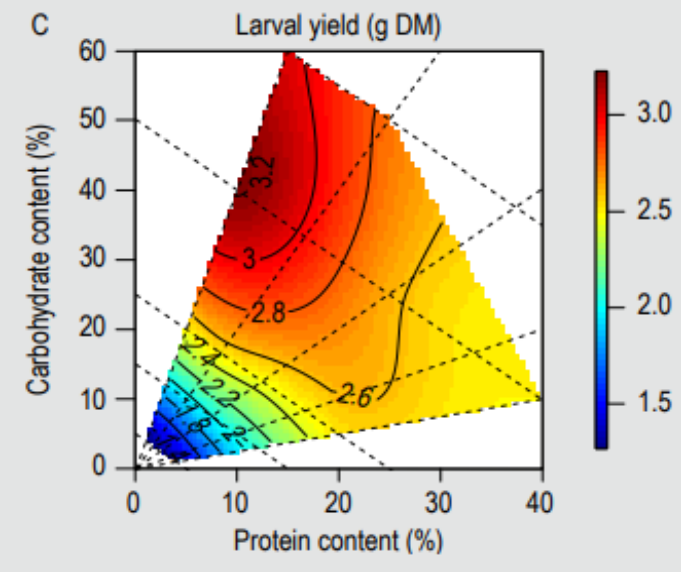
Context. Performances of BSFL vary greatly with P and C content

Barragan-Fonseca et al., 2021

25 artificial diets

Casein (P), starch (C), linseed oil, vitamins, minerals… in cellulose & water.

→ Larval yield x2 with high C+P content

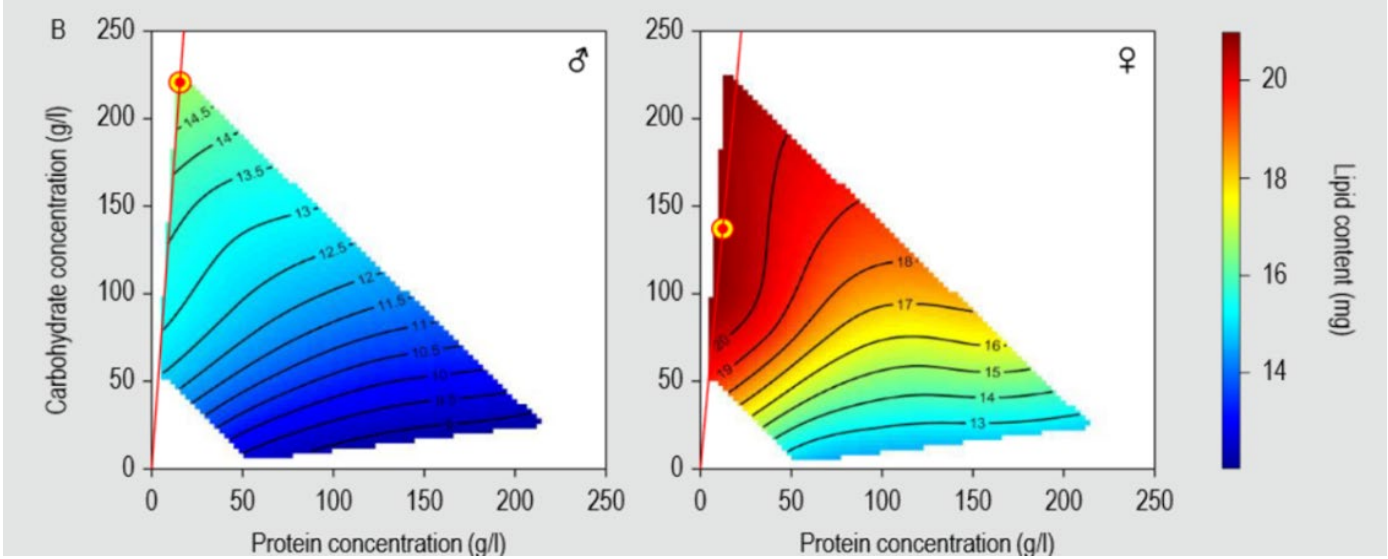


Cheon et al., 2022

32 chemically defined diets

Sodium caseinate (P), sucrose (C), cholesterol, lecithin, vitamins, minerals, … in agar gelled medium.

→ Crude lipid of larvae ↗ with C-biased diet



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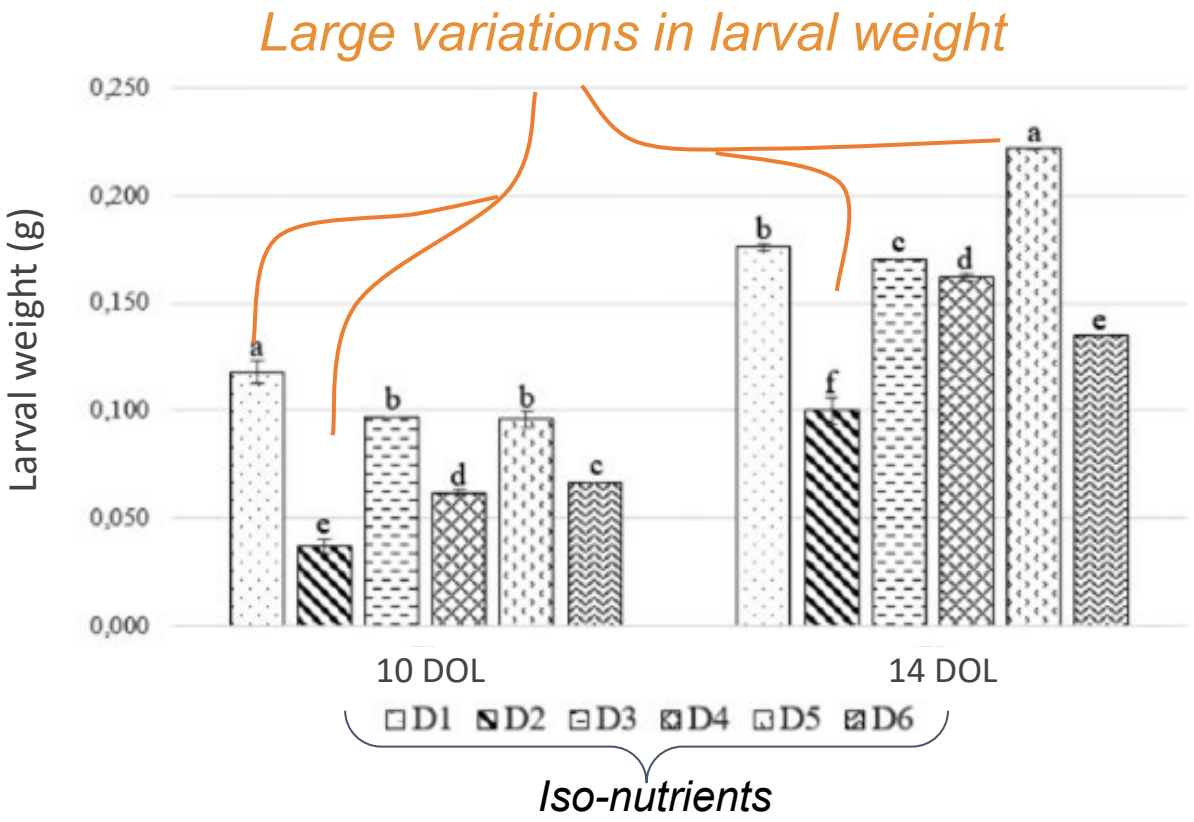
Context. Yet, nutrient content does <u>not</u> explain everything!

Bellezza Oddon et al., 2024.

Test of 6 diets **iso-proteic, iso-lipidic and iso-energetic**, formulated with 21 by-products.



Other factors of influence?

- ash content
- texture
- digestibility
- …

⇒ Need to validate P & C recommendations on by-products used by the insect industry.

