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Elevating aquatic feed sustainability: Unveiling the role of unicellular organisms

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NMBU

trouw nutrition
a Nutreco company

More Protein Will be Needed Until 2050

- An adult person needs to consume 60 g of protein per day;
- Over 800 million tones of protein will be required to feed people in 2050; That is >50% of today's production;
- Example: Beef cattle need about 100 kg of feed to produce 5 kg of body-mass, which could be interpreted as 1.3 kg of pure protein
- Is this calculation possible to achieve?

Yes, with sustainable aquaculture!

Feed materials through 2 generations

- Generation 1:
- Commercially available but in direct competition with human food supply. These depend on vast resources of arable land, irrigation and fertilizers;

- Generation 2:
- Less competitive with human food and not based on arable land and irrigation. Based on microbes and insects.

Bring Nutritionally Optimal Diet With Competitive Prices

ep-briquette-machine.com/

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The Importance of Aquatic Feed Sustainability

- Aquaculture is the fastest-growing subset of agriculture!
- Overfishing, habitat destruction, and inefficient feed practices are the important topics!

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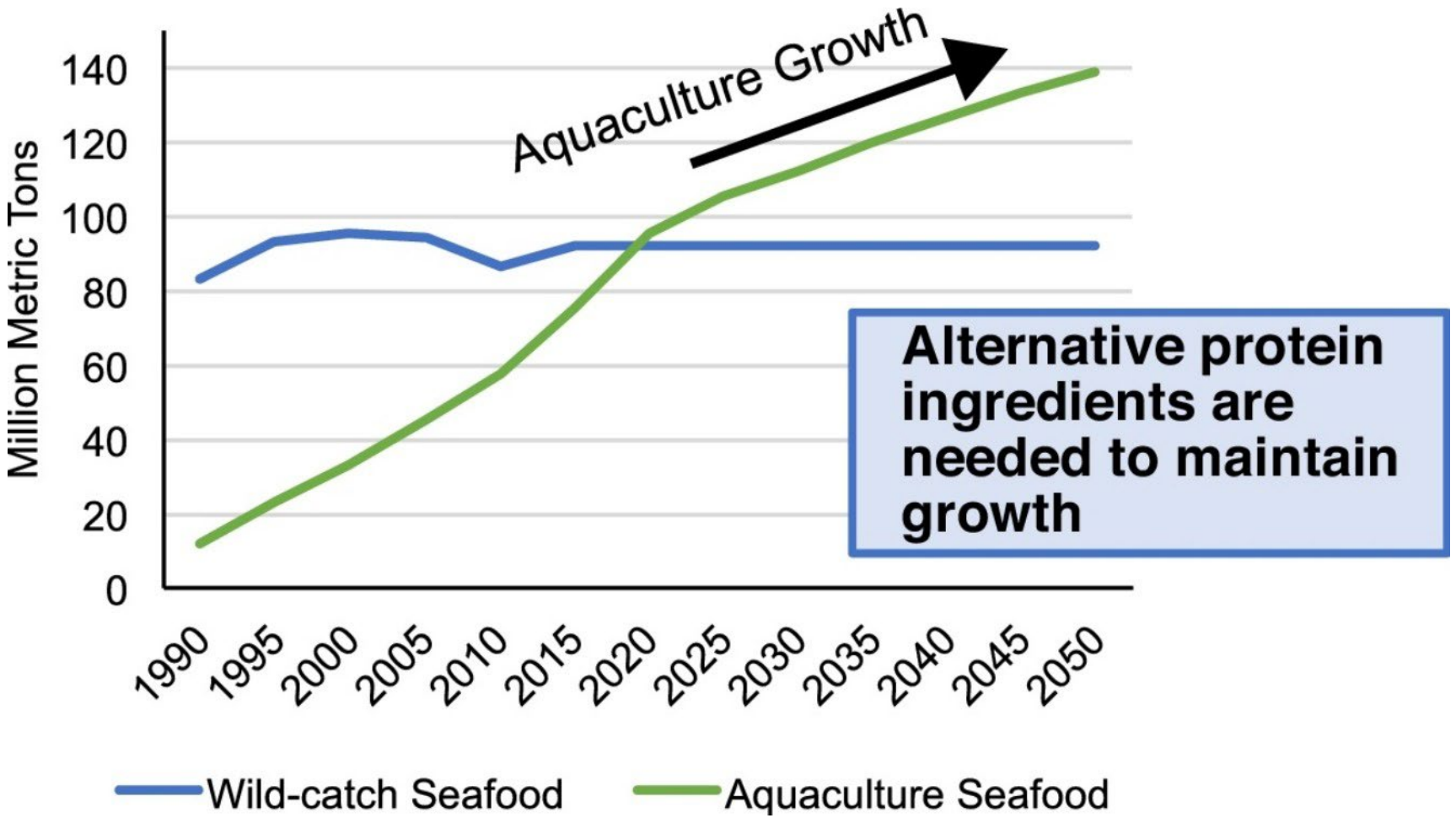
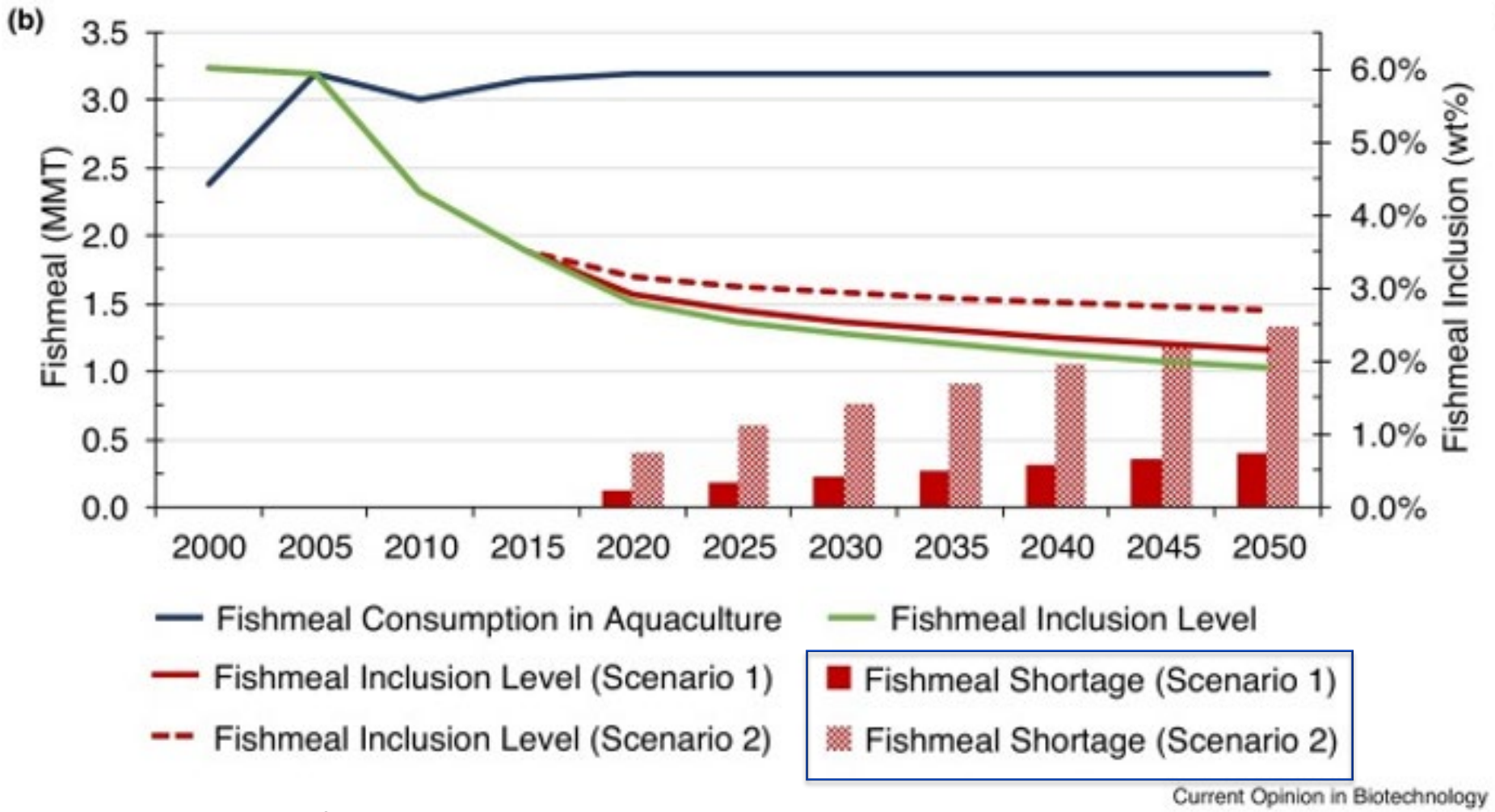
Aquacultural Growth Requires Alternative Protein Sources



