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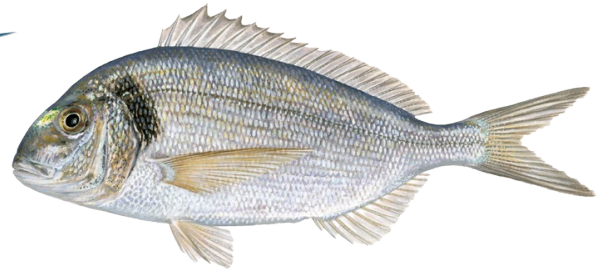

UNIVERSITÀ DEGLI STUDI DI PADOVA

Environmental impact of the inclusion of alternative raw materials in diets for gilthead seabream

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GAB Grupo de Acuicultura y Biodiversidad

75th Annual Meeting of the EAAP - Florence, Italy, 2024 - Section: Advances in fish nutrition

Alternative protein meals in aquafeeds

Vegetable proteins

Pea meal

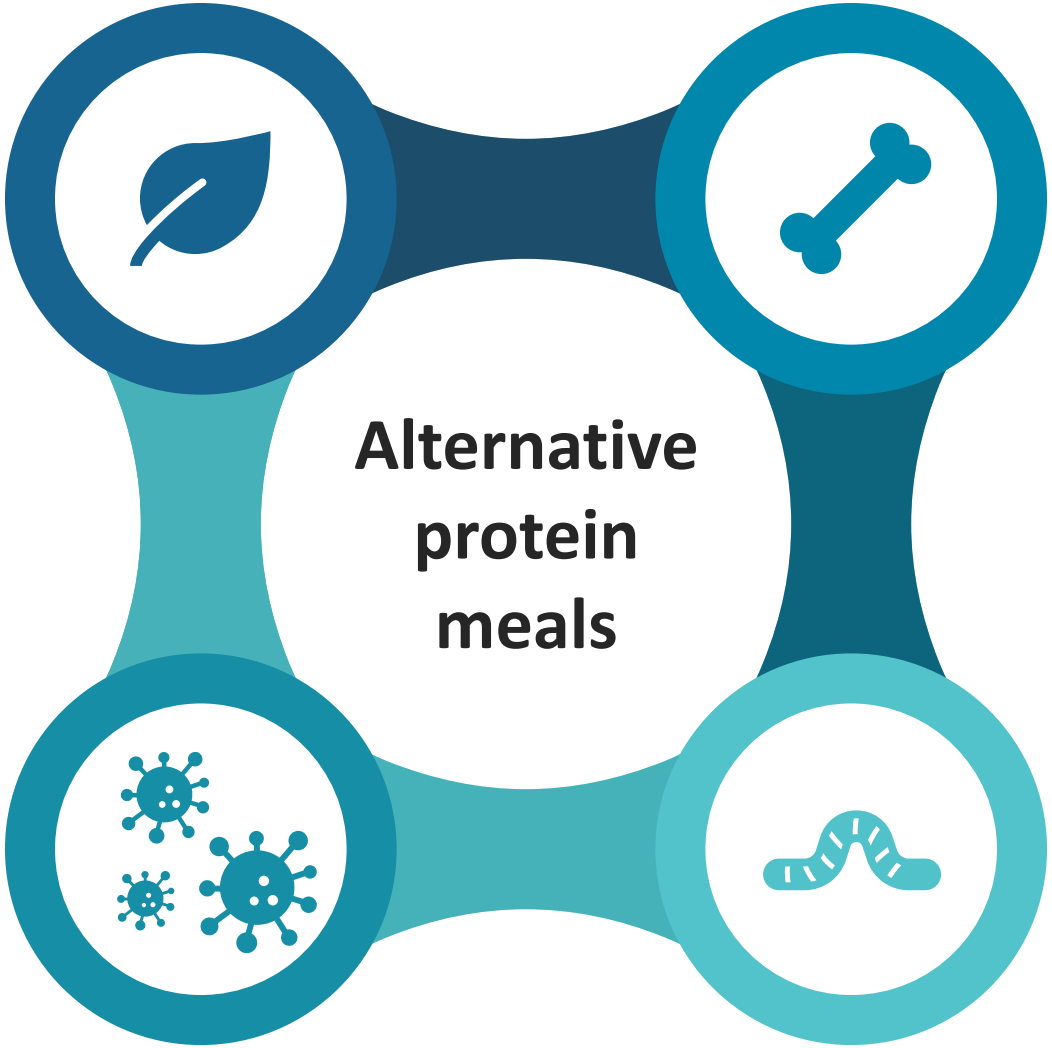
Rapeseed meal

Sunflower meal

Terrestrial/marine intensive cultures

Bacterial proteins

Algae meals



Rendered by-products

Poultry/pig by-product meal

Hydrolyzed feather meal

Blood meal (pig, poultry)

