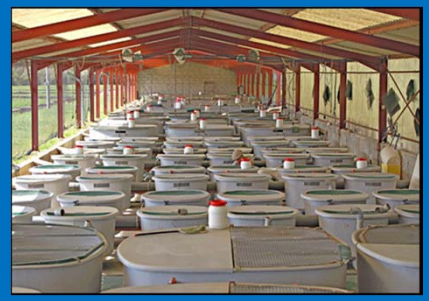

NO FISH MEAL AND FISH OIL IN AQUAFEED: A CHALLENGE FOR THE SUSTAINABLE DEVELOPMENT OF AQUACULTURE.

Skiba-Cassy S, Lazzarotto V, Corraze G. and Médale F.

UMR INRA – UPPA Nutrition, Métabolisme, Aquaculture (NuMéA)
64310 Saint Pée sur Nivelle

Part 1 - CONTEXT OF AQUACULTURE

Part 2 - IMPACT OF TOTAL SUBSTITUTION OF FISHMEAL AND FISH OIL BY PLANT INGREDIENTS

Part 3 – STRATEGIES TO REACH THE BEST ADEQUATION BETWEEN FISH AND NEW FEED

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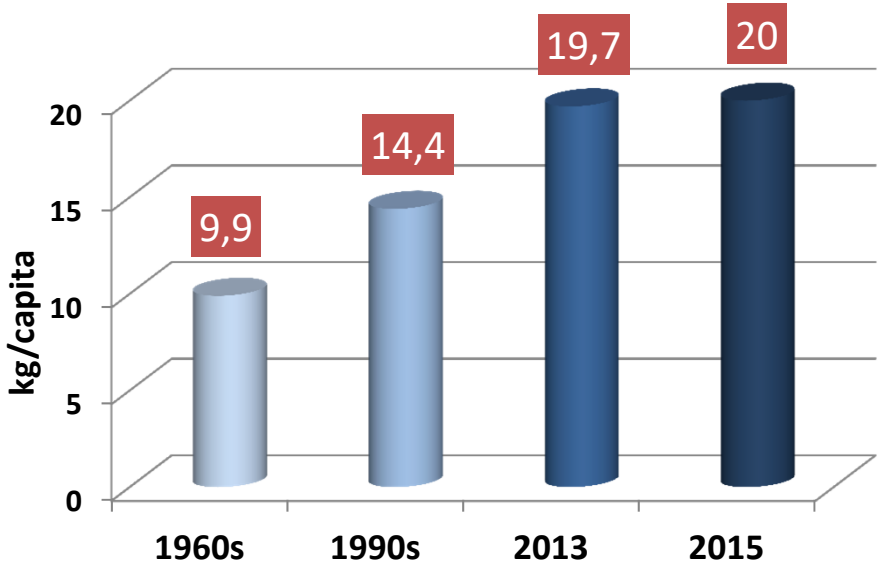
The proportion of seafood in human diets is increasing worldwide

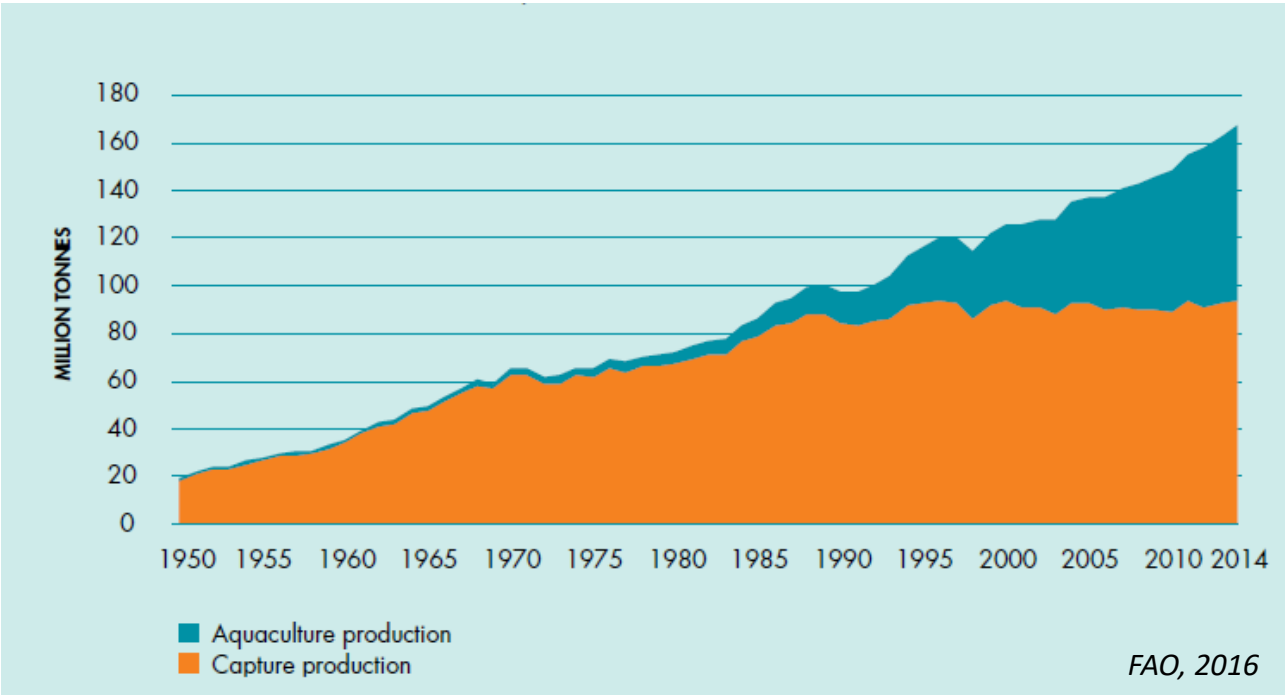
Apparent fish consumption per capita in the world



FAO, 2016

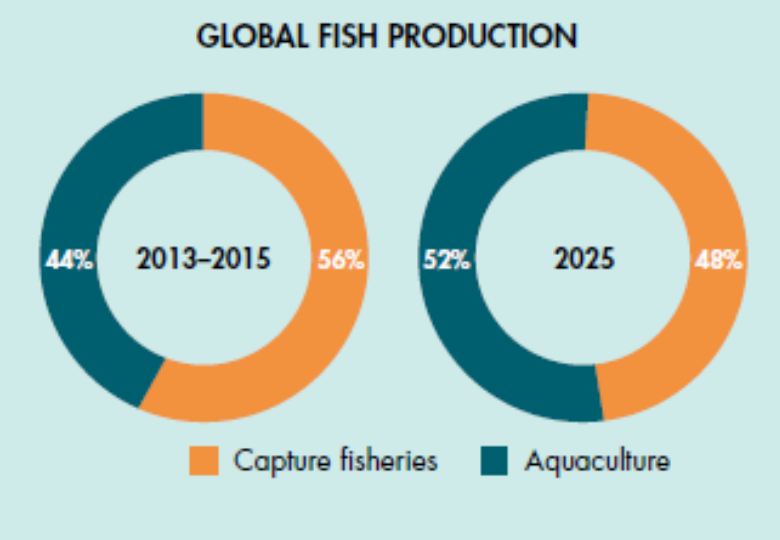
The great expansion of Aquaculture

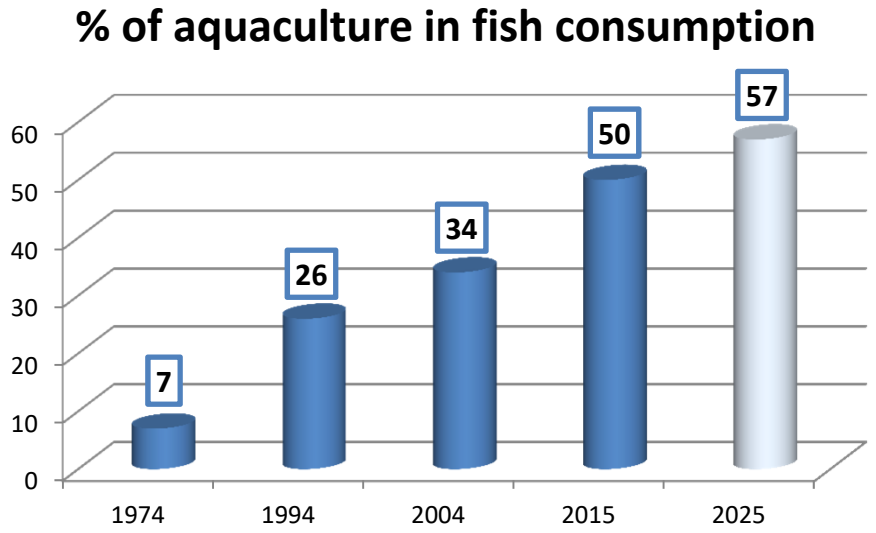
World capture fisheries and aquaculture production