Jones *et al.*, 2020

Potential Shortage of the Fishmeal (2025–2050)

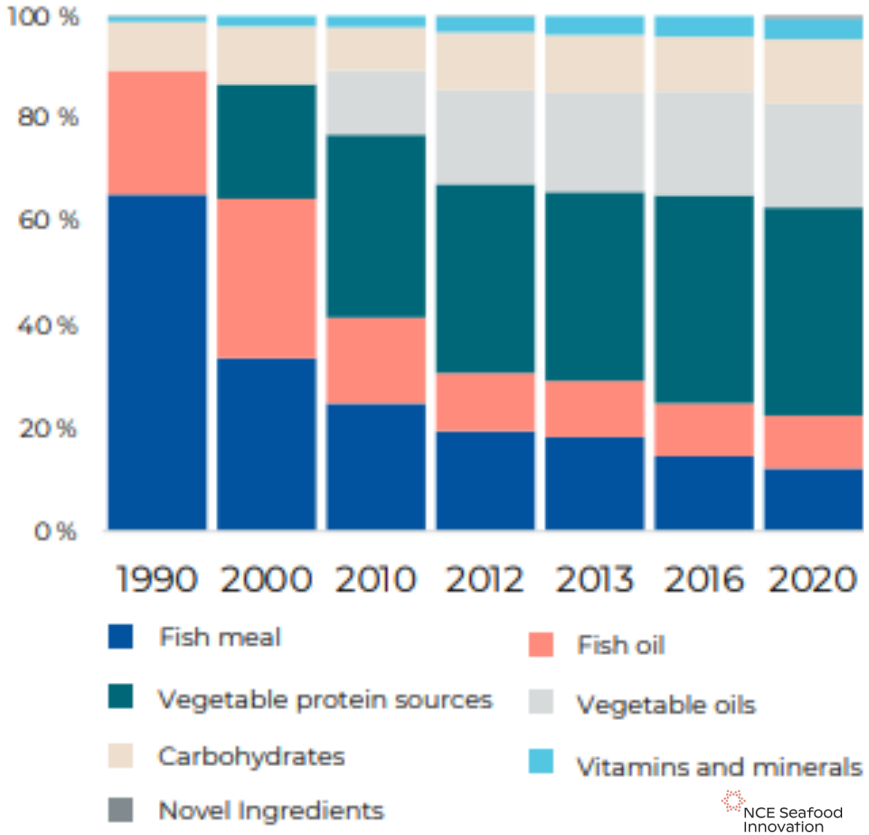


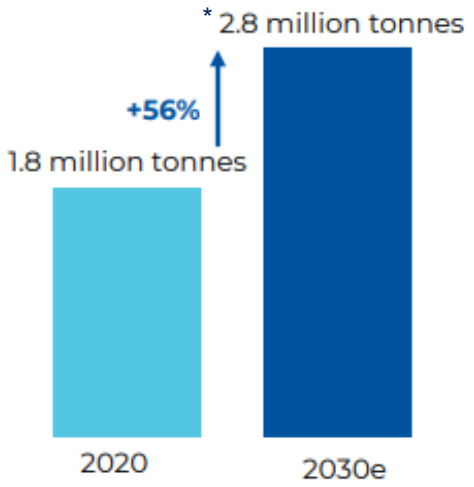
Jones *et al.*, 2020

Feed Gap and Solutions to Bottlenecks in Norway

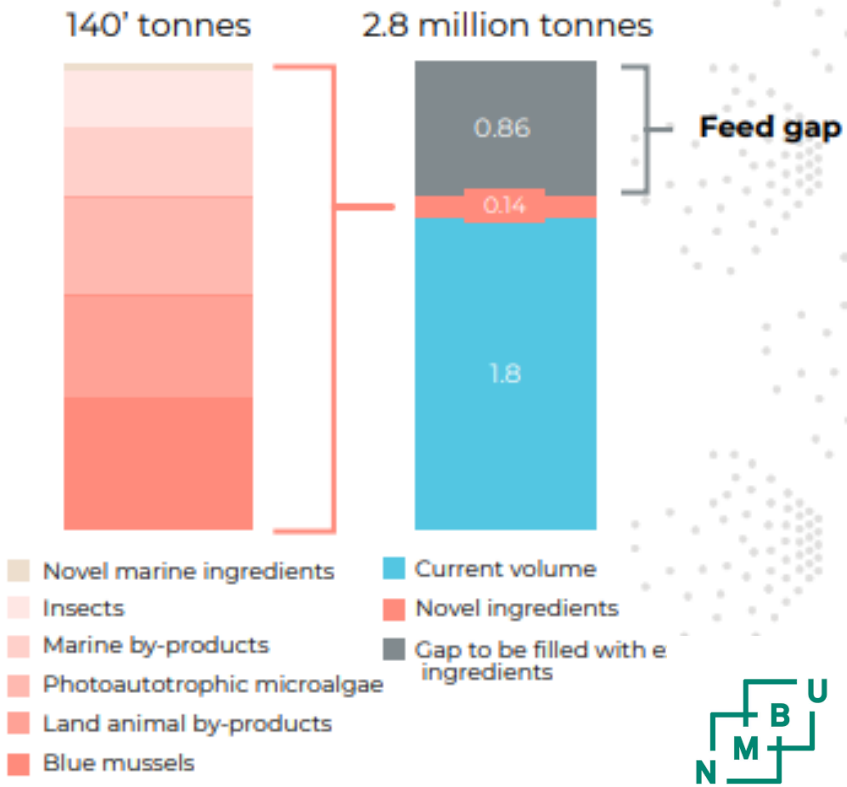
Critical situation - to meet the demand for sustainable feed, the production of novel feed ingredients must be industrialized!

Only 0.4% of Norwegian salmon feed consists of novel ingredients, and none are produced in Norway!