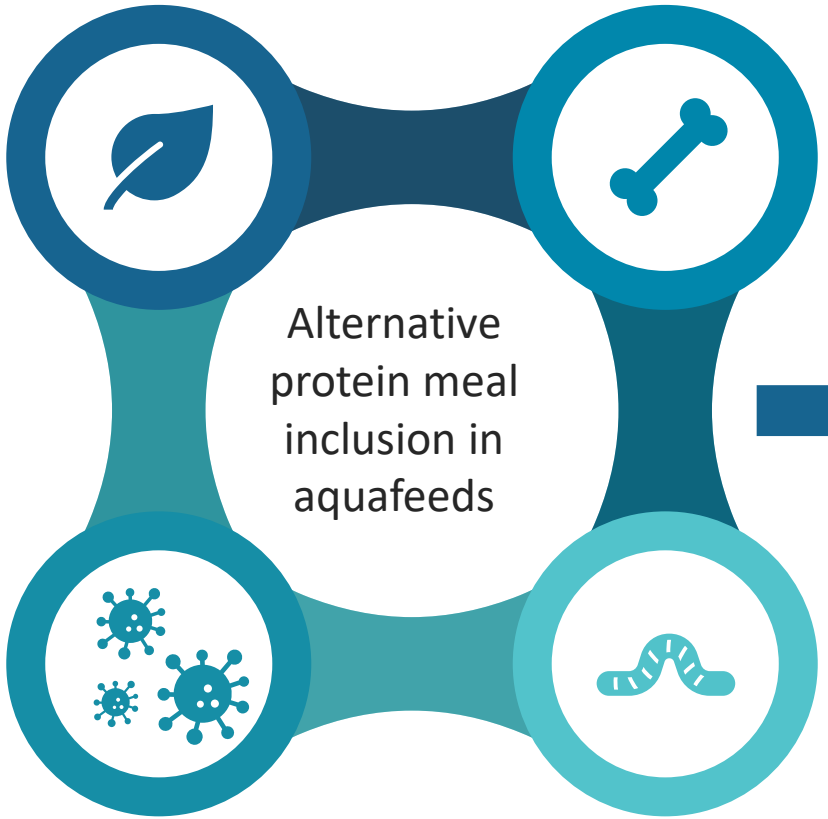
Insect meals

Black soldier fly larvae

Mealworm

Cricket

Environmental impact of aquafeeds including alternative meals



Environmentally sustainable?

FEW STUDIES

Maiolo et al., 2020; 2021

McKuin et al., 2023

Berton et al., 2023

Bordignon et al., 2023; 2024

FEW PRIMARY DATA

about the impact of ingredient production from research trials and production plants

LACK OF EMISSION FACTORS

from public databases related to alternative ingredients

Aims

To evaluate the effects of the inclusion of two alternative protein meals in replacement of fishmeal and vegetable proteins in diets for seabream:

1

Iberian pig by-product meal

10% of total Spanish pig production

Organic production → by-product meals interesting ingredients for organic aquafeeds

2

Microalgae meal *(I. galbana)*

High digestibility in seabream (Palmegiano et al., 2009)

Rich in bioactive compounds (Bonfanti et al., 2018)

- Fish **growth** performance and **feed conversion**
- **Environmental footprint** of the production of the **alternative protein meals**
- **Environmental footprint of the feeds** including the alternative meals at different levels

Experimental diets

Ingredients (alternative meals) (g kg^{-1} as fed)

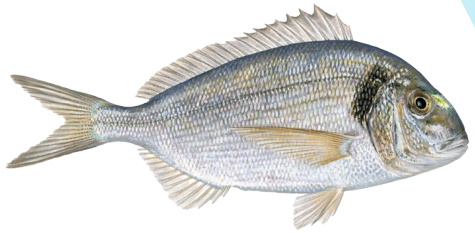
	FM100	FM25	FM10	FM0	FM0+
Fishmeal	590	150	60	-	-
Wheat meal	259	56	14	-	-
Soybean meal	-	171	206	220	206
Pea meal	-	101	122	129	111
Sunflower meal	-	101	122	129	111
Iberian pig meal	-	237	288	328	328
Microalgae *(I. galbana)*	-	-	-	-	50
Others*	151	184	188	194	194

Proximate composition

	FM100	FM25	FM10	FM0	FM0+
Fat, %DM	19.9	19.1	18.7	18.8	19.5
Protein, %DM	47.2	46.5	47.1	47.0	46.0
Gross energy (MJ kg^{-1})	21.8	23.3	23.3	23.7	23.5
Price (€/kg)	1.93	1.74	1.69	1.67	3.52

*Other ingredients: **Fish oil** (45-100 g kg^{-1}), **Soybean meal** (41-96 g kg^{-1}), DL-Methionine, calcium phosphate, vitamin and mineral premix