FAO, 2016

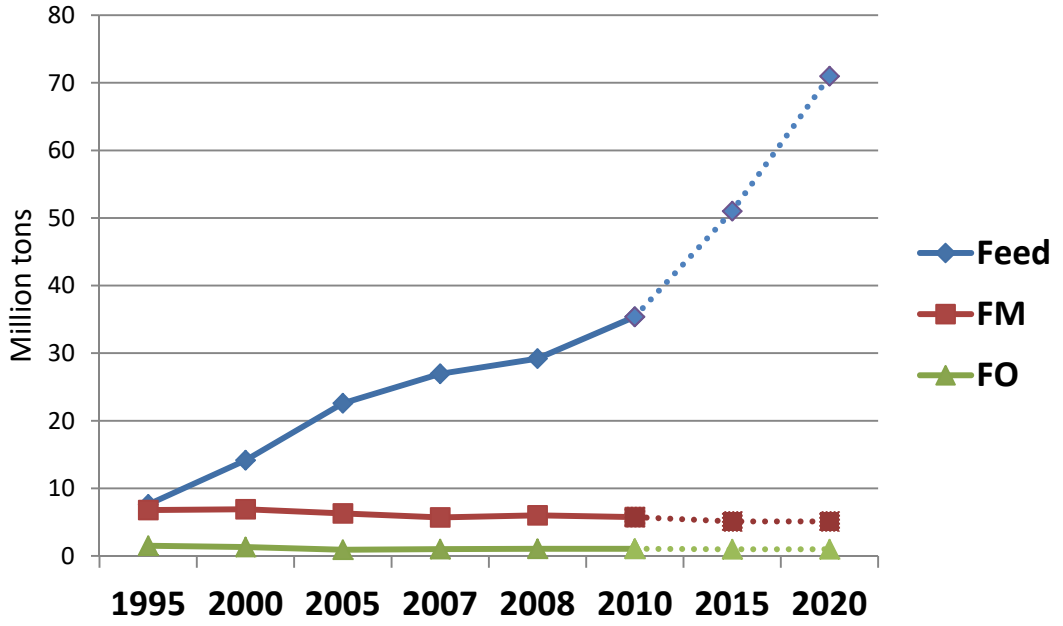
50% of fish consumed today in the world are coming from aquaculture





Increasing demand in aquafeeds

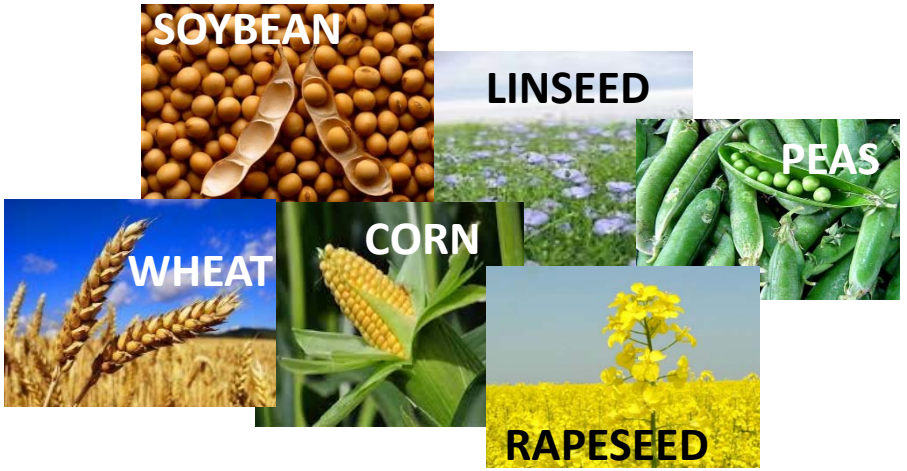
Fishmeal (FM), fish oil (FO) and feed production



Stability of FM (6 MT) and FO (1 MT) production

Find alternatives for the sustainable development of aquaculture

FM & FO vs plant ingredients



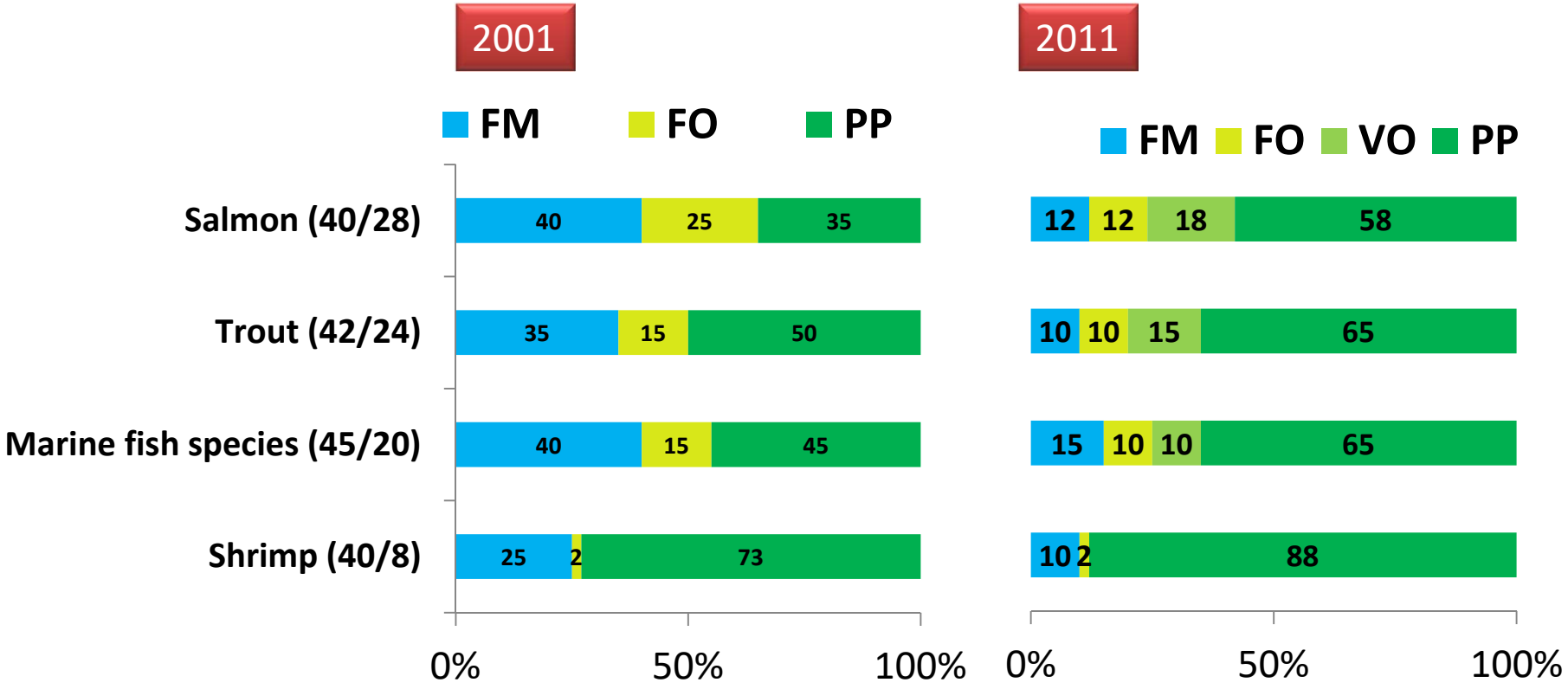
High protein content (>70%)
Adequate AA and FA profiles
FO - High level of n-3 LC HUFA
FM - Source in vitamins and minerals

High availability and diversity
Constant supply
Relatively low costs

Marine origin
Limited availability
Price volatility

Low protein content
AA deficiency (methionine, lysine…)
Anti-nutritional factors
Carbohydrates sources and content
Absence of LC-HUFA n-3

Reduction of percentage of FM and FO in commercial diets for fish



Several bottlenecks remaining with high levels of dietary replacement

- Decrease in FI and FE → impact growth and production efficiency
- Strong changes in body FA profile → reduced quality
- Alteration of metabolic pathways