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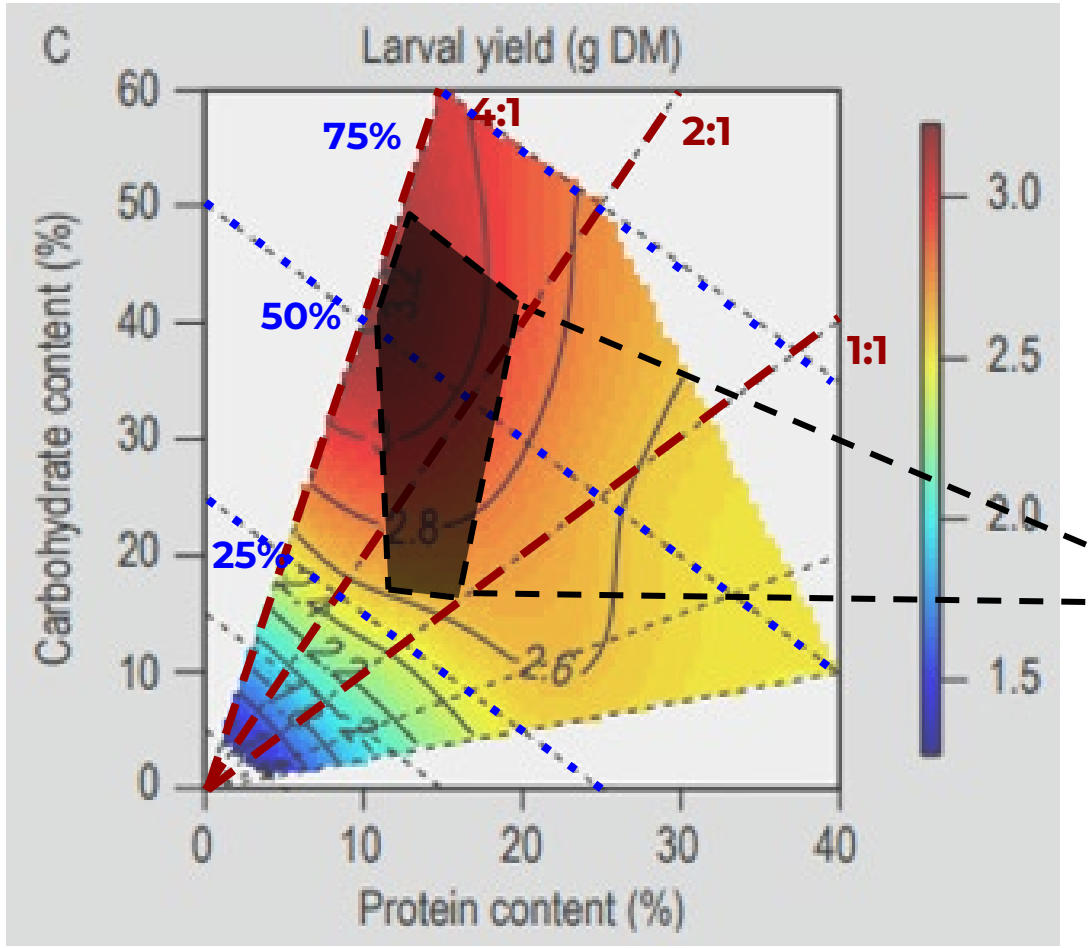
Our question: are nutritional recommendations based on *artificial* diets applicable for *industrial* diets?



Barragan Fonseca et al, 2021

Use of cereals and tubers by-products typical from **North-East of France**.

incl. in 8/17 recipes

Focus on a narrower range of [P] & [C] to confirm and fine-tune optimal balance.

- **C+P** [27 - 56]%DM
- **C:P** [1.2 - 3.9]

> 17 semi-industrial diets formulated

Material & methods. A trial focusing on bioconversion

Planning → Day before → Start trial : 7DOL → End trial : 14 DOL

The end!
14 DOL

Formulation

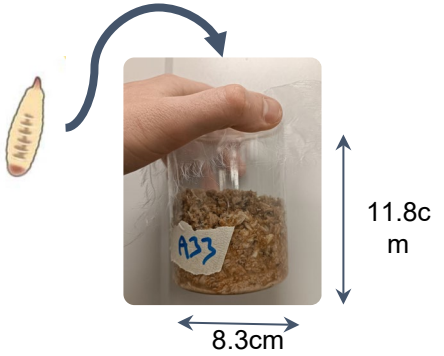
- 16 semi-industrial diets (M1 … M16) + control
- Varied P and C content
- Addition of corn starch for 8 diets

Preparation recipes

- **4 replicates per diet**
- DM = 25.9 ± 1.7%
- Fixed larval density (expr. as larva /g DM)

Start trial

- 7DOL sieved & seeded
- Larvae and diet in pots



Climate chamber

35°C, 40%RH

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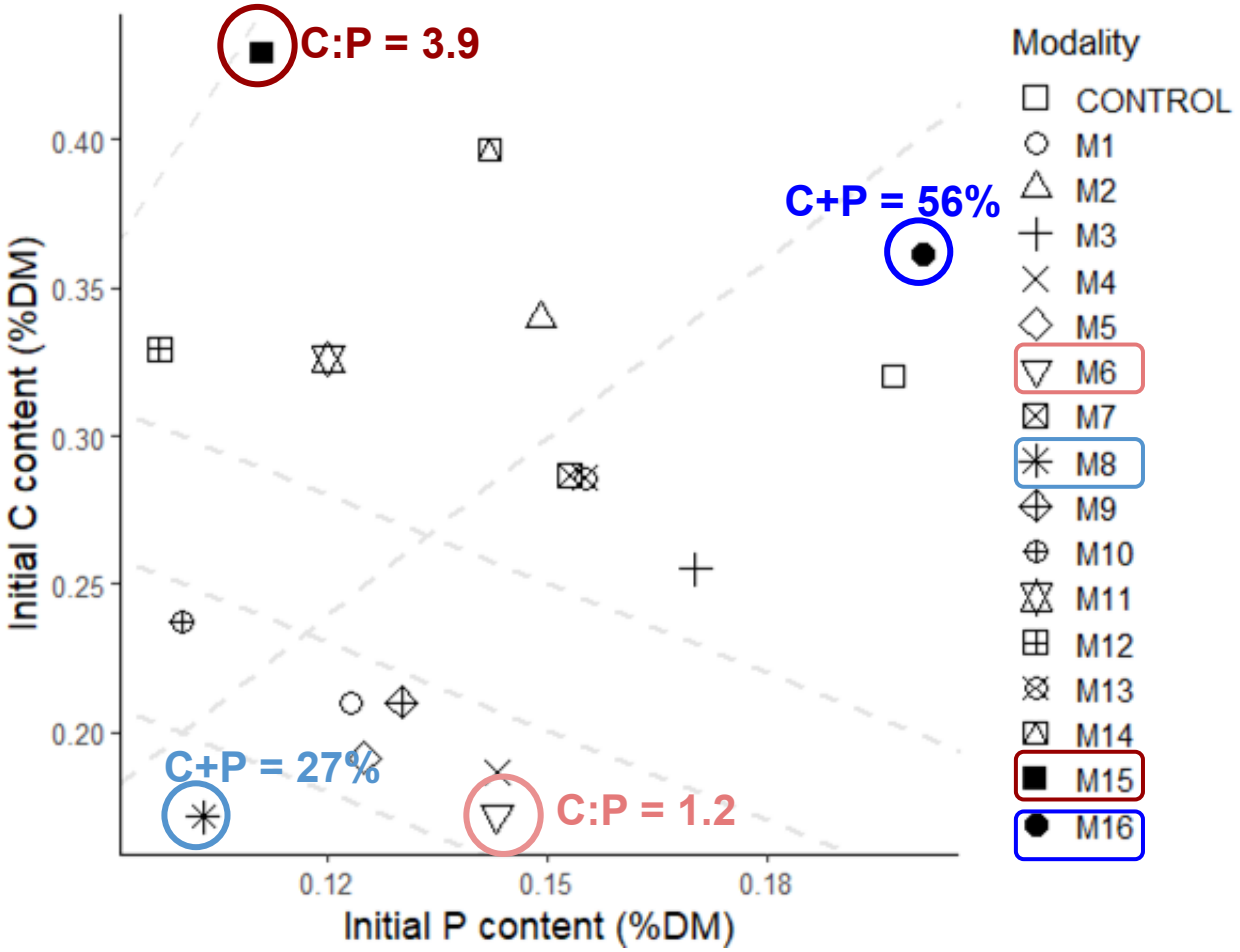
Material & methods.