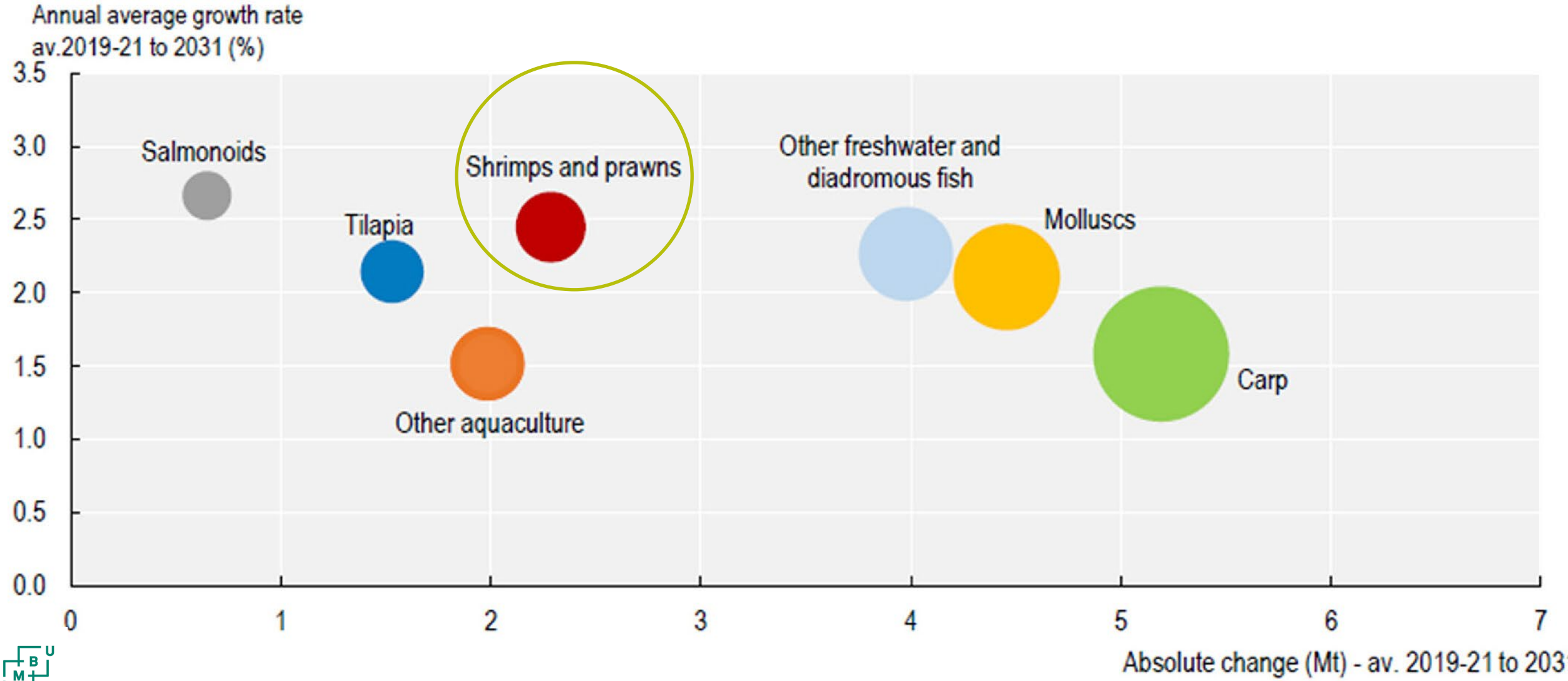


* based on current feed conversion ratio (FCR) measured in dry weight



NCE Seafood Innovation

Projected Demand for Fish Meal in Fed-Aquaculture Diets from 2019 to 2031



Alternative Proteins

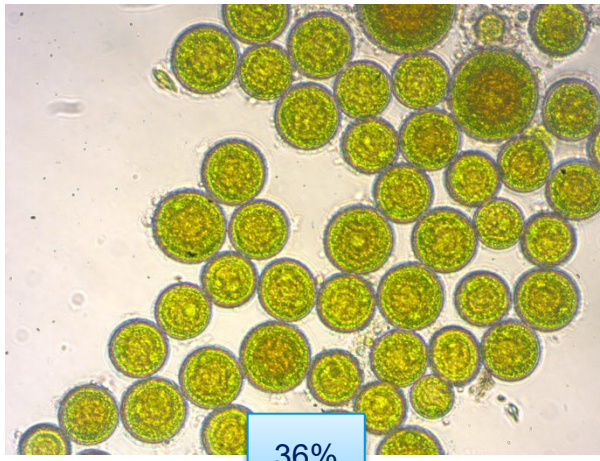
27%

- Whey proteins
- Caseins

41%

28%

- Storage proteins:
* Glycinin & β-conglycinin



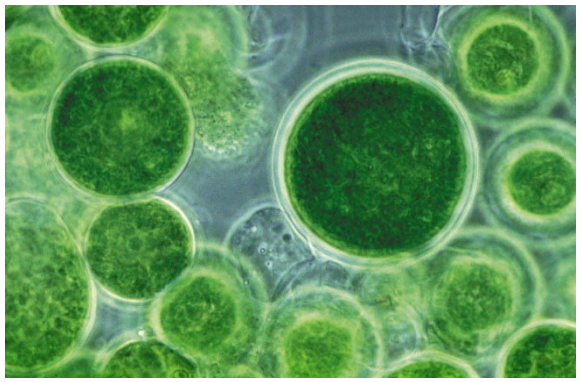
36%

Light harvesting complexes and their photosynthetic functions

Novel feed materials for greater impact on sustainable aquaculture

Growth Rate of Unicellular Organisms

Microalgae - once a day

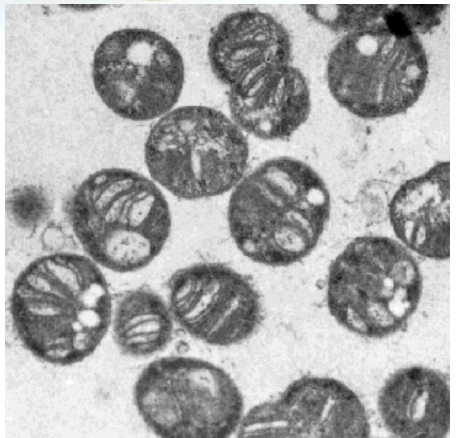


Chlorella vulgaris

Yeast - every 2 hours

Cyberlindnera jadinii

Bacteria - every 20 minutes



Methylococcus capsulatus

Bacterial meal VS Soy

Methylococcus capsulatus	BPM	SBM
Metabolizable energy (MJ kg^{-1})	15.89	14.15
Dry matter	949	885
Crude protein ($N \times 6.25$)	657	461
Crude fat	120	21
Ash	70	56
Amino acids		
Aspartic acid	8.3	11.8
Threonine	4.2	3.9
Serine	3.5	5.5
Glutamic acid	11.2	19.9
Proline	3.8	5.1
Glycine	5.0	4.3
Alanine	6.9	4.4
Cysteine[a]	0.6	1.4
Valine	5.9	5.2
Methionine	2.5	1.3
Isoleucine	4.4	5.0
Leucine	7.5	7.8
Tyrosine	4.0	4.5
Phenylalanine	4.0	5.1
Histidine	2.3	2.8
Lysine	5.4	6.3
Arginine	6.4	7.7
Tryptophan	3.3	1.4

[a] Cystine and cysteine.