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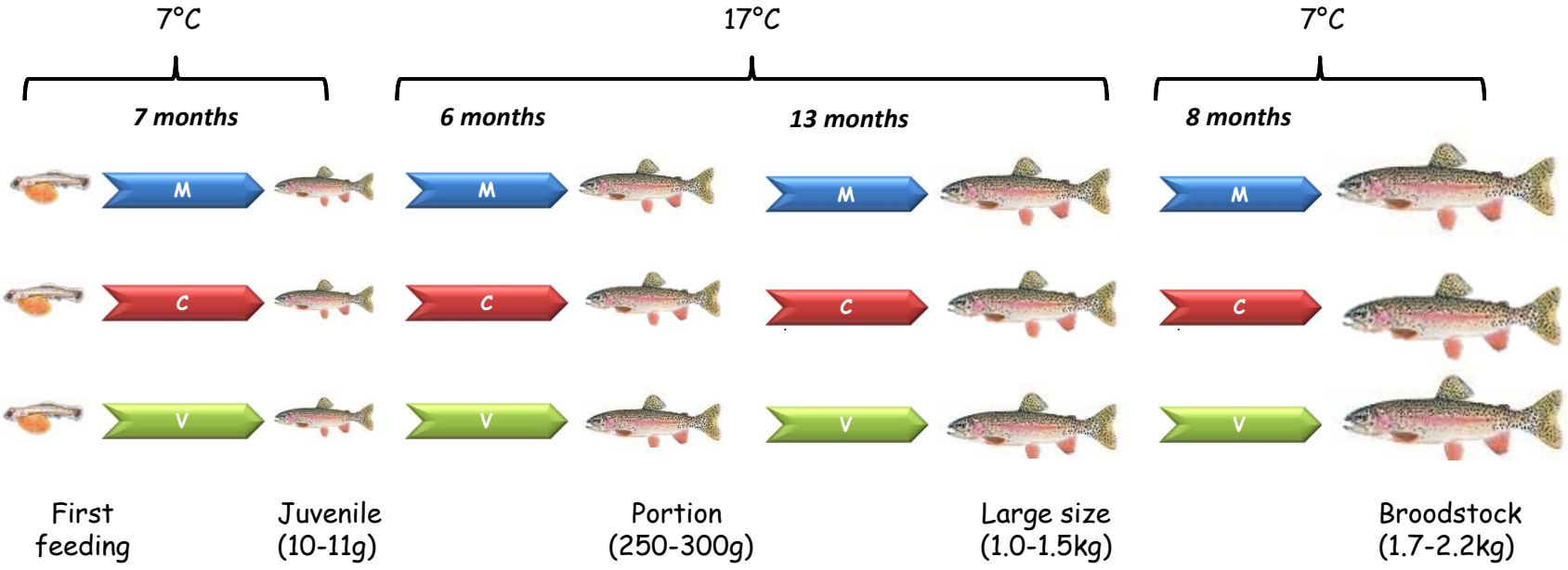
Total fishmeal and fish oil replacement by plant ingredients during the whole life cycle of the rainbow trout

ARRAINA
Advanced Research Initiatives for Nutrition & Aquaculture
FP7 European project

Experimental design

Rainbow trout fed 3 diets from first feeding until the reproduction

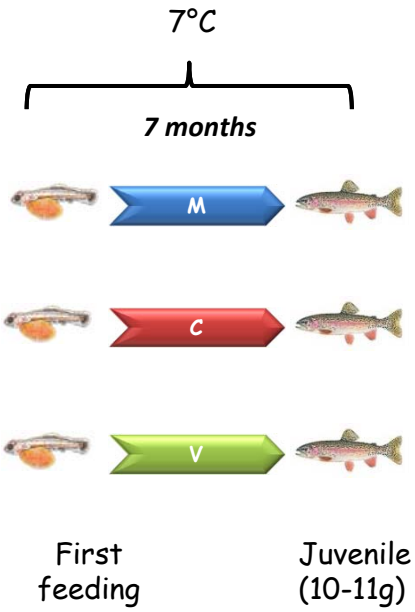
- Marine diet **M** → fishmeal and fish oil
- Vegetal diet **V** → plant based diet free of marine ingredients
- Commercial like diet **C** → lower levels of fishmeal and fish oil



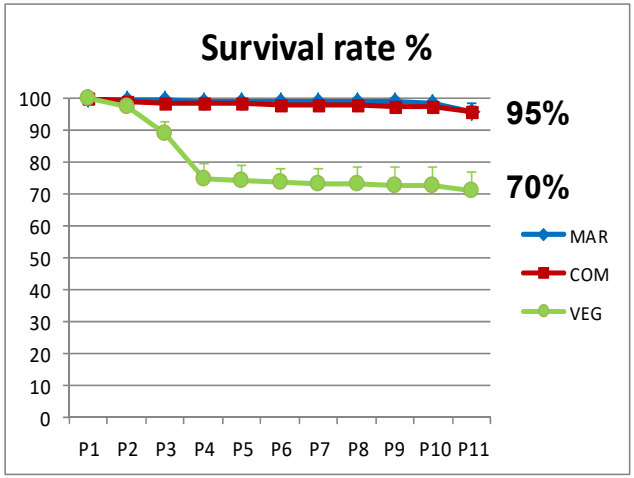
Diet composition

Ingredients	MAR	COM	VEG
Fish meal	65.21	30	0
Corn gluten	0	13.16	24
Wheat gluten	0	10.02	22.25
Soybean meal 48	0	6.06	1.8
Soy protein concentrate	0	10.24	20
White lupin	0	0.38	2.53
Peas	0	4.06	0
Rapeseed meal 00	0	6.23	2.26
Extruded whole wheat	21.11	1.31	0
Fish oil	11.68	8.11	0
Rapeseed oil	0	8.12	6.7
Linseed oil	0	0	6.7
Palm oil	0	0	3.55
Soy Lecithin	0	0	2
L-Lysine	0	0.3	1.5
L-Methionine	0	0.006	0.3
CaHPO4.2H20 (18%P)	0	0	2.91
Attractant Mix *	0	0	1.5
Min. premix	1	1	1
Vit. premix	1	1	1
Analytical composition			
DM %	94.27	95.34	95.46
Protein %DM	48.93	53.34	52.86
Lipid %DM	21.46	22.05	21.76
Energy kJ/g DM	23.02	24.20	24.05
Ash %DM	9.24	6.22	5.61

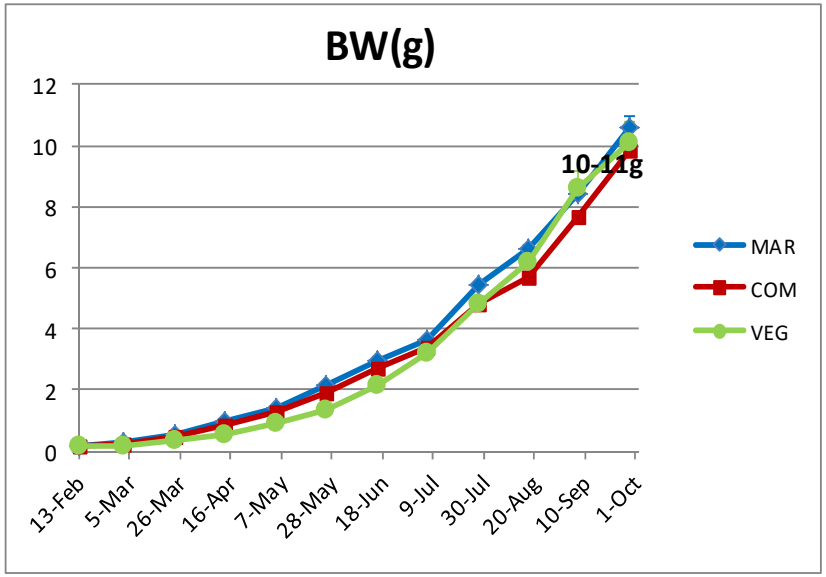
First feeding until juvenile (11g) - 7 months at 7°C