Composition of the most extreme diets tested



Diet composition **(% DM)**	M6	M8	M15	M16
Wheat soluble	40		16	16
Wheat bran	14	14	40	15
Distillers spent grains	3		4	3
Potato peel	3			3
Mashed potato	9	41		35
Beetroot pulp, wet	27	45		25
Brewery spent grains	4			3
Beetroot pulp, dry			3	
Pea hull			15	
Corn flour			23	
C+P (%DM)	*32*	*27*	*54*	*56*
C:P	***1.2***	*1.8*	***3.9***	*1.8*

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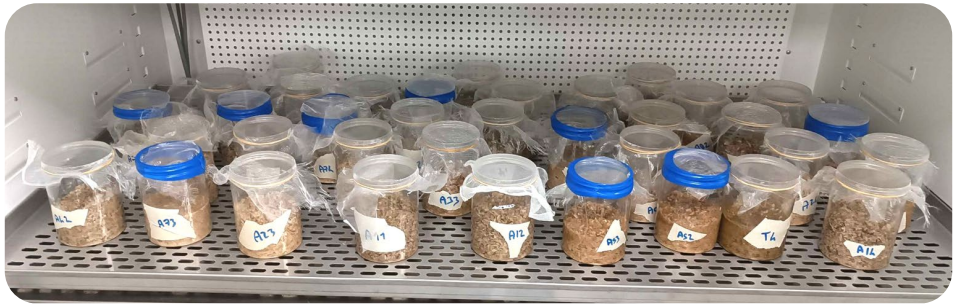
Material & methods. Variables of interest.



Estimation of

- Mass of larvae (7 & 14 DOL)
- Survival rate
- FCR d/d

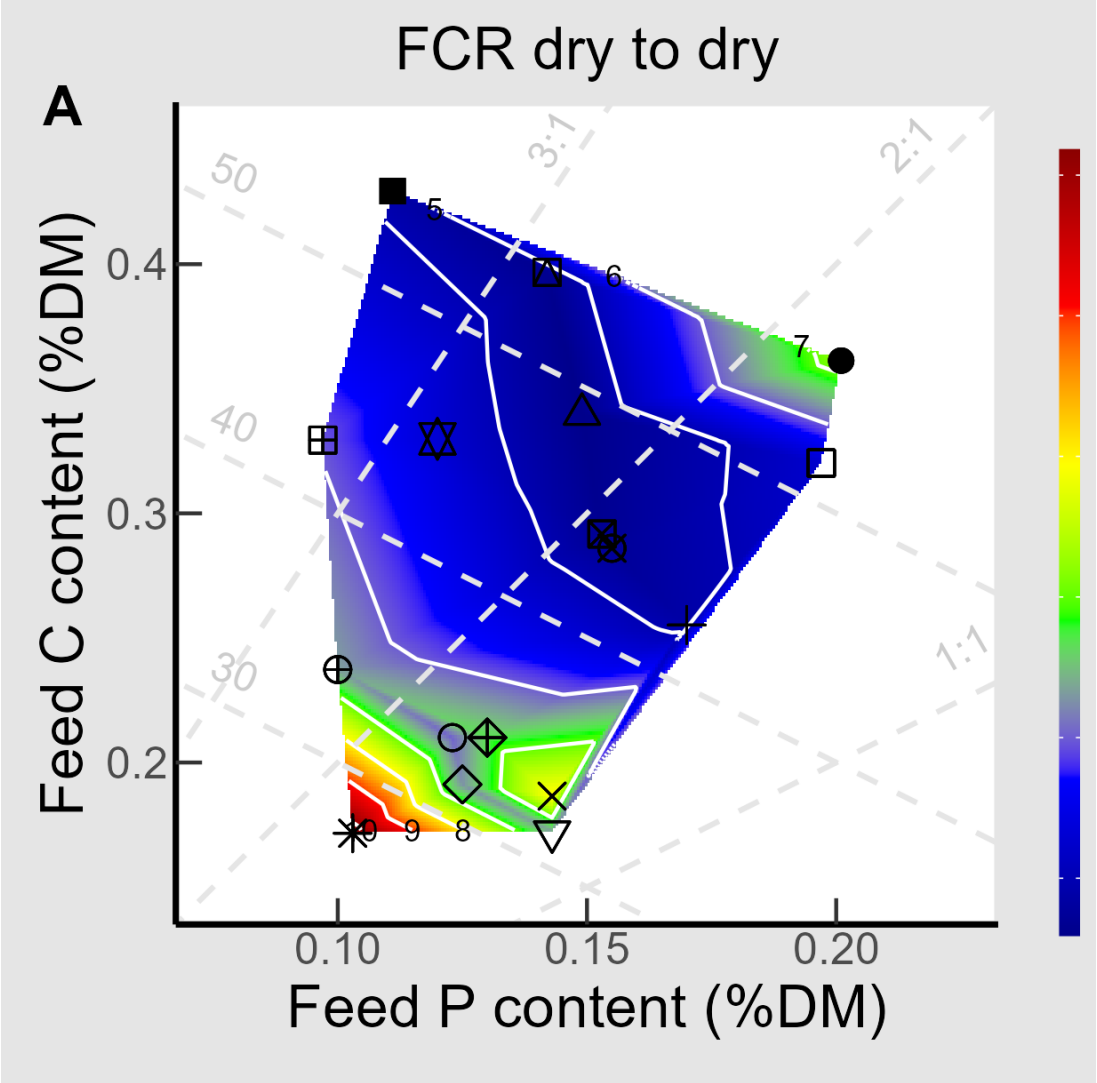
$$FCR\ d/d = \frac{Dry\ feed\ provided}{Dry\ mass\ 14\ DOL - Dry\ mass\ 7DOL}$$

Chemical analysis :

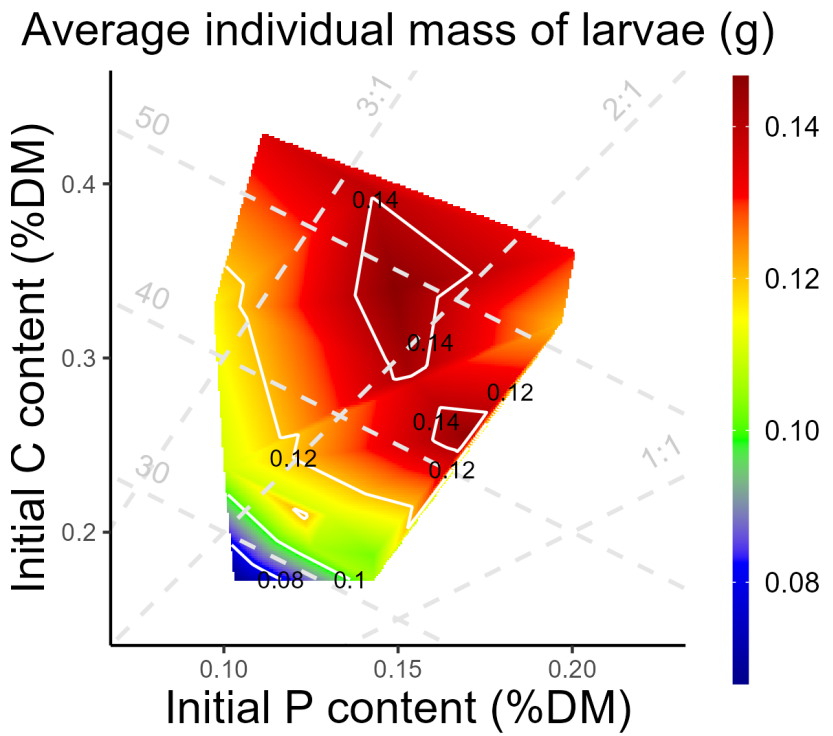
- Nutrient content of initial diets
- Protein, lipid and ash content of larvae
- Nutrients remaining in frass

$$\textbf{Ex}: N\ removal = \frac{N\ in\ feed - N\ in\ frass}{N\ in\ feed}$$

Results. Low FCR were obtained with high C+P (>35%DM) and C:P incl. [1.5 - 3.9].