Experimental trial and results



P<0.05

	FM100	FM25	FM10	FM0	FM0+
Specific growth rate (% d^{-1})	1.4^{c}	1.2^{cb}	1.1^{b}	0.8^{a}	1.2^{b}
Feed intake (g 100 g $fish^{-1}$ day^{-1})	1.8	1.6	1.7	1.7	1.7
Protein efficiency ratio	1.6^{b}	1.6^{b}	1.4^{ab}	1.1^{a}	1.5^{b}
Condition factor	2.1^{c}	1.9^{ab}	1.8^{ab}	1.7^{a}	1.9^{b}

Experimental trial setup:

360 seabream (64 ± 1.3 g)
- 15 RAS tanks (3 tanks/diet)
- 24 fish/tank
- Trial lasted 88 days
- Fed twice a day to satiation

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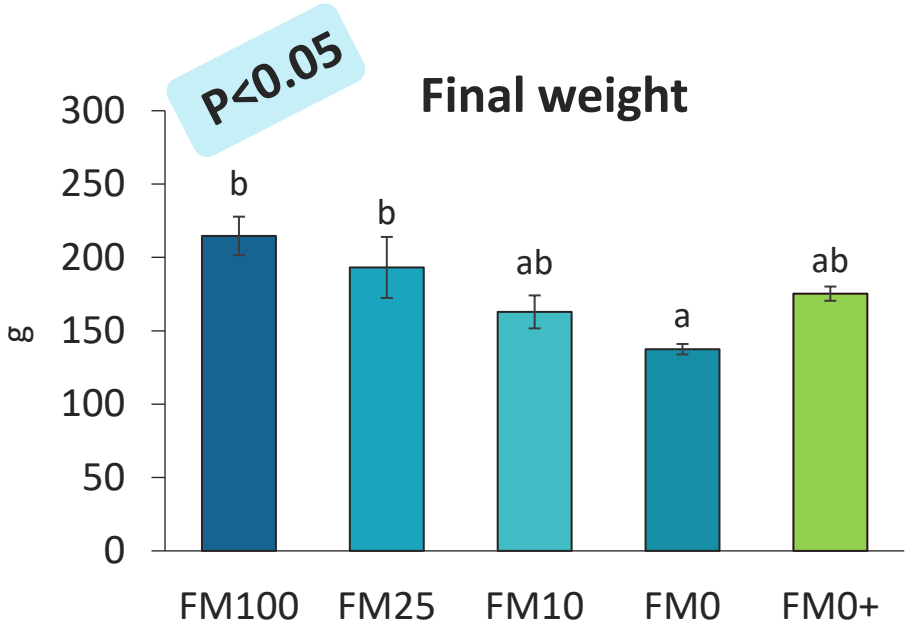
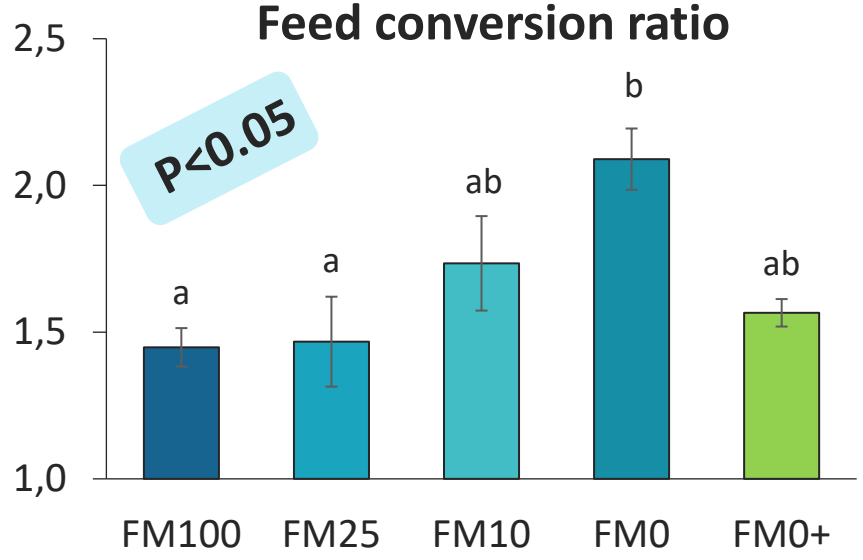
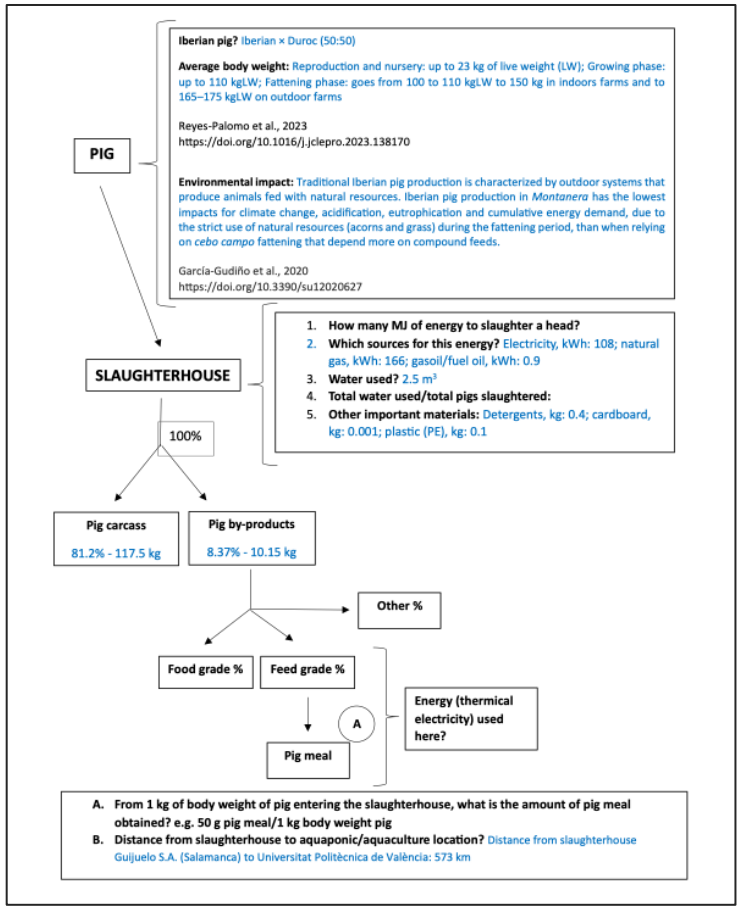