First feeding until juvenile (11g) - 7 months at 7°C

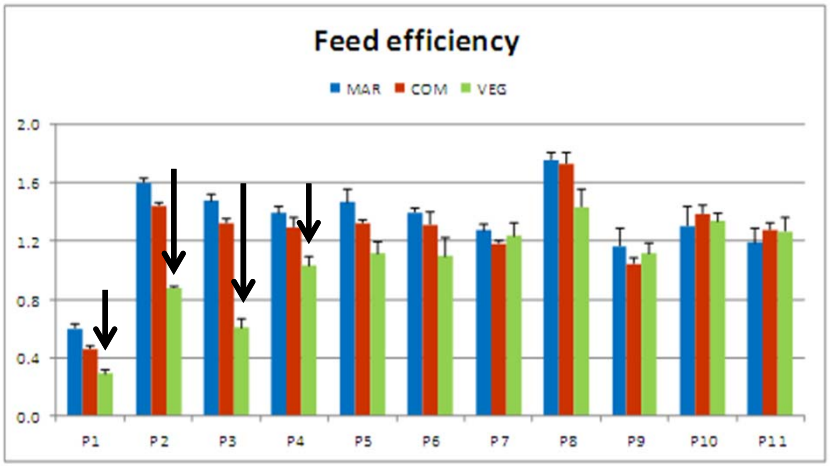


→ Decrease of the survival rate down to 70% in fry fed V diet



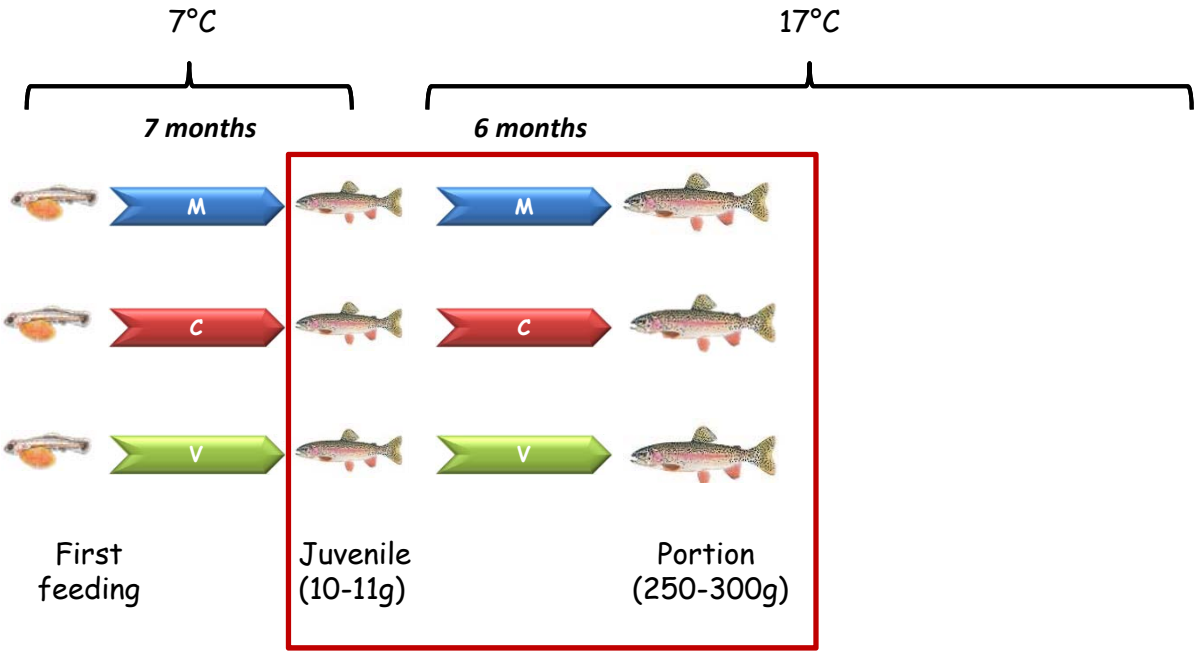
→Lower growth with V diet during the first 4 months

→No more difference in BW and SGR after 7 months

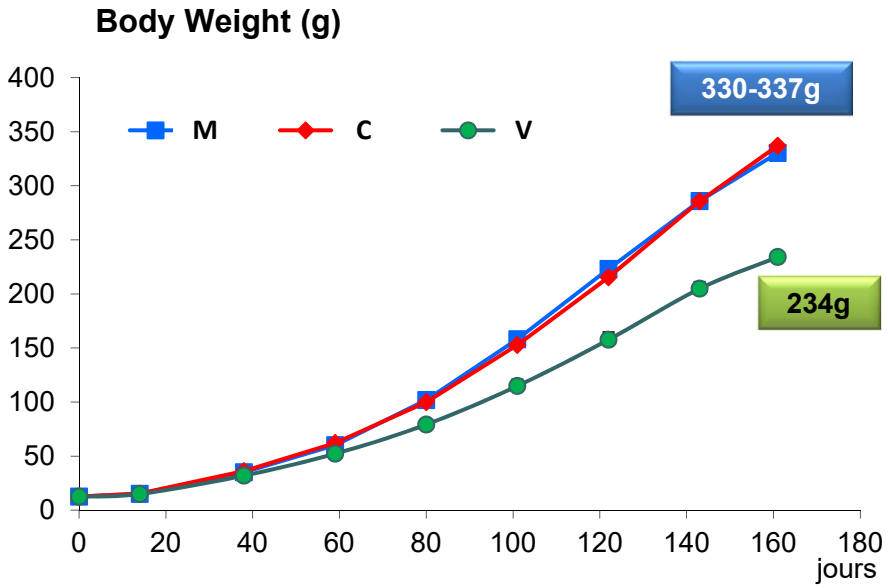


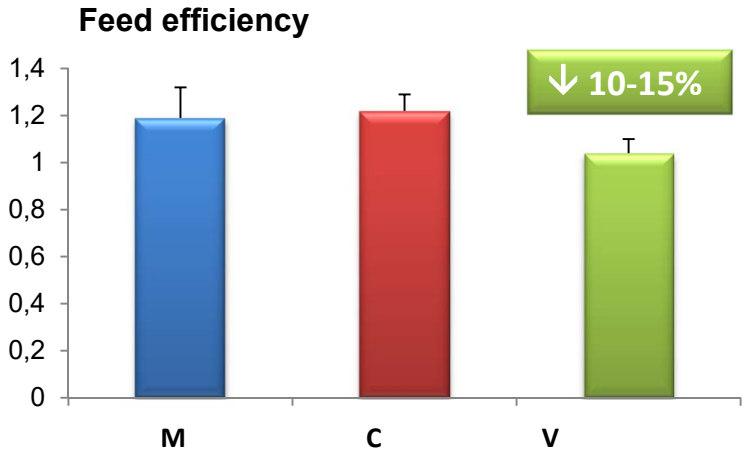
→ Reduction of FE (-10%) with V diet during the first months – No more difference after 7 months

Juvenile to 250-300g portion trout - 6 months at 17°C



Juvenile to 250-300g portion trout - 6 months at 17°C





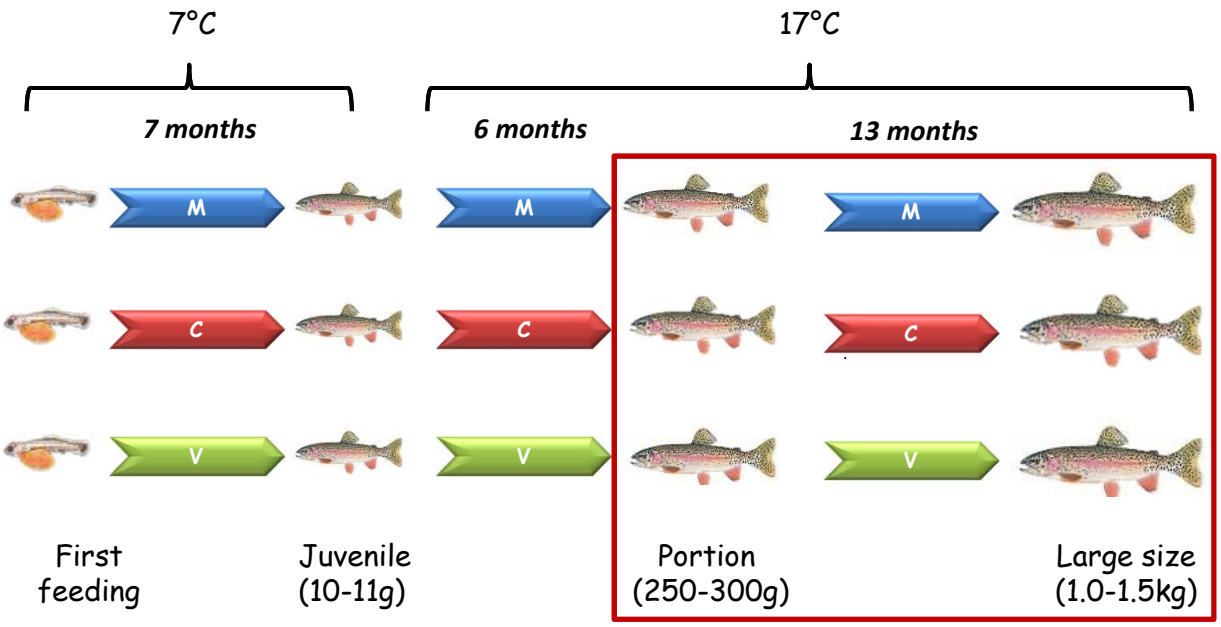
→Good and similar survival (96-98%)