Diane Labombarbe/Getty Images

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Metahanotroph Bacteria Meal Feed to Shrimps

- No significant differences in survival and growth performance (weight, weight gain, growth rate, FCR) in 6-week feeding trial!

Jintasataporn *et al.*, 2021

Front. Mar. Sci., Sec. Marine Fisheries, Aquaculture and Living Resources

Insect meal – an alternative that should not be rejected

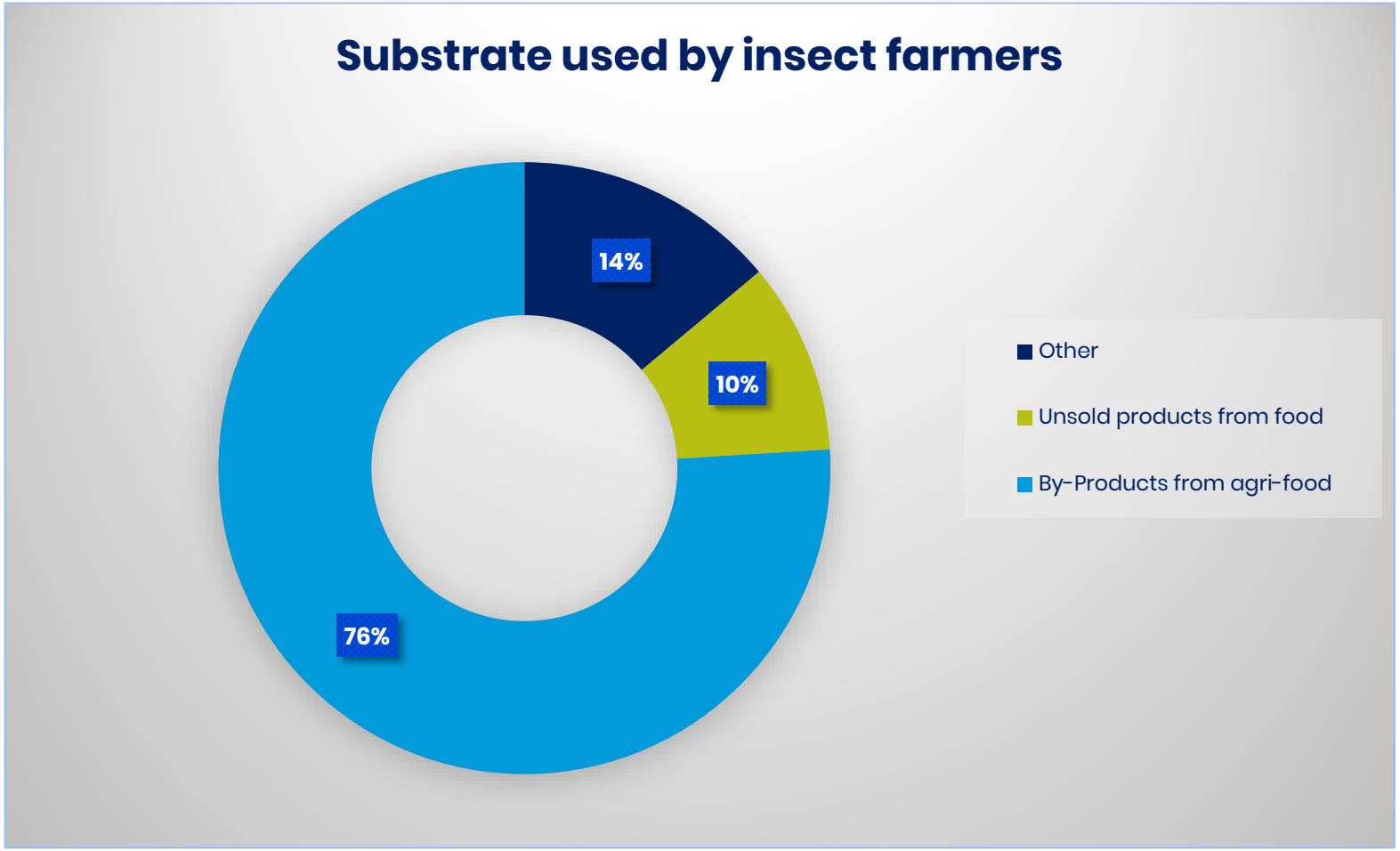
- Feed conversion and the growth of insects is high!
  - About 2 kg of organic byproducts is needed to make 1 kg of insect-based protein with a required space of 1m²

- Insect meal has a protein similar to fishmeal!
  - Contain high-grade fatty acids
  - About 30% of fishmeal can be successfully replaced by insect meal for small fish diets

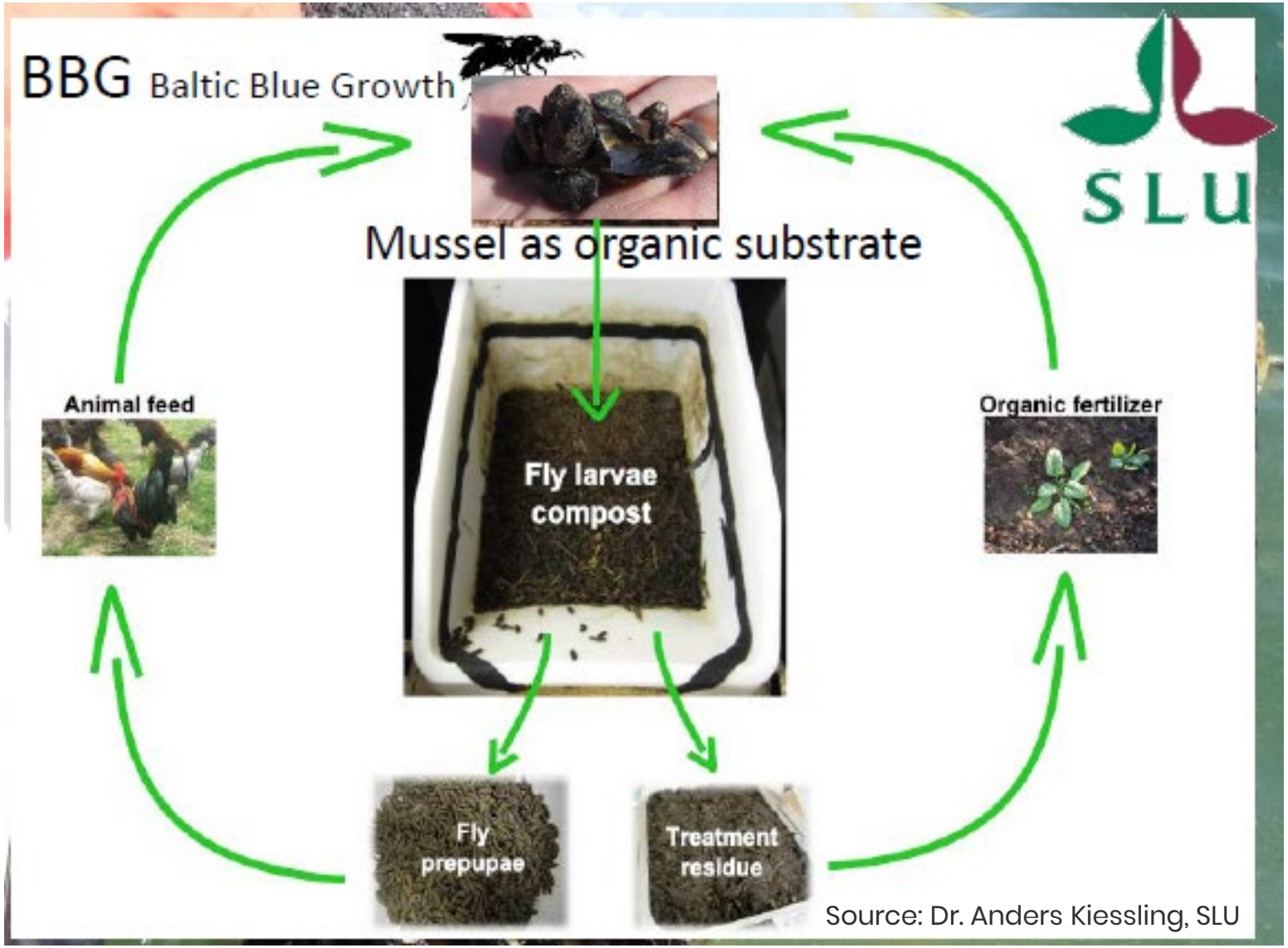
- In the feed for whiteleg shrimp (*L. vannamei*) 50% of fishmeal could be replaced with insect meal.