Primary data: production of the alternative protein meals

Example of the interview sheets used to collect data about Iberian pig production (rearing and processing) and microalgae production



Iberian pig meal

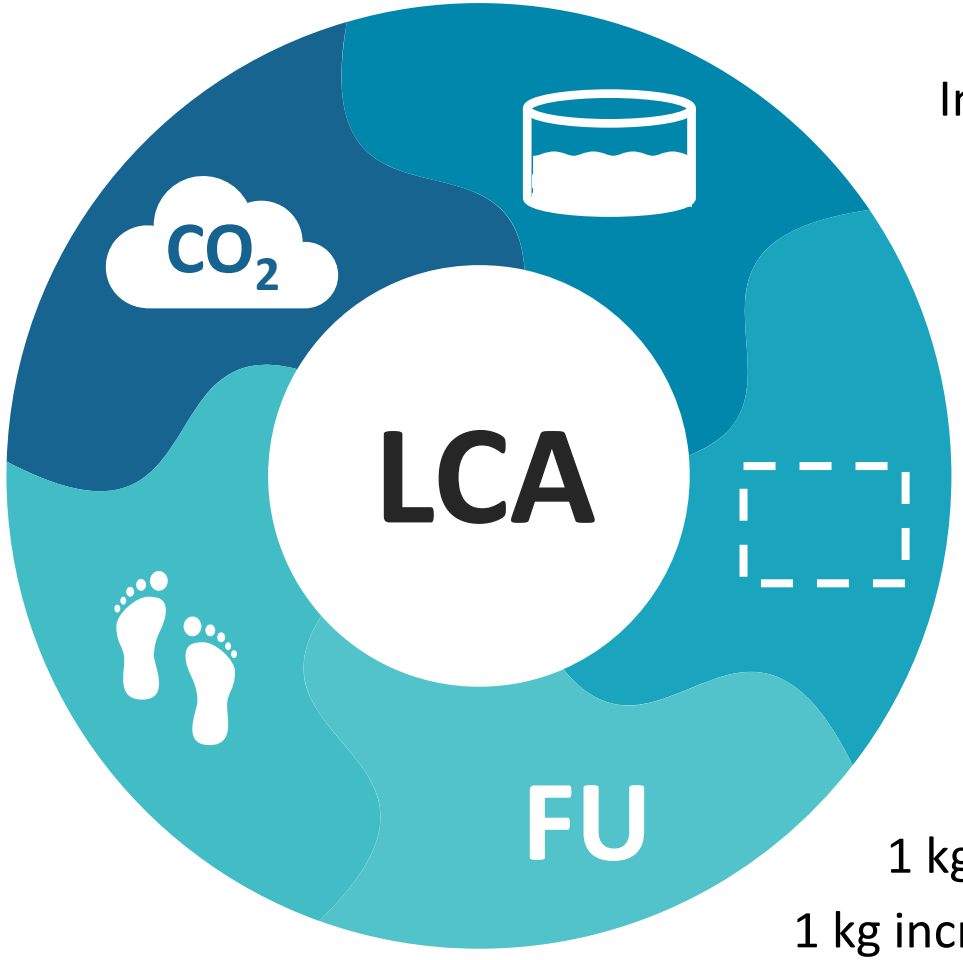
Production data per production cycle, as average (or per average day or per average year)