→Reduction of growth with V diet from 38 days at 17°C

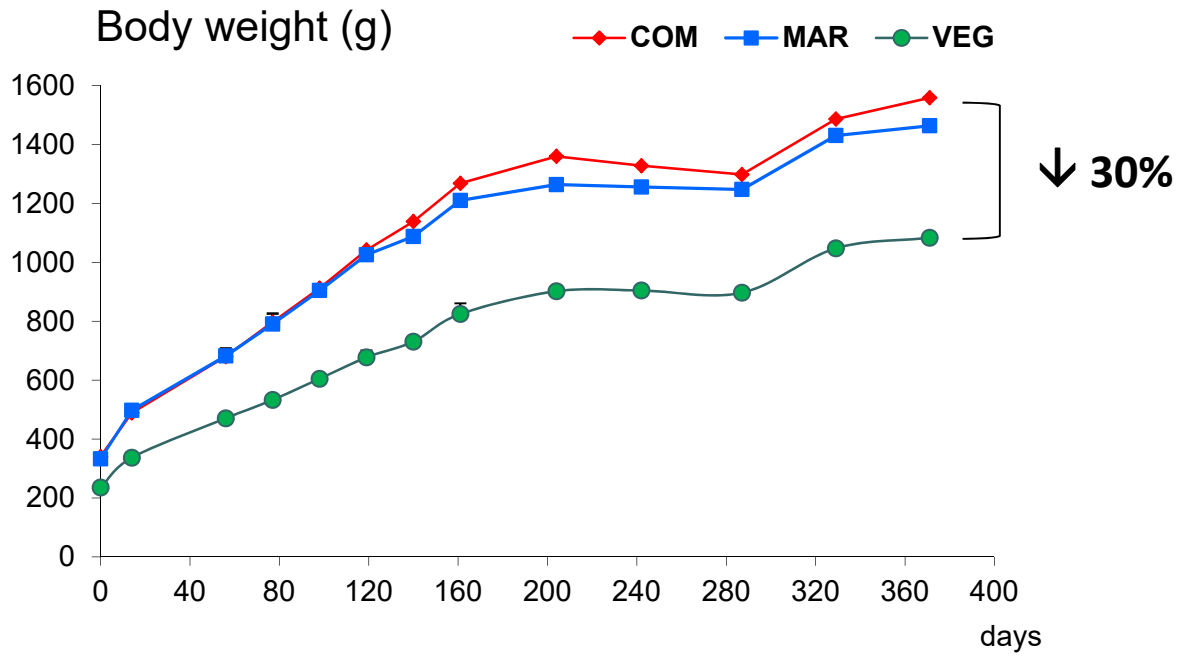
→Lower feed efficiency with V diet (-10%-15%)

→Similar feed intake between the diets around 1,1 BW%/day

250-300g portion trout to large size tout - 13 months at 17°C



250-300g portion trout to large size tout - 13 months at 17°C



→Lower growth with V diet during the whole period

→Reduced FE in trout fed V diet

Body composition

- No difference in whole body protein content (16-17%)

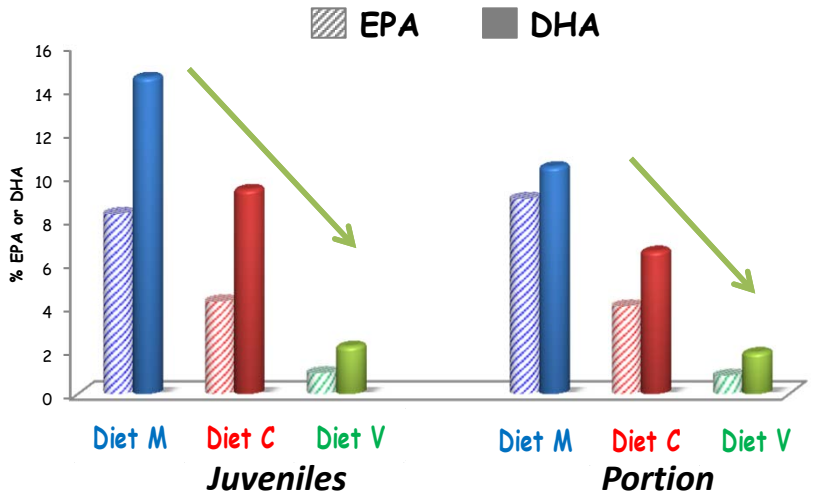
- Body lipids increased in trout fed plant-based diet in juveniles and large size trout

Body lipid (%WW)	M	C	V
Juveniles	9.39 ± 0.38^{b}	9.94 ± 1.52^{b}	**13.20 ± 0.88^{a}**
Portion	15.05 ± 1.10	16.20 ± 0.76	15.16 ± 0.94
Large size	13.01 ± 0.63^{b}	10.08 ± 5.76^{b}	**17.51 ± 0.71^{a}**

- No difference in muscle lipid content (6-7%)

Whole body n-3 Long Chain Highly Unsaturated Fatty Acids

EPA & DHA proportions in whole body lipids

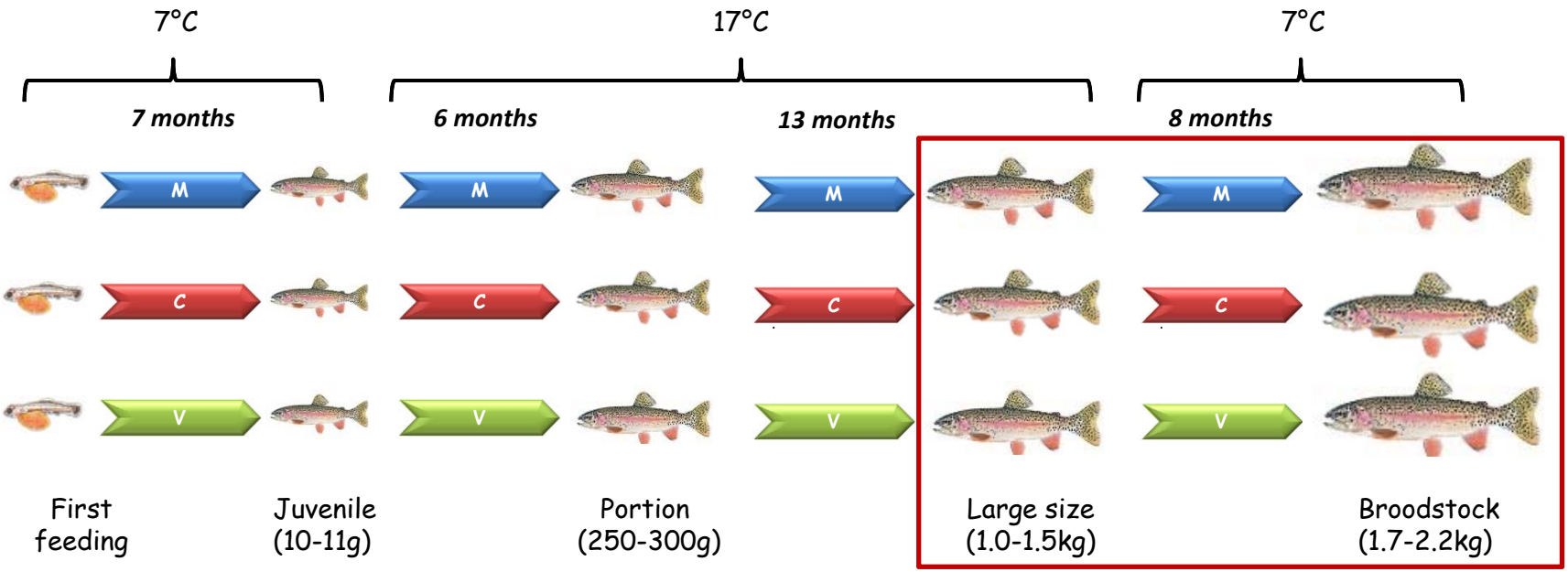


	First feed.	Juv.	Portion
EPA + DHA mg/fish	2.6	39.6	904

→ Presence of 0,9% EPA and 2% DHA of whole body lipids despite absence of n-3 LC-HUFA dietary supply

→ Biosynthesis of n-3 LC-HUFA

Large size trout to broodstock – 8 months at 7°C



Large size trout to broodstock – 8 months at 7°C

	M	C	V
GSI (%)	15.5 ± 0.8 a	13.4 ± 2.9 ab	**11.7 ± 0.9 b**
Egg weight (mg)	48.5 ± 5.0 a	**40.7 ± 4.6 b**	**41.4 ± 4.0 b**
Fry weight (mg)	86 ± 5 a	**75 ± 7 b**	**74 ± 6 b**
Eyed egg (%)	90.3 ± 5.5	90.4 ± 4.6	71.7 ± 22.9
Hatching (%)	89.8 ± 5.3	89.4 ± 4.0	68.8 ± 23.9

→ Total substitution of FM and FO

- affected the development of the ovaries
- reduced egg and fry weight (also observed with partial substitution)

CONCLUSION

Trout fed a total plant based diet from first feeding until reproduction

is able to…

- Survive and grow
- Biosynthesize n-3 LC-HUFA
- Reach sexual maturation and produce viable eggs and fry

however…

- Growth performance is lower
- Low levels of EPA and DHA/ consumer expectations
- Reproductive performance are a little bit reduced

Feeding trout without marine ingredients during the whole life cycle is possible but further improvements are needed to better preserve growth and reproductive perfomance

- *Lazzarotto, V. et al., 2015. PLoS One. 10, e0117609.*
- *Lazzarotto, V. et al., 2016. Br. J. Nutr. 115, 2079-2092.*
- *Lazzarotto, V. et al., 2016, submitted*