- Up to 100% of the fish protein can be replaced in salmon diets with no adverse effects on fish growth or later on the peculiar taste of fish fillets!

What do Insects Feed On?



Insect Growing on Blue Mussel as Substrate



Yeast – Advances in Fermentation Technologies

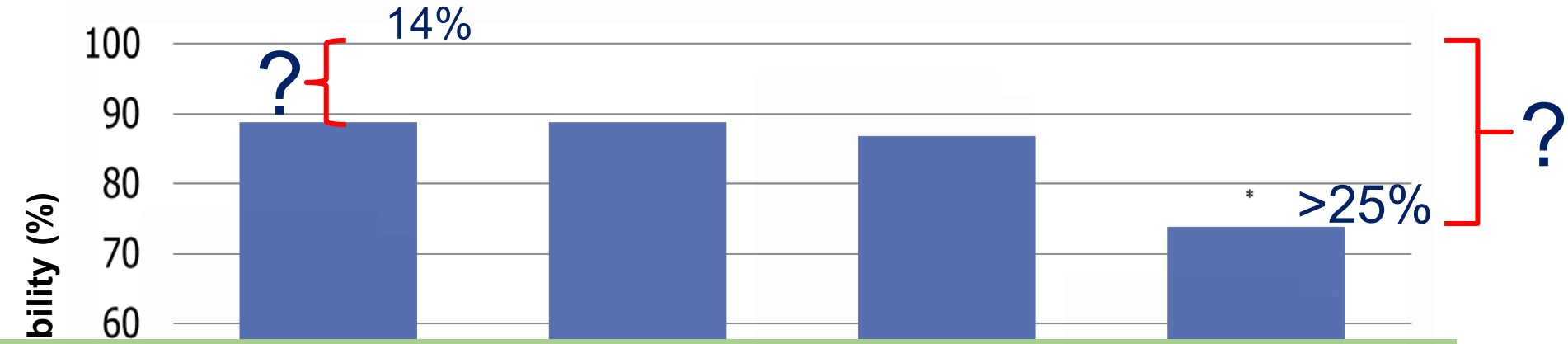
Yeast represents sustainable ingredients in aquatic feeds due to its ability to convert low value biomass into high value feed.

- Annually 10 mg of yeast can produce 150 tonnes of the yeast cell biomass;
- Swedish University of Agricultural Sciences in Uppsala (SLU) showed that the yeast species level in the diets did not affect gut microbiota;
- Yeast species found in feed diets were not found in the fish gut - full digestibility of the yeast materials;
- *Cyberlindnera jadinii* and *Kluyveromyces marxian*us may possibility replace up to 40% of protein from high-quality fishmeal, without any harmful effect on fish growth performance, digestibility or nutrient retention.

Yeast – Similar AA Composition to FM & SBM

Essential AA (%)	Yeast	FM (LT70)	SBM 48%
Arg	3.4	3.7	3.0
His	1.1	1.4	1.0
Ile	2.1	2.5	1.8
Leu	3.45	4.5	3.0
Lys	3.6	4.7	2.4
Thr	2.1	2.5	1.6
Trp	0.57	0.7	0.5
Val	2.5	2.7	1.9
Met	0.2	1.8	0.6
Cys	0.05	0.4	0.6
Phe	2.2	2.4	2.0
Tyr	1.8	1.9	1.4

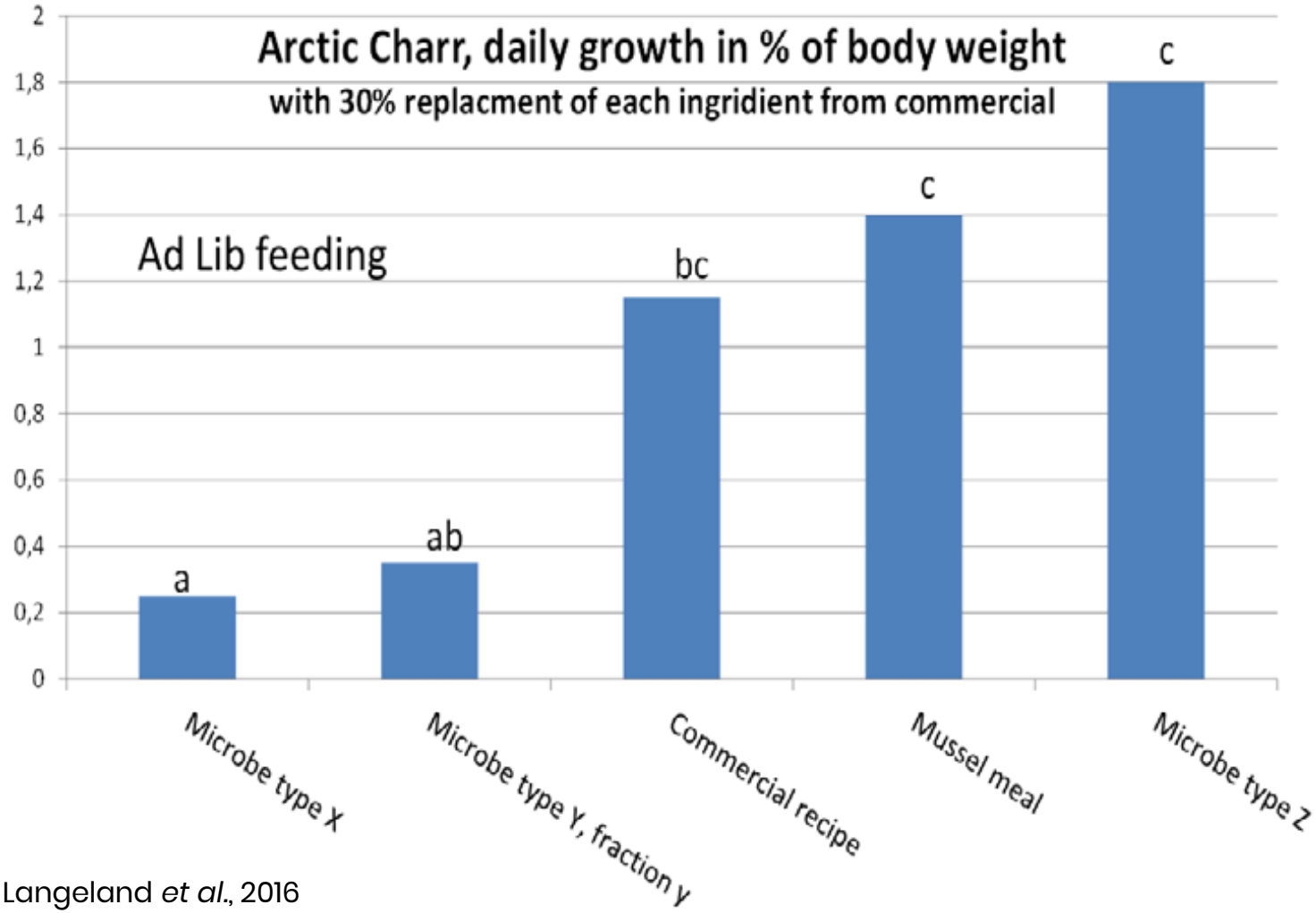
Cyberlindnera jadinii and *Kluyveromyces marxianus*