Item	Unit	Value	Notes
Water	Liters (or m^3)	3 m^3	seawater
Nutrients added into the water			
$NaHCO_3$	kg	0 $g \cdot L^{-1}$	No needed
$NaNO_3$	kg	12 mM	Fertilizer
K_2SO_4	kg	5.74 mM	Fertilizer
NaCl	kg	0	No needed
KH_2PO_4	kg	0.37 mM	Fertilizer
$MgSO_4$	kg	0.2 mM	Fertilizer
EDTA·Na_2·$2H_2O$	kg	12.1 µM	Fertilizer
others			$FeCl_3$ (0.01–0.06 mM), NaH_2PO_4 (0.08–0.43 mM), trace metals (1 mL), vitamins B1 (1°mg°L^{-1}) and B12 (0.05°mg°L^{-1})
CO_2 for microalgae rearing	kg (or Liters or m^3)	On-demand pure CO_2 at 3 l min^{-1}	In total 2.5 kgCO2 /kg biomass
Flocculants (if use)	kg	0	NO, direct centrifugation
Electricity, from grid	kWh	10 kWh/kg	Electricity
Electricity, from local photovoltaic plant	kWh	0	Not used
Heat	MJ	0	Not used
Heat source (natural gas, fuel, ….)			Not used
Harvested microalgae, wet	kg	10 kgwet/kg dry	
Harvested microalgae, dried	kg	3.8 t/year	The biomass is harvested and concentrated by centrifugation daily in continuous mode, then is freeze-dried to obtain dry biomass

Production of microalgae (*I. galbana*)

LCA analysis

Comparative life cycle assessment



REFERENCE UNIT

Ingredient production (ingredients)
RAS farming system (feeds)

SYSTEM BOUNDARIES

From feed ingredient production to gilthead seabream (about 200 g) leaving the system

EMISSION FACTORS

Alternative protein meals: Calculated from collected primary data

Other ingredients in the feeds
Databases: Ecoinvent, Agrobalyse and Agri-footprint

FUNCTIONAL UNITS

1 kg dry weight alternative ingredient

1 kg increase of gilthead seabream (feeds)

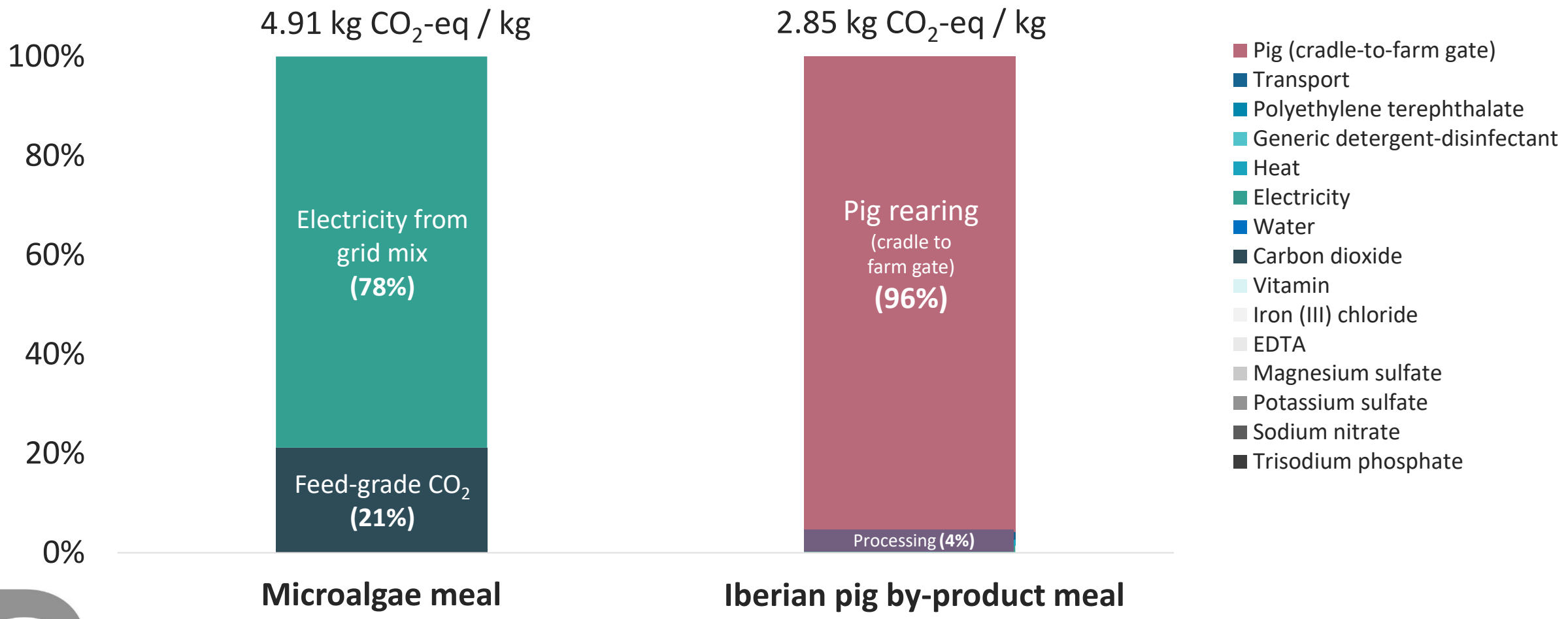
Impact categories

Preliminary evaluation
(presented here)
considering only global warming potential