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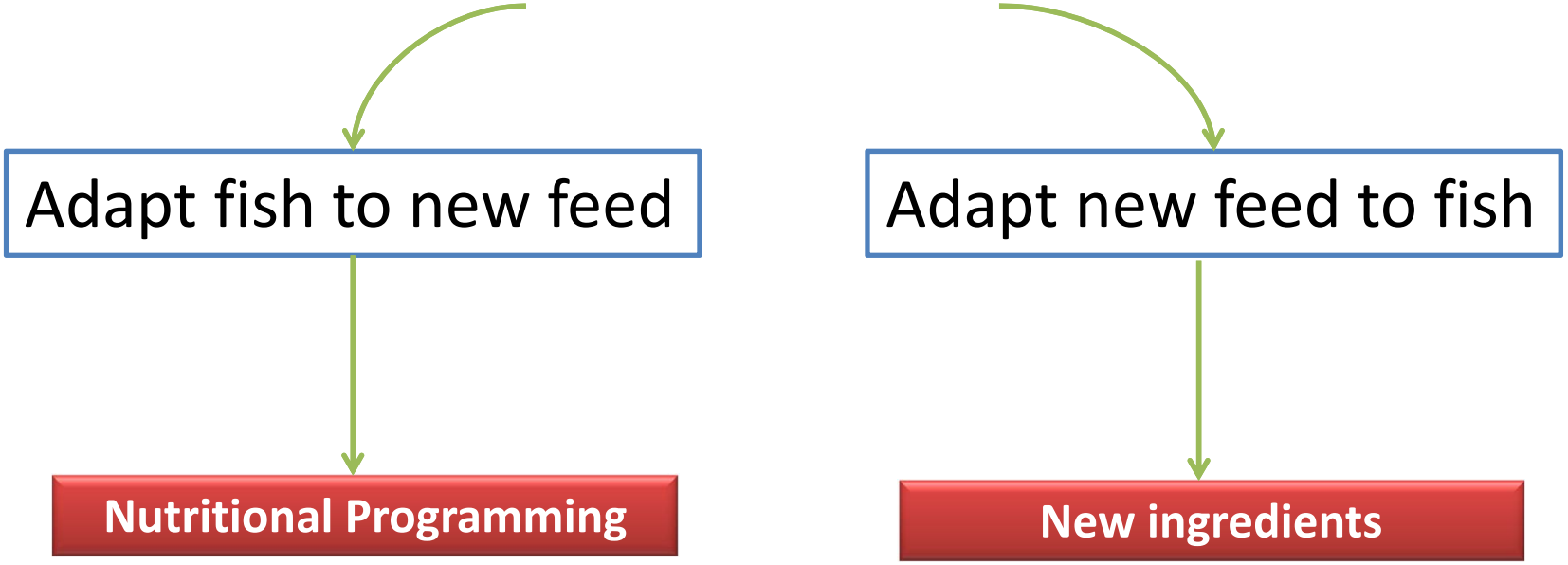
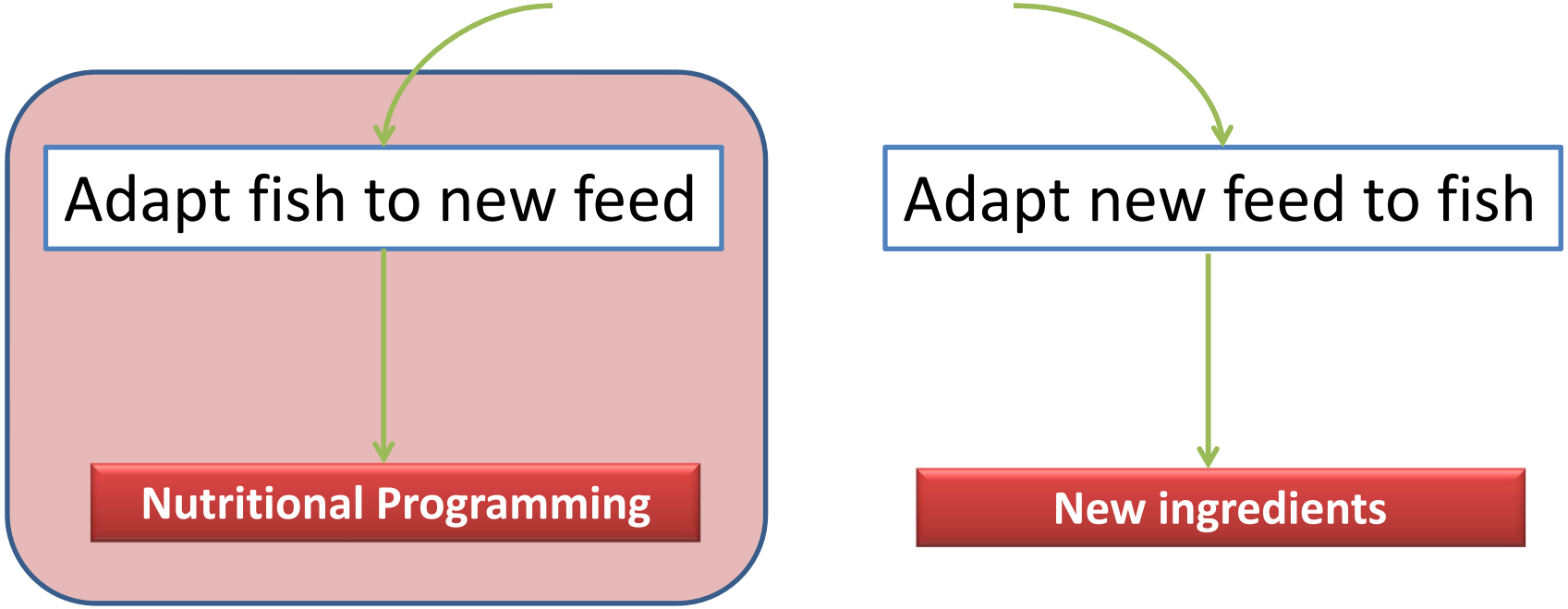
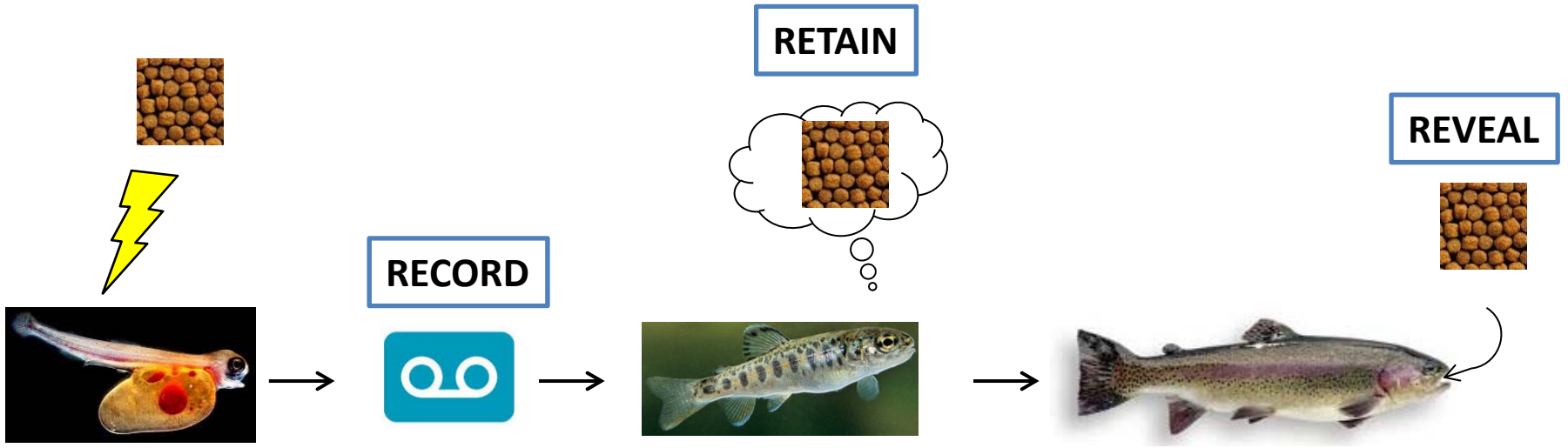


STRATEGIES TO REACH THE BEST ADEQUATION BETWEEN FISH AND NEW FEED



Nutritional Programming

"Early nutrition programming is the concept that differences in nutritional experience occurring at critical periods in early life, both pre- and post-birth, can program the development, the metabolism and the health of a person for the future."



Nutritional Programming of plant based diet utilization

Nutritional history

(21 days, fry)

V Challenge

(25 days, juveniles)

7 months

Diet M: Marine
FM and FO diet

Diet V: Vegetable
no FM and no FO

First-feeding (diet M)

First-feeding (diet V)

Diet M
Intermediate rearing

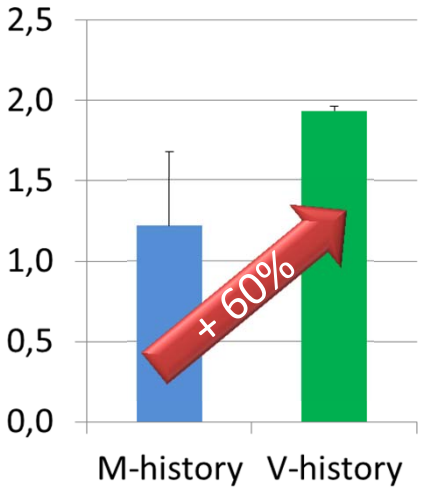
Challenge (diet V)

Challenge (diet V)

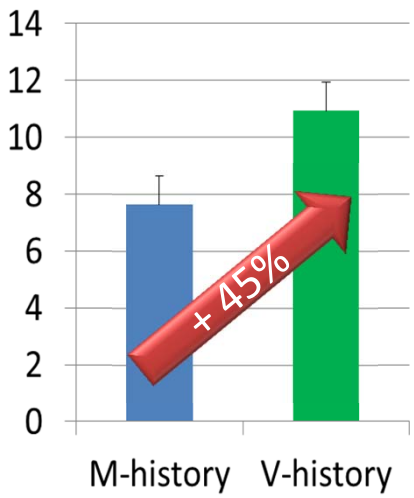
Long-term effect associated with early nutritional history ?