Amino Acid	FM	Torula	Milk yeast	Bakers yeast
Lysine	87 %	87 %	84 %	68 %
Methionine	86 %	83 %	79.5%	74 %
Agrinine	89 %	89 %	87 %	75 %
Leucine	88 %	89 %	81 %	67 %
	Fish meal	Candida utilis	Klyveromyces marxianus	Saccharomyces cerevisiae

Source: Øverland *et al.*, 2013, Aquaculture

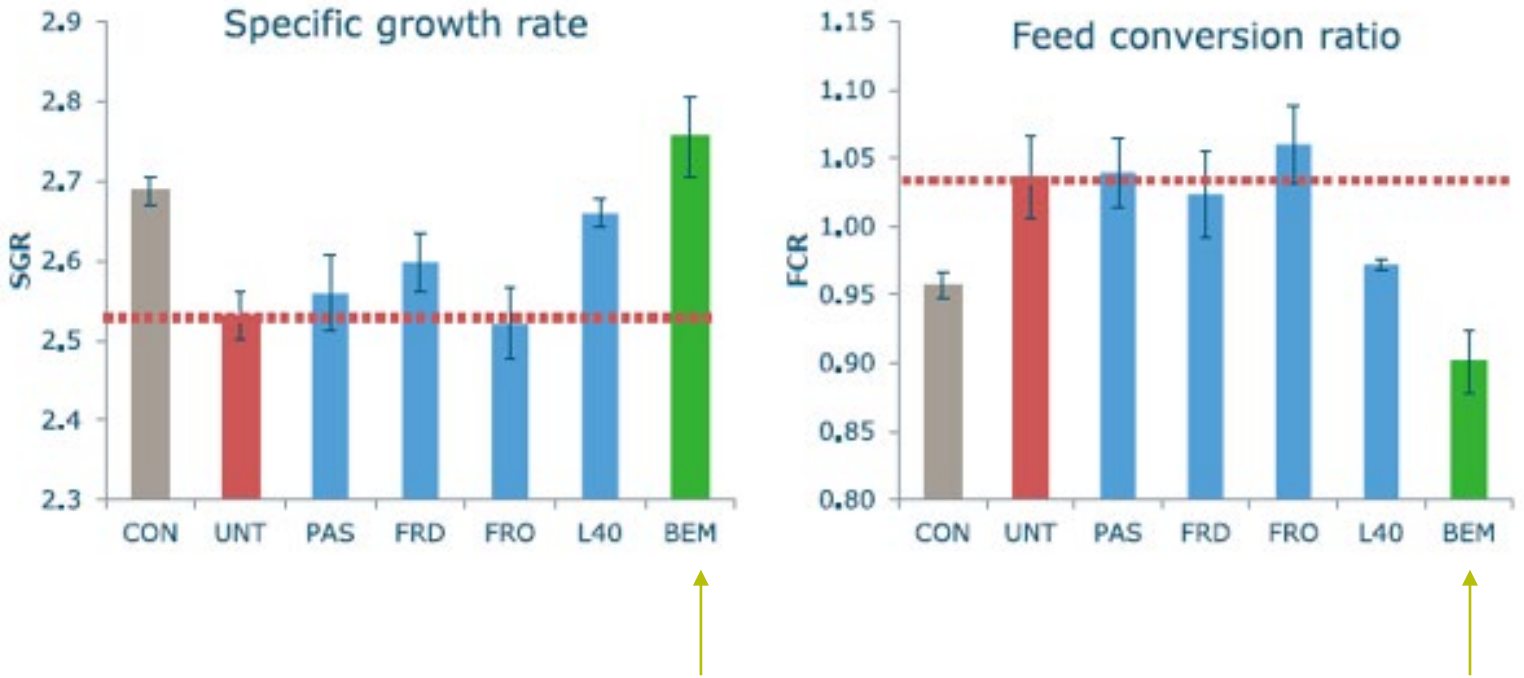
Mussel Meal and Yeasts – Good Alternative for Fish



Langeland *et al.*, 2016

30 % of Nannochloropsis g. – Alternative for High Fish Performance

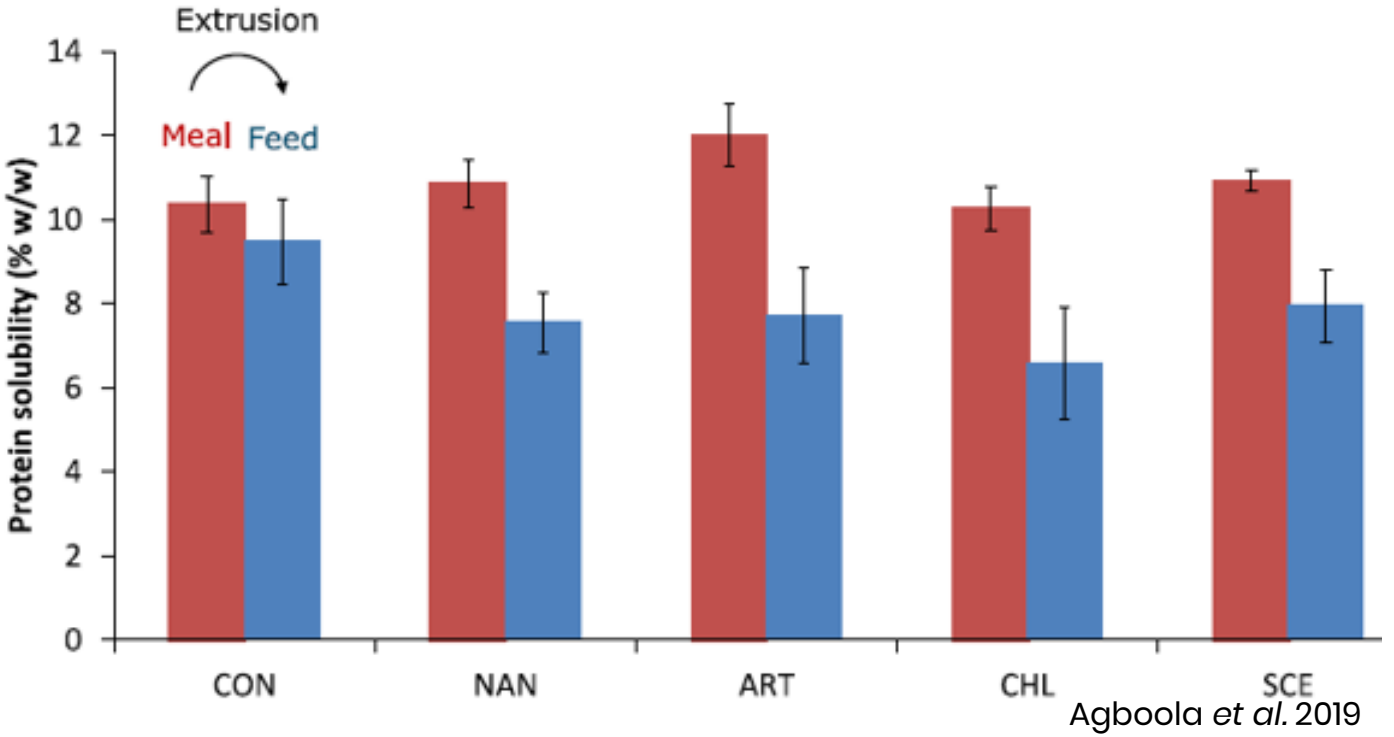
- Juvenile Nile tilapia fed with bead milled (BEM) diet performed better than the control group;