In progress:
Comprehensive evaluation of the environmental footprint of the selected feeds considering other impact categories

Environmental impact of the alternative protein meals

Global warming potential computed for Iberian pig meal and microalgae (1 kg dry weight)



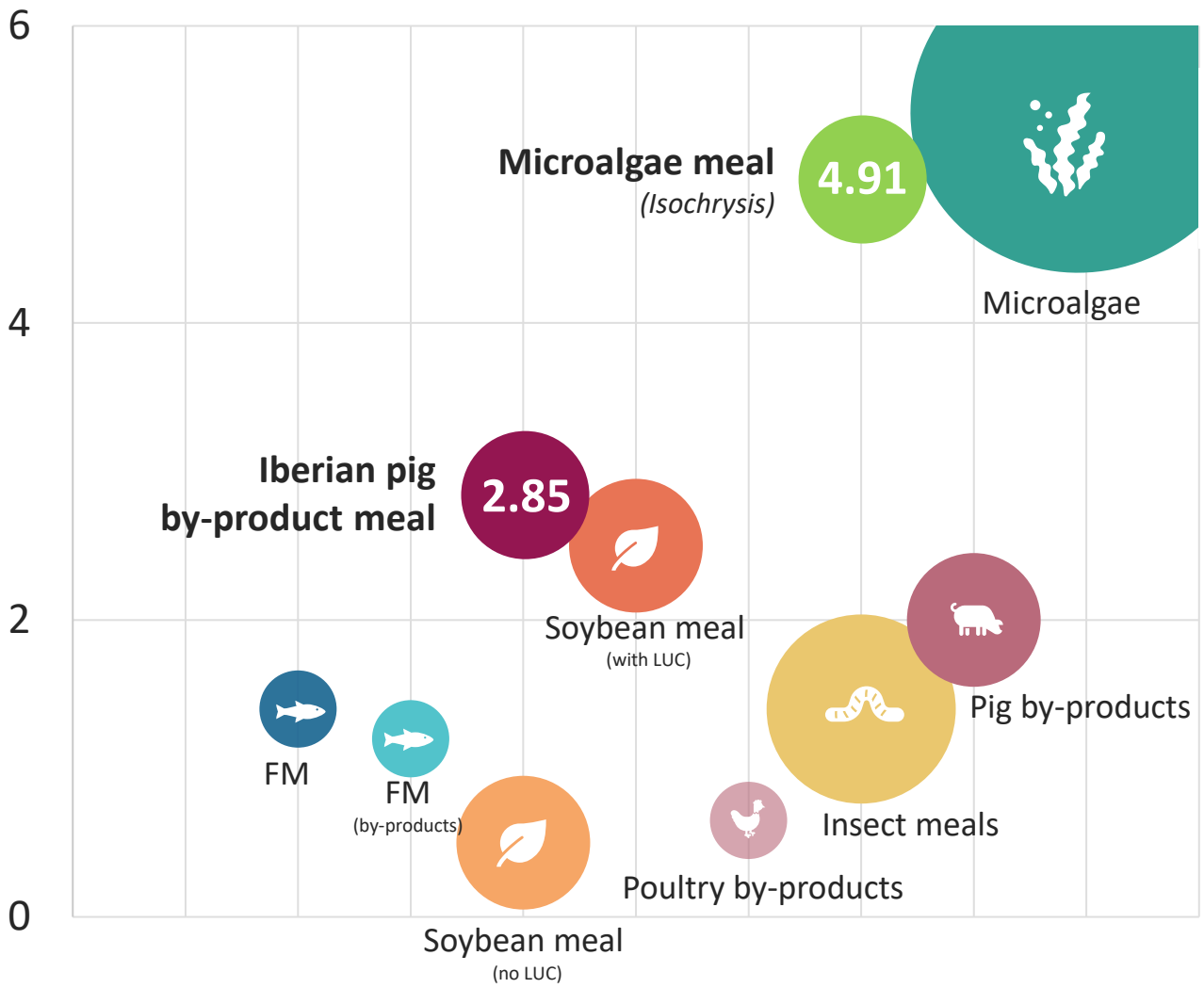
Environmental impact of the alternative protein meals