Related to higher body weight



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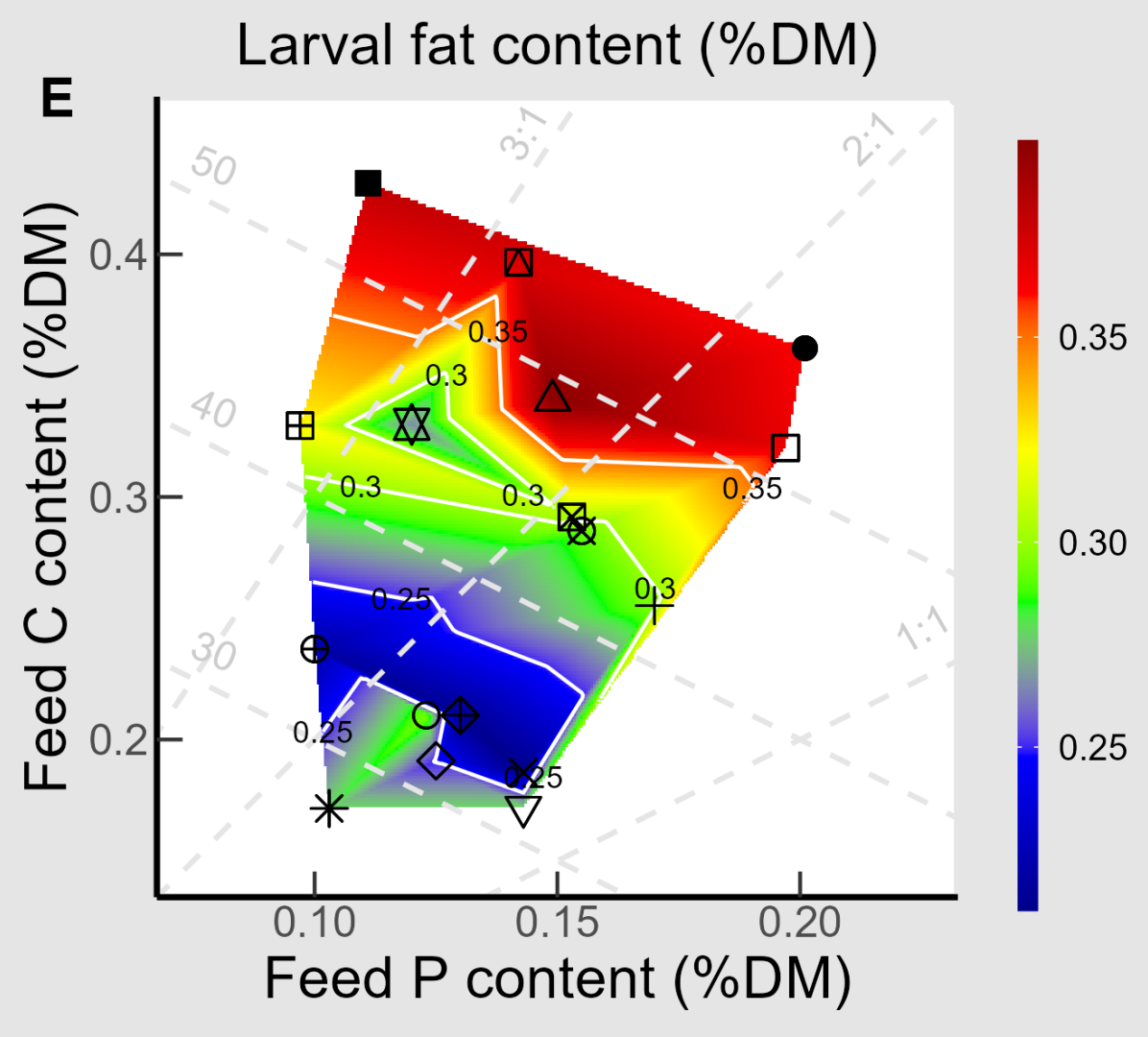
Results. Larval lipid content increases with high C+P

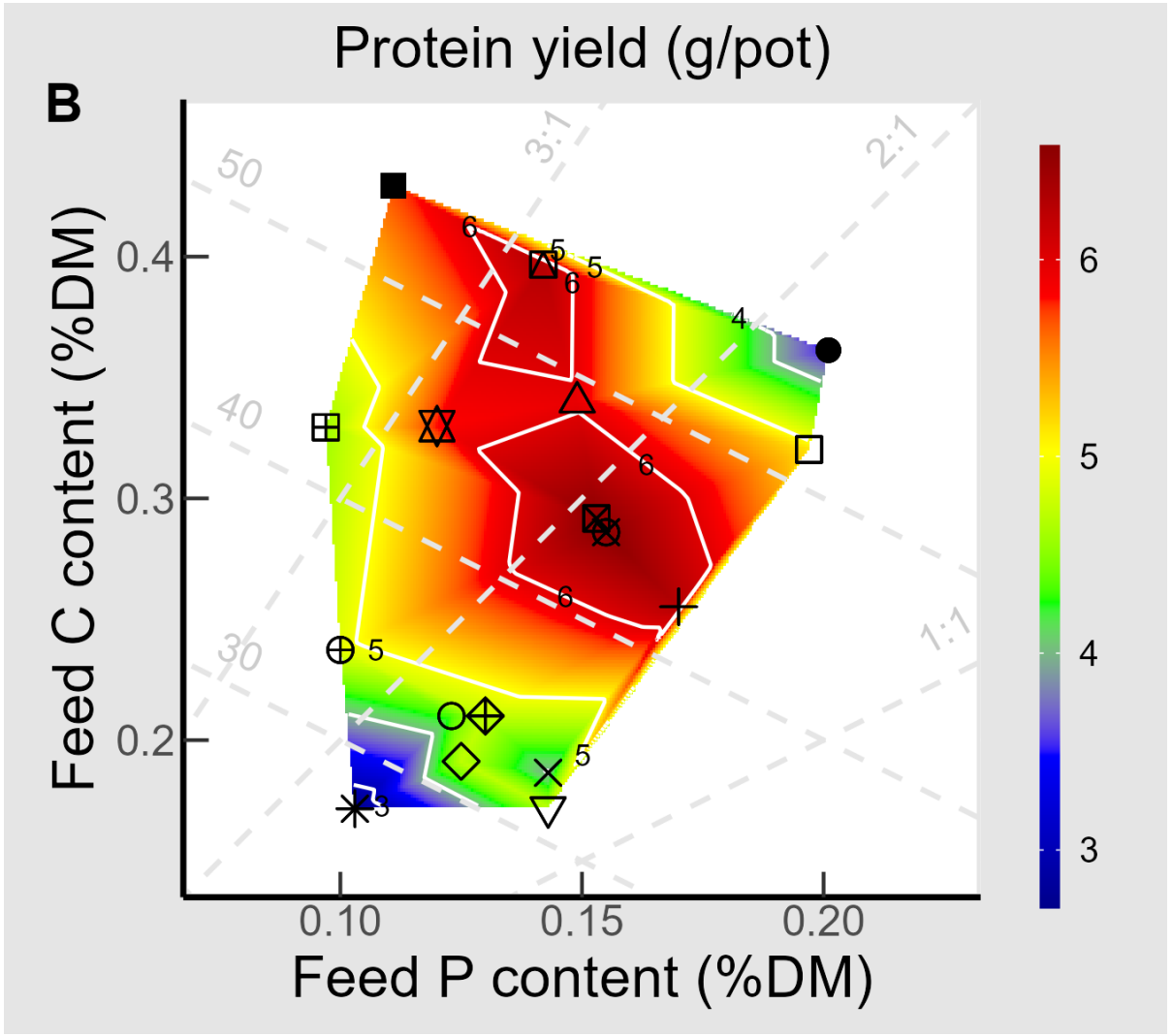
Larvae had >35% fat in DM when C+P> 50%DM and C:P incl. [1.6 - 3.9]