Nutritional Programming of plant based diet utilization

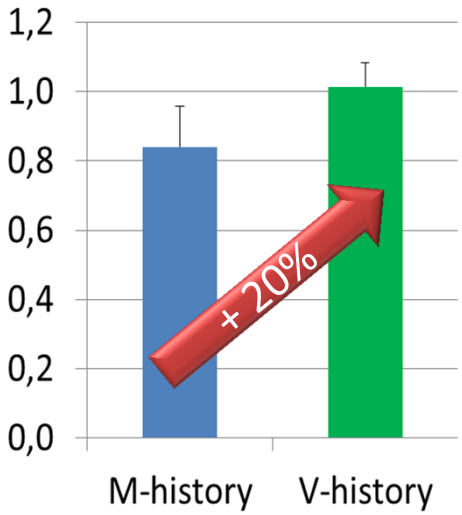
SGR (%BW/jday)



Feed Intake (g/kg Met BW/day)



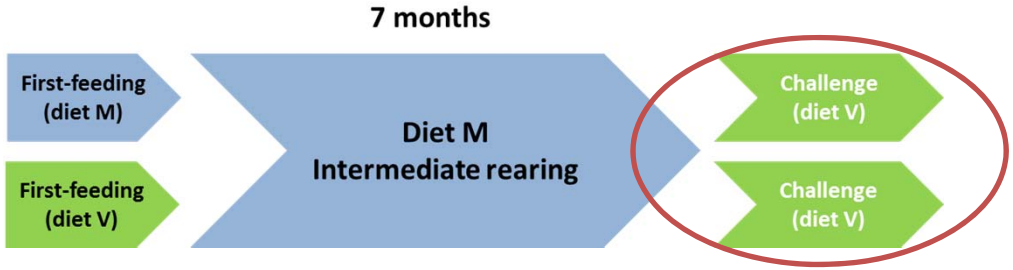
Feed Efficiency (g/kg Met BW/day)

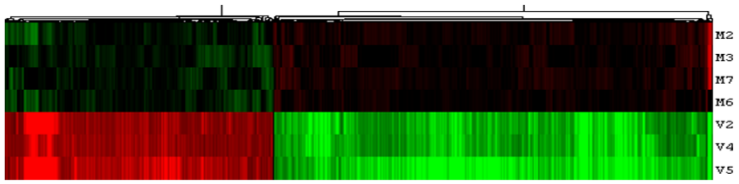


→Short-term exposure of the fry to a plant-diet at first feeding improves acceptance and utilization of plant based-diet at later life stage

Geurden I. et al., 2013, Plos One 8: e83162

Nutritional Programming of plant based diet utilization

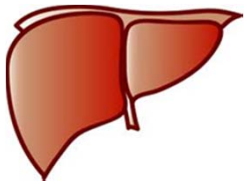




Transcriptome analysis

Brain

Liver

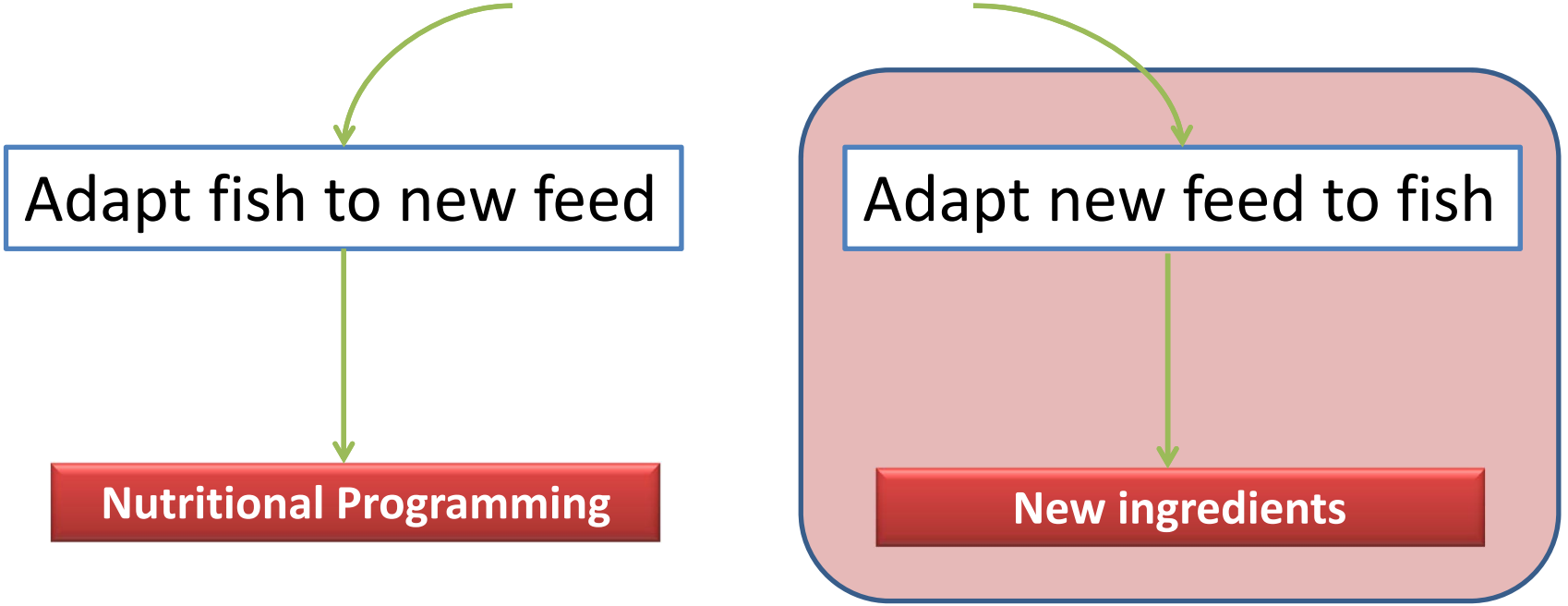


- Sensory perception
- Synaptic transmission
- Methylation
- Appetite control - neuropeptides

- Metabolism (xenobiotic, intermediary)
- Protein turnover
- Cytoskeleton

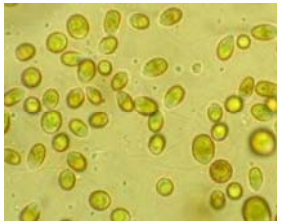
Balasubramanian et al. 2016 BMC Genomics 17: 449

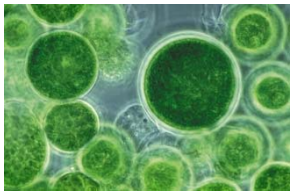
STRATEGIES TO REACH THE BEST ADEQUATION BETWEEN FISH AND NEW FEED



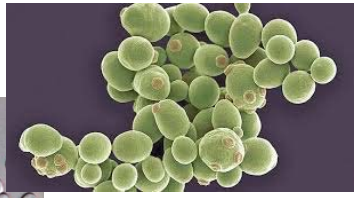
New ingredients

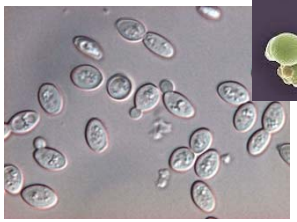
INSECTS





MICROALGAE





YEAST

Insects – Proximate composition

	Tenebrio Wheat worm	Hermétia Black soldier	Fish meal
	 	 	 
Dry matter (%)	96.3	91.5	92.8
Proteins (% MS)	**73.9**	**61.3**	**73.0**
Lipids (% MS)	15.9	11.9	11.4
Energy (kJ/g MS)	24.5	24.7	21.7
α-glucanes (% MS)	1.2	2.5	0.3
Phosphorus (% MS)	0.9	1.1	2.1

Desirable insect biorefinery

ANR

Insects – Digestibility

Insect meal	DM	Proteins	Energy	Lipids
Tenebrio	**83.4 b**	**89.9 b**	**87.2 c**	**104.4 c**
Hermetia	76.6 a	83.0 a	53.9 a	93.7 a
Hermetia + Chitinase	77.3 a	82.9 a	**81.2 b**	**100.4 b**
	P<0.001	*P<0.001*	*P<0.001*	*P<0.001*