Comparison with other protein meals

(Kg CO_2-eq / kg dry weight)

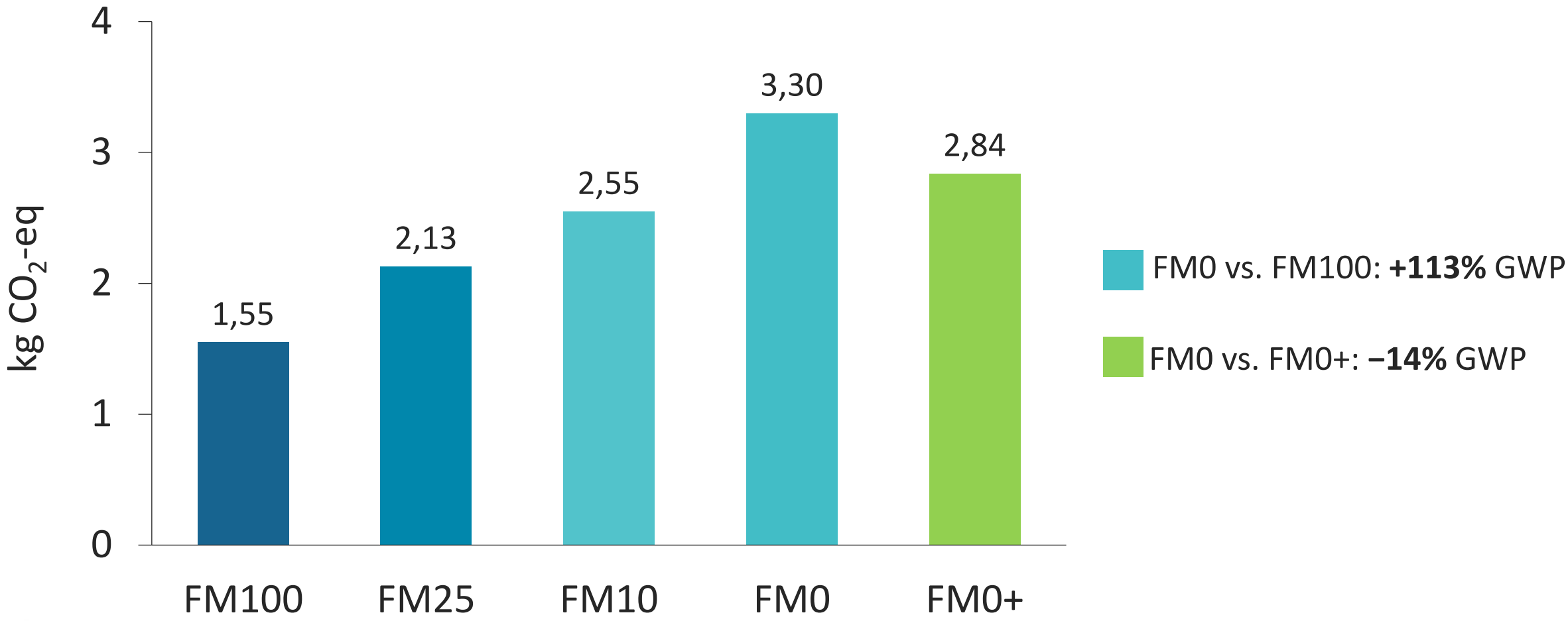
- Fishmeal: 1.2-1.4 (Rustad, 2006)
- Soybean meal: 0.4-3.0 (Dalgaard, 2008)
- Poultry by-products: 0.6-0.8 (Campos et al., 2020)
- Pig by-products: 0.3-0.8 (Campos et al., 2020)
- Insect meals: 0.5-1.96 (Campos et al., 2020; Bordignon et al., 2024)
- Microalgae spp.: 0.85-11.0 (Thielemann et al. 2021; Cuñha et al., 2024)

Global warming potentials (Kg CO_2-eq / kg dry weight)



Environmental impact of aquafeeds

Global warming potential (per 1 kg fish body weight gained) due to feed consumed



Hotspot analysis – Global warming potential

Marine ingredients (7-55%)

- Fish meal (0-47%)
- Fish oil (7%)