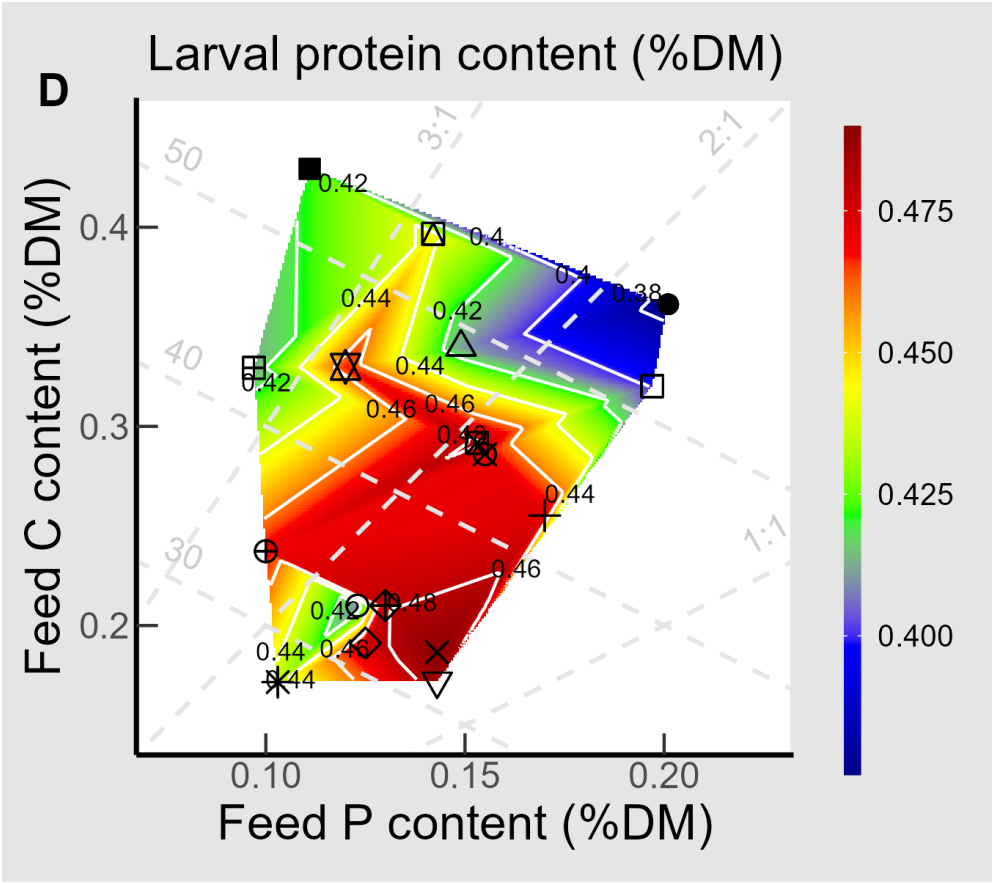


Modality

- CONTROL
- M1
- M2
- M3
- M4
- M5
- M6
- M7
- M8
- M9
- M10
- M11
- M12
- M13
- M14
- M15
- M16

Results. Maximum P yield were obtained on diets with high C+P content (>40%DM), despite lower protein content ⇒ size matters!





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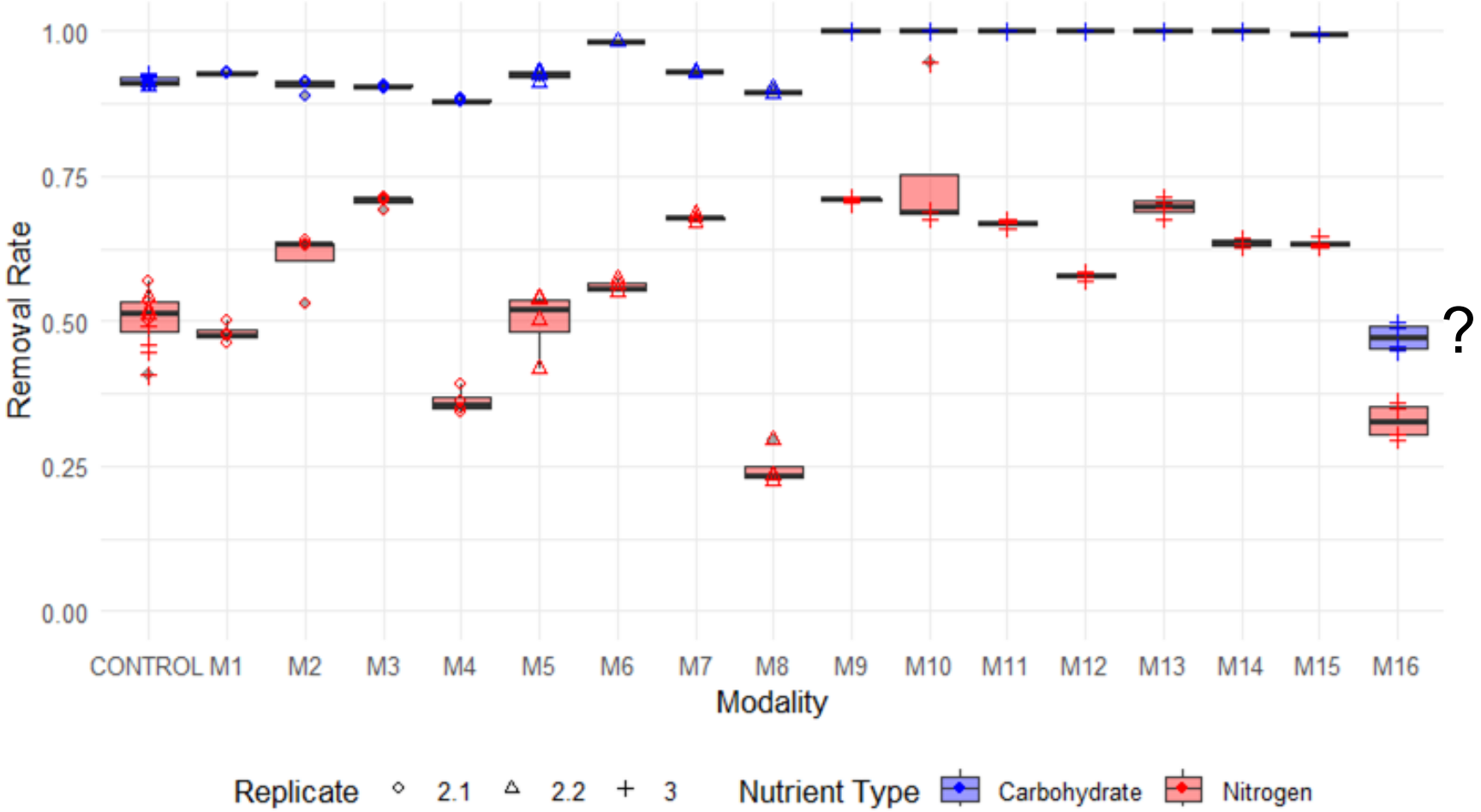
Results. Nutrient removal at the end of the trial.

Raises questions about BSFL (& microbes) metabolism



Most of carbohydrates were removed in all diets, except M16 (= diet with highest C+P and 35% incl. of mashed potato).

Nitrogen removal was lower, with larger variability across diets (25-70%)

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Strengths & limitations

- ★ **Test of 10 potential industrial diets and 7 semi-industrial diets (= incl. corn flour)**
- ★ **Test of nutrient content as varied as possible**
- ★ **Analysis of nutrient removal in frass**

- ❑ **Chemical analysis of diets, frass and larvae : 1 per modality**
- ❑ **Remaining nitrogen: from urea, NH4+, protein …?**
- ❑ **Validation at large scale needed**

Take-home messages

1. **High C+P content (>40%DM)** results in **lower FCRd/d** → *confirmed for industrial scenarios in NE of France*
2. Higher **protein yield** comes along with higher **lipid yield**
3. **No clear effect of C:P with the ratio tested in this study** (only C-biased diets)

Perspectives

- Estimate **digestibility** of P and C in each raw materials (cf Guillaume et al., 2023)
- Investigate further **macronutrient needs** of BSFL: (simple vs complex sugars, amino acid needs…)
- Role of **texture, fibre, ash, …** on larval performances?

Thank you!