Teuling *et al.* 2018

Why bead milling?

Effect of Extrusion on Cell Integrity for Protein Solubility



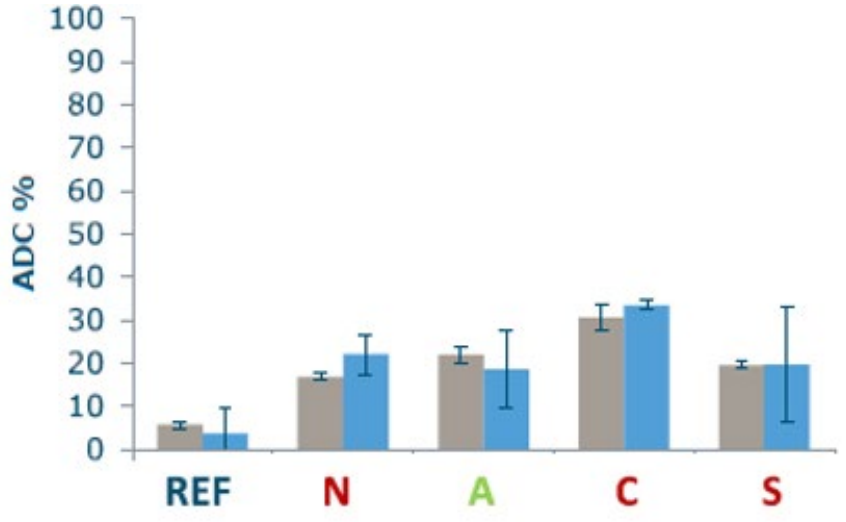
Agboola *et al.* 2019

No indication of loss of algae cell wall integrity during processing

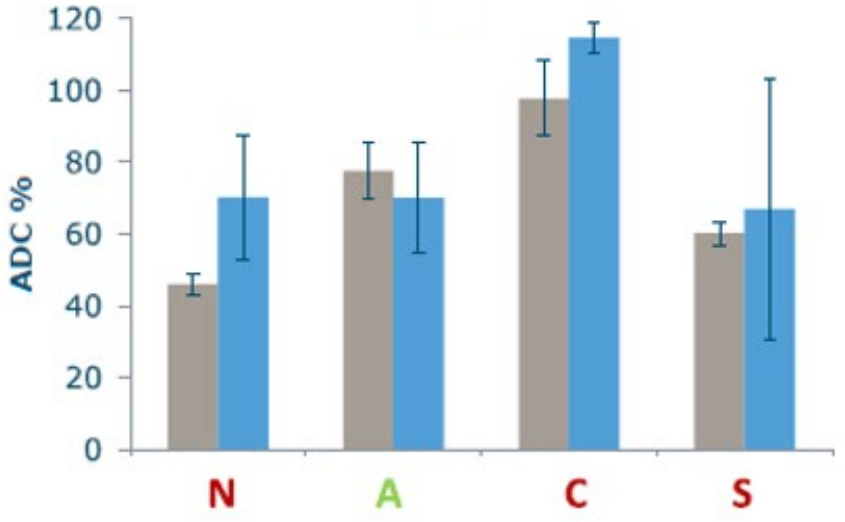
NSP from Microalgae is NOT a Problem for the Fish!

NSP – Apparent digestibility coefficients (ADC%)

NSP - Terrestrial



NSP – From microalgae



Tilapia Catfish

Teuling *et al.* 2018

- NSP from terrestrial sourced (REF) not digested (<30%)
- NSP from microalgae digested (>40% ADC)

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Challanges and Characteristics of Novel SCP

SCP sources	Protein content	Special characteristic	Example of specific	Challenges
Microalgae	60–70%	Phototrophic growth Production of omega-3 fatty acids	*Chlorella vulgaris* *Desmodesmus* sp.	Economical scale-up Cell disruption to release nutrients
Yeasts	30–50%	Use of a variety of feedstocks Production of vitamins and micronutrients	*Saccharomyces cerevisiae* *Cyberlinderna jjadini*	Improve protein and EAA content
Bacteria	50–80%	High protein Growth on C1	*Methylococcus* *Cupravidus nectar*	Palatability issues

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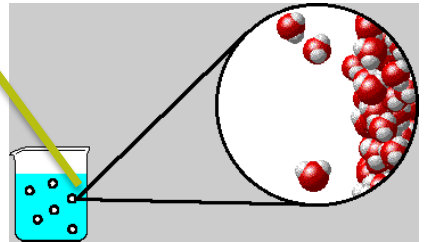
Physical Pellet Quality - Challenges with pelleted feed