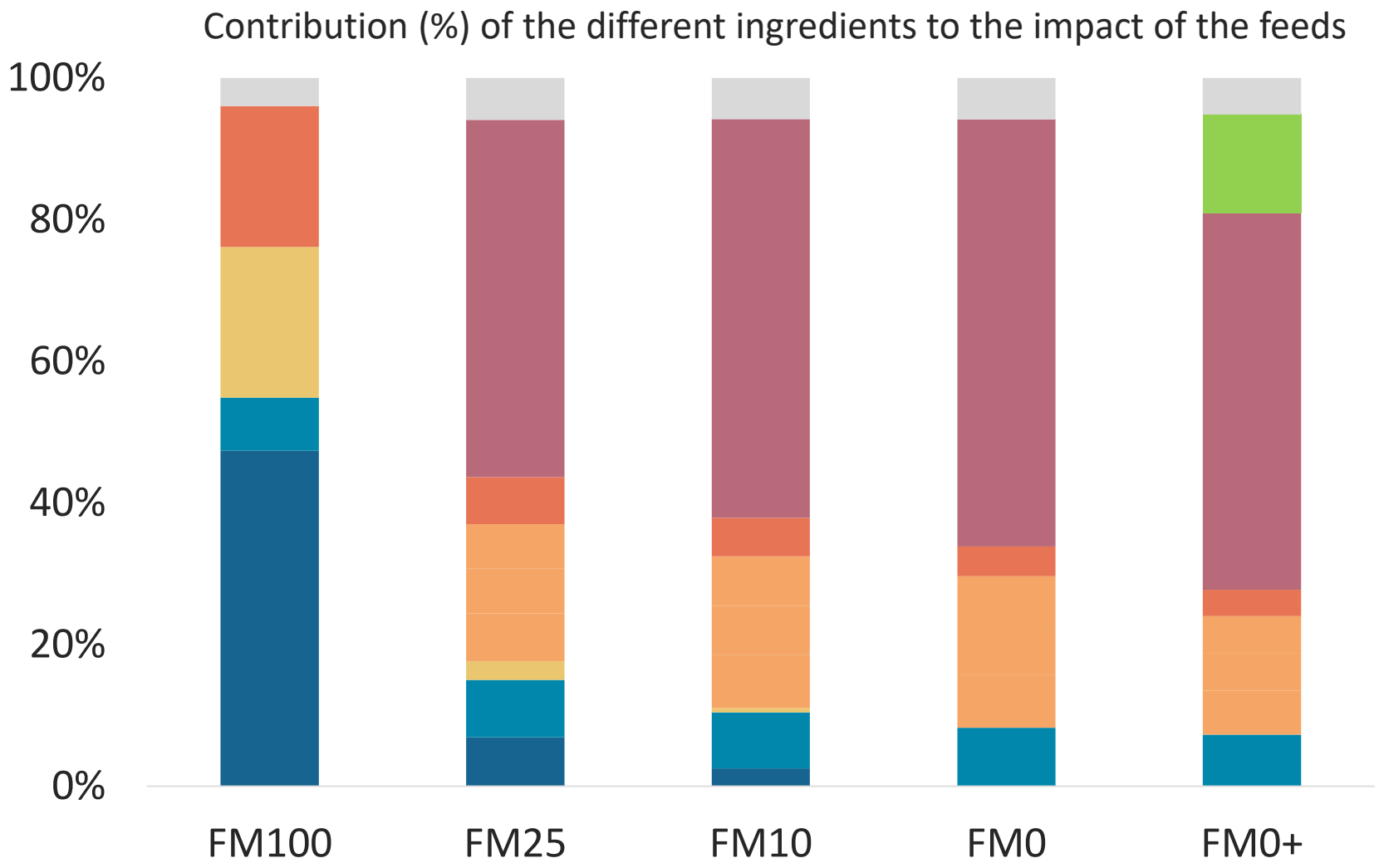
Vegetable ingredients (20-41%)

- Wheat meal (0-21%)
- Protein meals (0-21%)
  (Soybean meal, pea meal, sunflower meal)
- Soybean oil (4-20%)

Alternative protein meals

- Iberian pig meal (50-60%)
- Microalgae meal (14%)

- Vitamin-mineral mix



Main conclusions

1

Impact of alternative protein meals

New results about the footprint of alternative protein meals using primary data obtained from ingredient production processes

2

Iberian pig by-product meal (IPM)

- Total replacement of FM with vegetable proteins and IPM (33% inclusion) showed reduced performance both in terms of growth and environmental impact.
- The replacement of FM at 75% (24% IPM inclusion) could represent the best trade-off considering fish performance and global warming potential

3

Microalgae meal (*I. galbana*)

The inclusion of microalgae (5%) in a FM-free diet rich in IPM (33% inclusion) improved fish performance and reduced global warming potential

Next steps…

1 To complete the environmental footprint assessment of alternative protein meals and feeds including other impact categories (land use, water scarcity, eutrophication,…)

2 To evaluate the environmental consequences of fish meal replacement with alternative protein meals along the different production chains (consequential LCA)

Take a look!

ELSEVIER

Aquaculture

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Fish oil substitution with vegetable oils in diets for greater amberjack (*Seriola dumerili*): A consequential life cycle assessment approach

Francesco Bordignon [a], Angela Trocino [a b] ✉, Enrico Sturaro [a], Silvia Martínez-Llorens [c], Ana Tomas-Vidal [c], Gerolamo Xiccato [a], Marco Berton [a]