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Raise and rise together

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References

Barragan-Fonseca, K. B., Gort, G., Dicke, M., & Van Loon, J. J. A. (2021). Nutritional plasticity of the black soldier fly (Hermetia illucens) in response to artificial diets varying in protein and carbohydrate concentrations. *Journal of Insects as Food and Feed*, *7*(1), 51-61.

Cheon, D. A., Jang, T., & Lee, K. P. (2022). Visualising the nutritional performance landscapes for the black soldier fly, Hermetia illucens (Diptera: Stratiomyidae). *Journal of Insects as Food and Feed*, *8*(5), 481-493.

Bellezza Oddon, S., Biasato, I., & Gasco, L. (2022). Isoenergetic-practical and semi-purified diets for protein requirement determination in Hermetia illucens larvae: consequences on life history traits. *Journal of Animal Science and Biotechnology*, *13*(1), 17.

Bellezza Oddon, S., Biasato, I., Resconi, A., & Gasco, L. (2024). Black soldier fly life history traits can be influenced by isonutrient-waste-based diets. *Italian Journal of Animal Science*, *23*(1), 331-341.

Guillaume, J. B., Mezdour, S., Marion-Poll, F., Terrol, C., & Schmidely, P. (2023). Asymptotic estimated digestibility, a new indicator of black soldier fly (Hermetia illucens) conversion efficiency in relation to larval density. *Journal of Insects as Food and Feed*, *9*(7), 893-906.

BACK UP SLIDES

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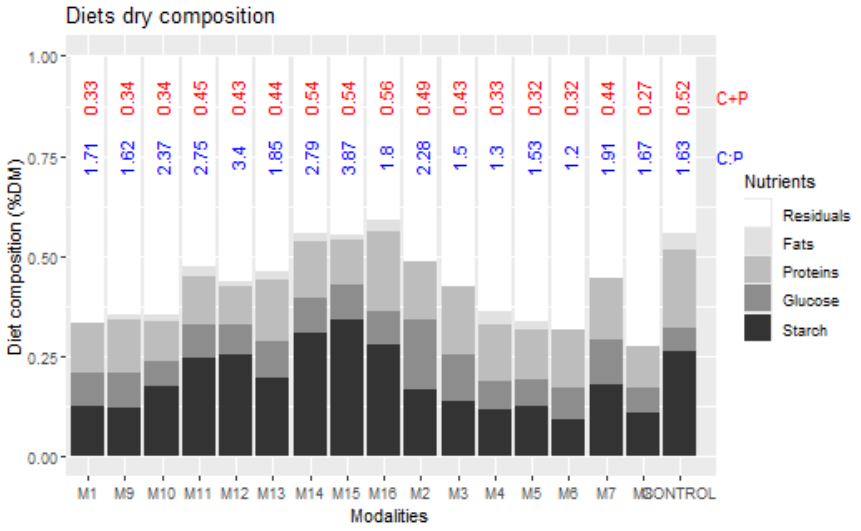
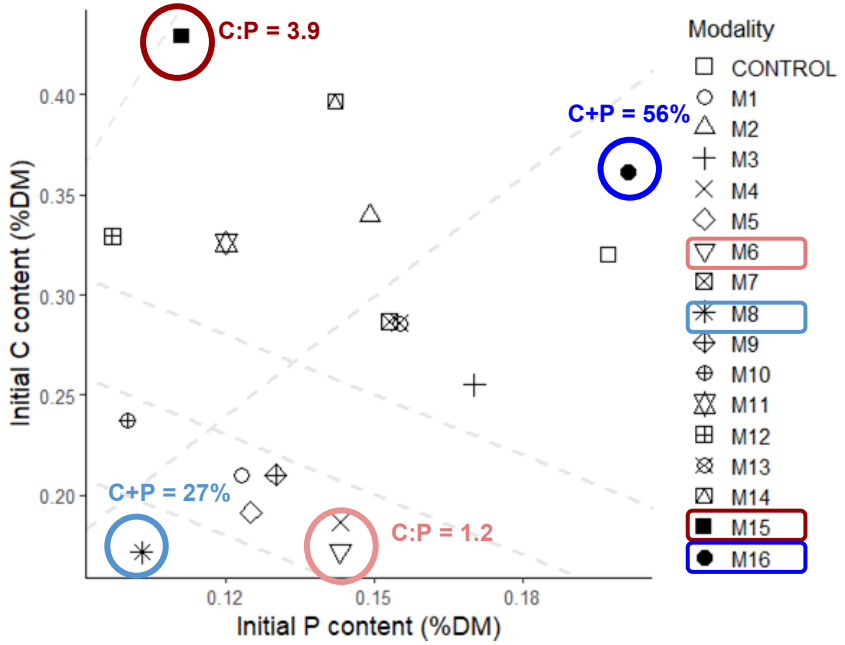
Material & methods. Composition of the diets tested

Diet	*M1*	*M2*	*M3*	*M4*	*M5*	*M6*	*M7*	*M8*	*M9*	*M10*	*M11*	*M12*	*M13*	*M14*	*M15*	*M16*	*CONTROL*
Initial C (% DM)	21	34	26	19	19	17	29	17	21	24	33	33	29	40	43	36	32
Initial P (%DM)	12	15	17	14	13	14	15	10	13	10	12	10	16	14	11	20	20
C+P (%DM)	33	49	43	33	32	32	44	27	34	34	45	43	44	54	54	56	52
C:P	1,7	2,3	1,5	1,3	1,5	1,2	1,9	1,7	1,6	2,4	2,7	3,4	1,8	2,8	3,9	1,8	1,6

C+P [27 - 56]%DM



C:P [1.2 - 3.9]



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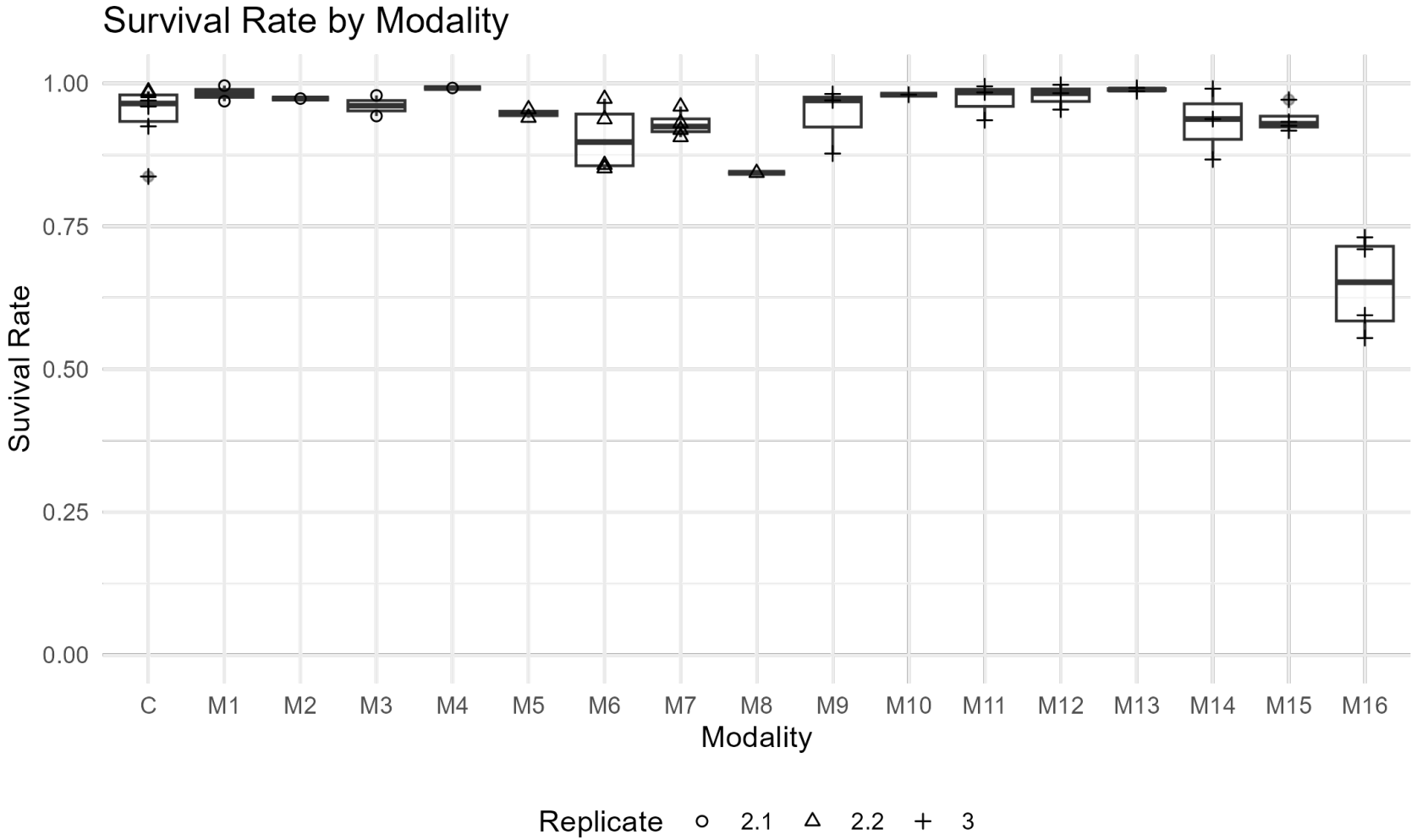
Material & methods. Composition of the diets tested