- Higher digestibility of tenebrio meal → especially for energy
- Enzymatic digestion (↘ chitin) improves energy and lipid digestibility

Desirable insect biorefinery

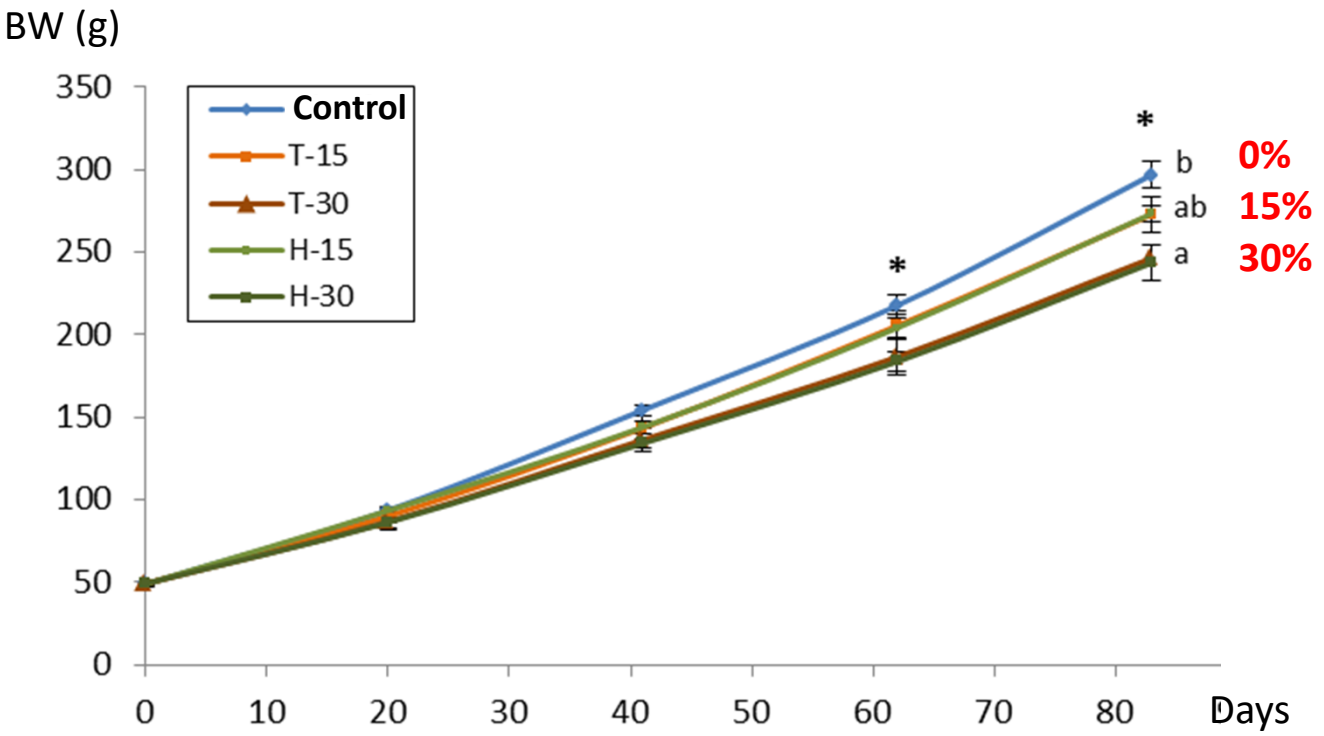
ANR

Insects – Growth performance

- Growth trial at 17°C
- Trout of 50g initial BW
- Fed until satiation (2/day) *ad libitum*
- Duration 84 days

	Control	T-15%	T-30%	H-15%	H-30%
Fish meal	**30.0**	**15.0**	0.0	**15.0**	0.0
Tenebrio meal	0.0	**15.0**	**30.0**	0.0	0.0
Hermetia meal	0.0	0.0	0.0	**15.0**	**30.0**

Insects – Growth performance



- Total replacement of FM by insect meal reduced growth performance

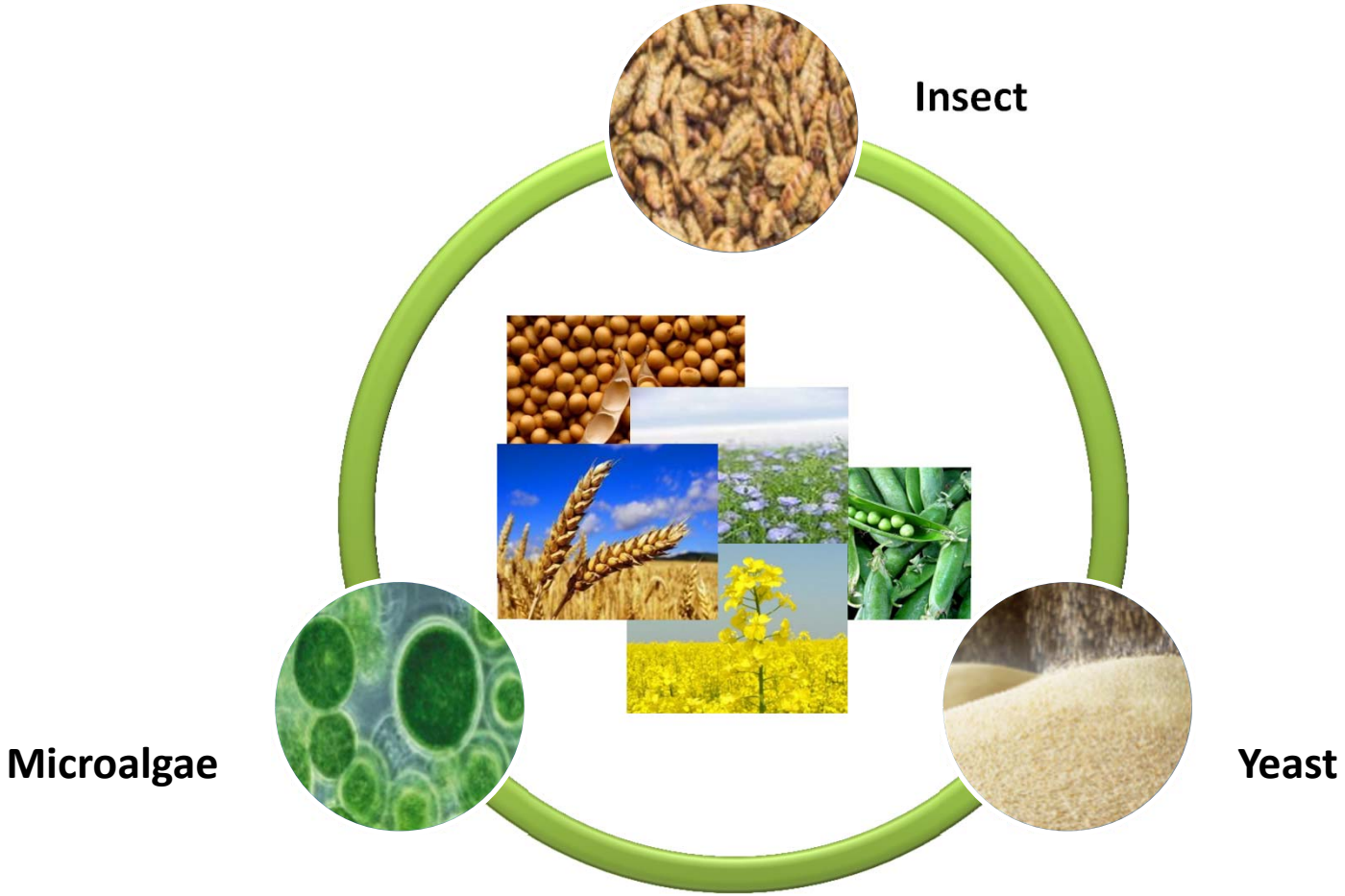
CONCLUSIONS

- Good digestibility of tenebrio meal
- Chitinase may be added to improve digestibility of hermetia meal
- No impact on feed palatability (even at 30%)
- 15% → no significant impact on growth
- 30% → reduction of growth performances (↓ FE) compared to fish meal

Desirable insect biorefinery ANR

NINAqua project (2015-2019) – New Ingredients for New Aquafeeds

Objective *: Creating new aquaculture feed enabling companies operating in the French fish-farming industry to be prepared for full substitution of fishmeal and fish oil in aquaculture feed.*



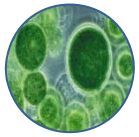
NINAqua project (2015-2019) – New Ingredients for New Aquafeeds

Funded by the French “Unique Interministries Fund” and four Regional Councils

Selection and production of new ingredients


Insect


Yeast


Microalgae

Production of new Aquafeeds


Sea bass


Trout

Impacts on

- *Growth and Metabolism*
- *Fish Quality*
- *Health*

Fish farm sustainability

- *Acceptability*
- *Water quality*
- *Life Cycle Analysis*

Thanks for your attention