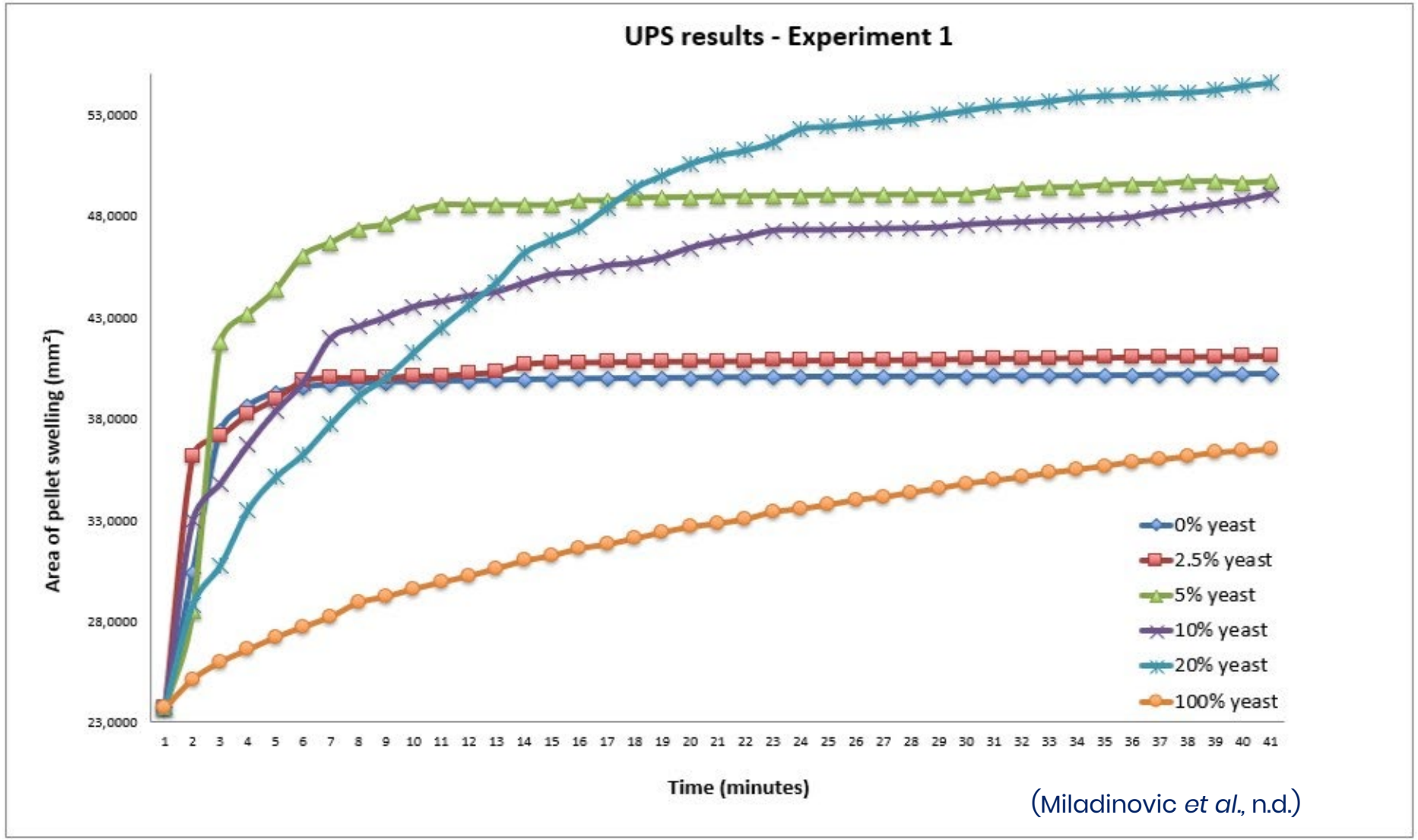
Sustainable ingredients are undoubtedly the most important **challenge** for the **aquaculture** industry

Physical quality – aquatic feeding



Challenge – Water Stability (swelling)

Pellets With 20% Torula Yeast Swell Significantly Faster Underwater



(Miladinovic *et al.*, n.d.)

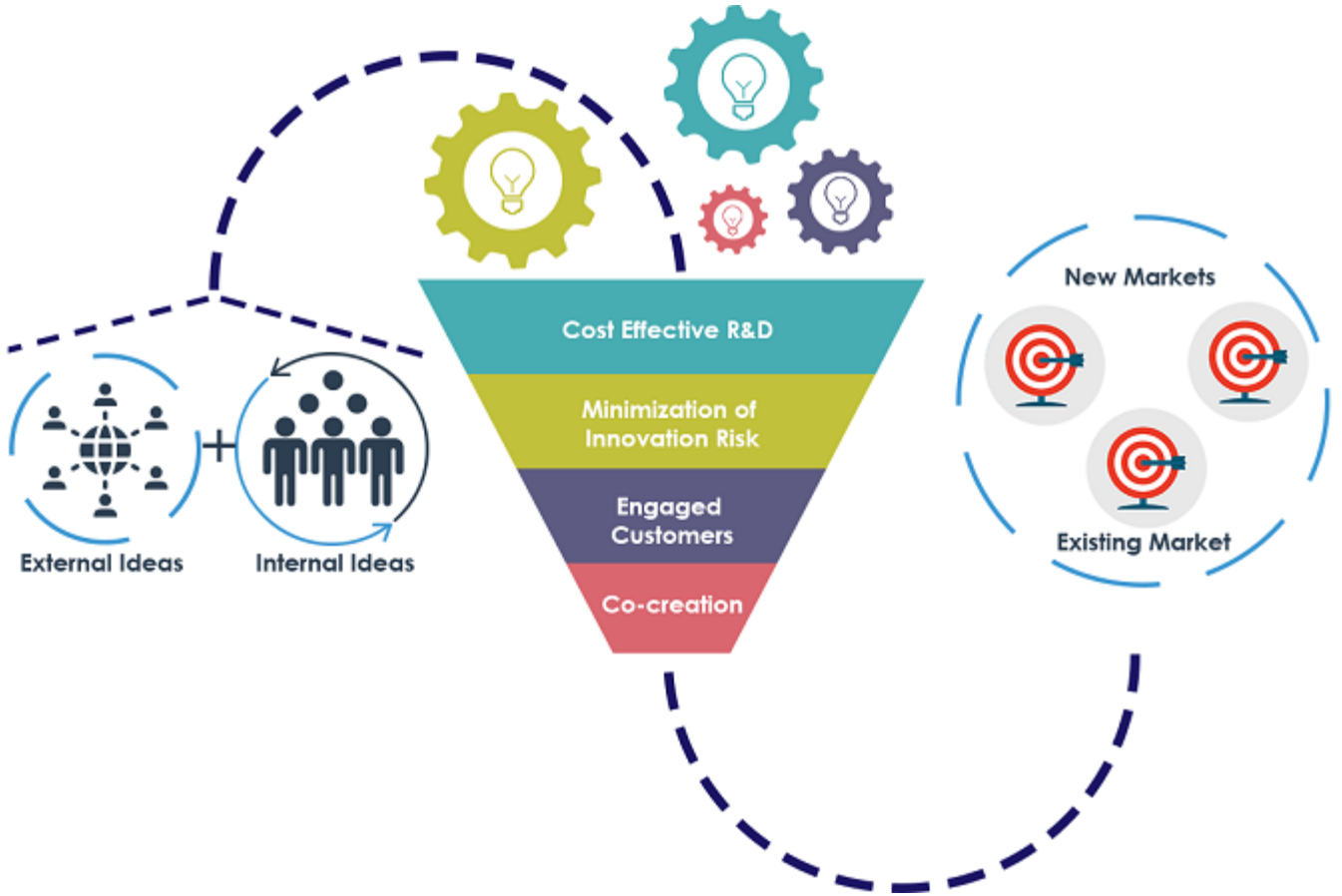
Challenges and Future Directions

- Scaling up production (must meet the demands of commercial aquaculture);
- Cost-effectiveness (optimization to ensure competitiveness with conventional feed ingredients)
- Research and innovation (strain selection, cultivation techniques, and feed formulation)
- Regulatory considerations (politics must evolve to support the integration of unicellular organisms into aquafeed while ensuring safety and sustainability)

Conclusion

- The aquatic feed industry can move towards stable and sustainable production by leveraging the nutritional value of the novel feed ingredients, their rapid growth, and resource efficiency;

- Collaboration between researchers, industry, and policymakers through OPEN INNOVATION may bring the full potential of unicellular organisms in aquafeed.



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Thank you!

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