Diet (% DM)	M1	M2	M3	M4	M5	**M6**	M7	**M8**	M9	M10	M11	M12	M13	M14	**M15**	**M16**
Wheat soluble	16	33	32	21	19	**40**	10		16	10	12	16	16	16	**16**	**16**
Wheat bran	15	15	20	20	15	**14**	15	**14**	35	15	40	16	40	40	**40**	**15**
Distillers spent grains	3	6	15	8	3	**3**	15		3	3	4	3	16	14	**4**	**3**
Potato peel	3	3	15	15	9	**3**	10									**3**
Potato purée	35	35	3	3	21	**9**	35	**41**								**35**
Beetroot pulp, wet	25	3	7	25	25	**27**	7	**45**								**25**
Brewery spent grains	3	5	8	8	8	**4**	8									**3**
Beetroot pulp, dry									12	3	3	13	3	3	**3**	
Pea hull									34	58	30	30	19	8	**15**	
Corn flour										11	12	21	5	19	**23**	

Survival rate



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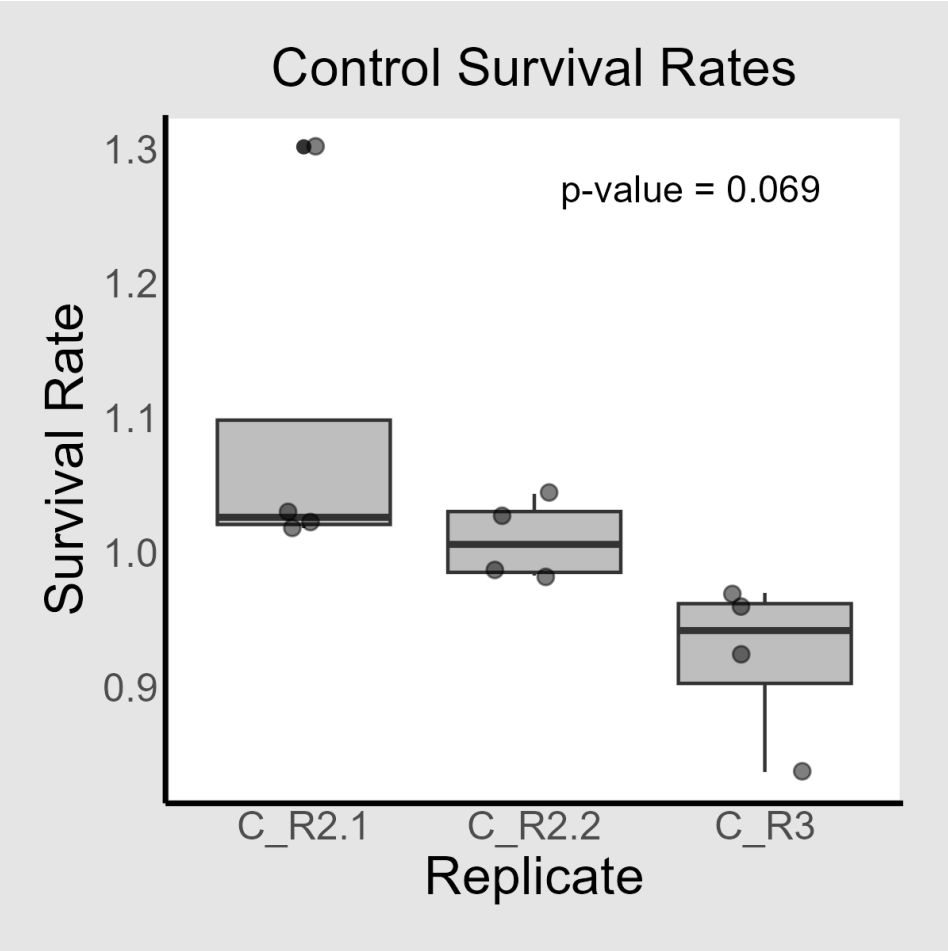
Survival rate



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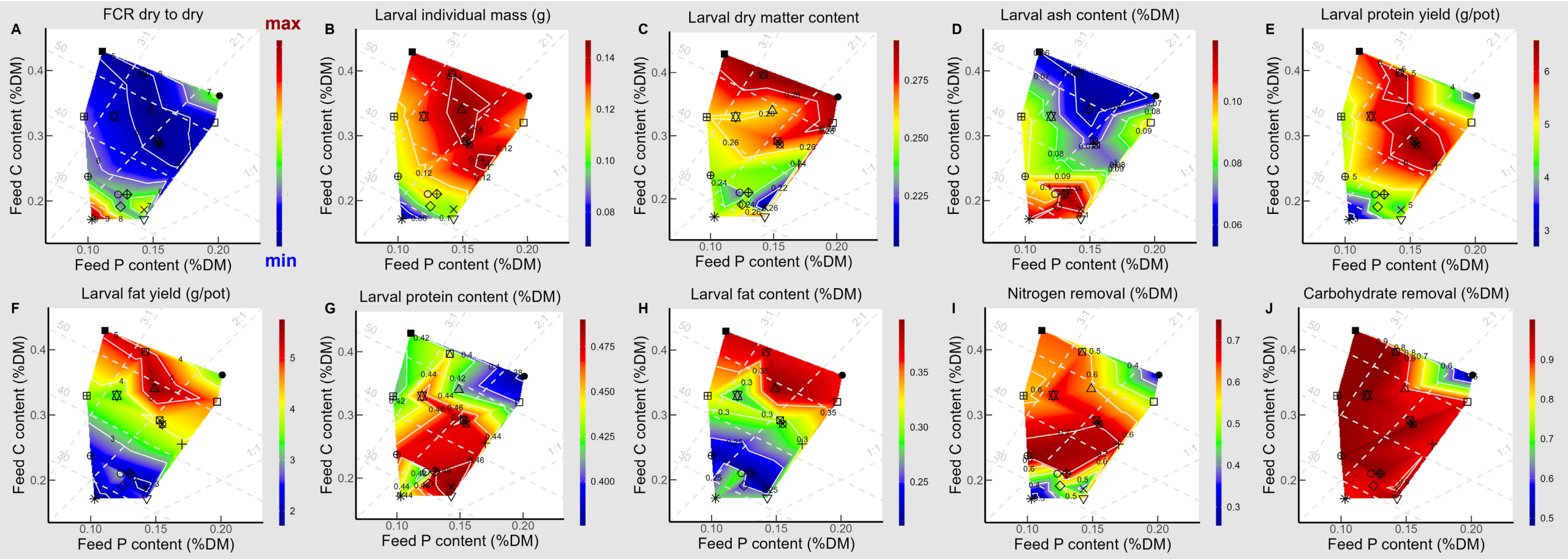
Results. X= Feed proteins content (%DM) & Y= Feed carbohydrates content (%DM)



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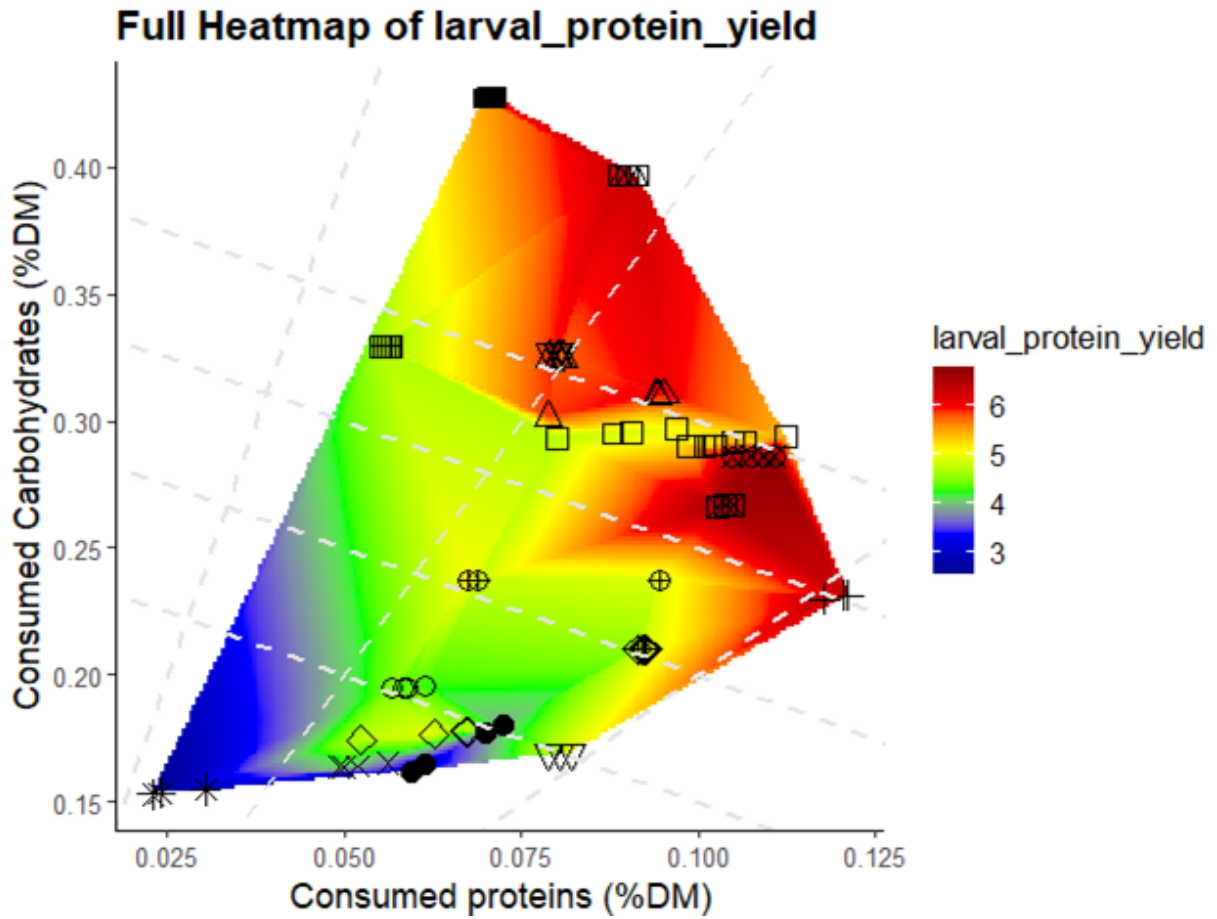
Protein yield, taking into account nutrient removal



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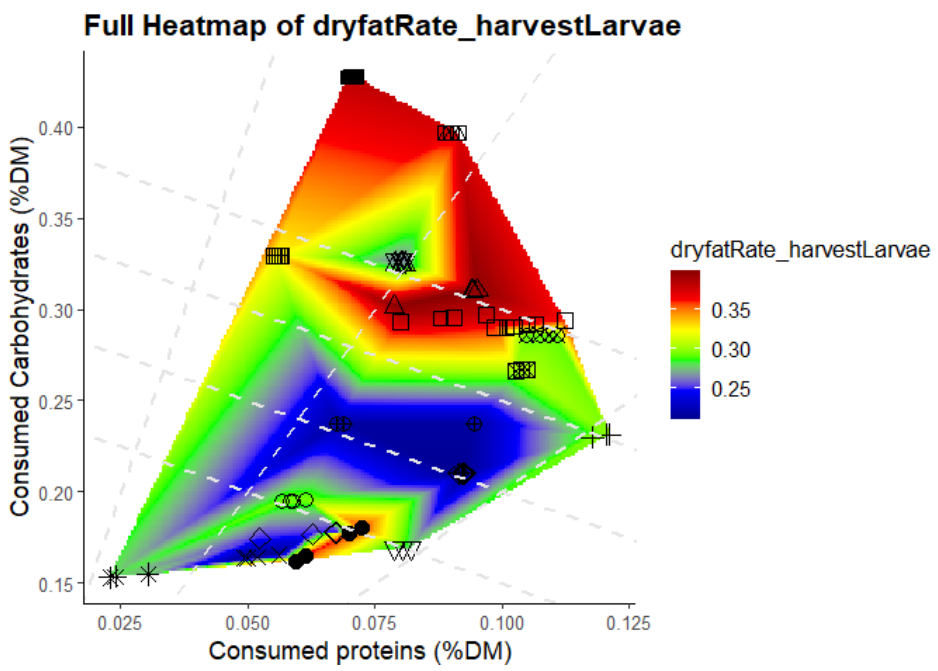
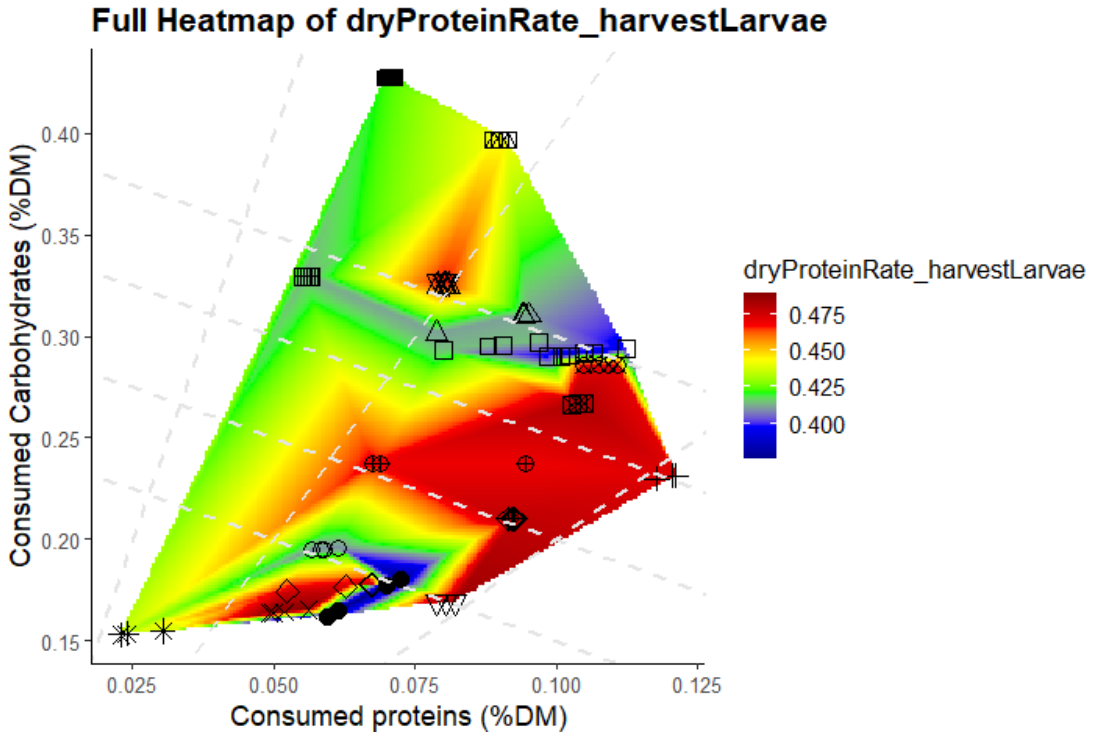
Fat and protein content of larvae, considering nutrient removal





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