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Microbes – a sustainable aquafeed resource for the future

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Overview

- Background - production, fermentable substrates, cell growth – type of microbe
- Some examples of microbial ingredients (single cell protein) that have been evaluated in aquaculture diets

GOAL: to convert inexpensive and inedible surplus or waste carbohydrates into high-value protein-rich and/or lipid-rich feed ingredients.

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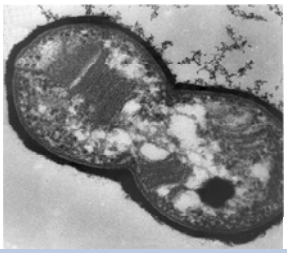
Introduction to Microbial ingredients

Bacteria
Methylococcus capsulatus



Yeast
Rhizopus oryzae, Pichia spp., Kluyveromyces spp

Microalgae
Phaeodactylum tricornutum, Nannochloropsis oceanica, Isochrysis galbana

Production - many possible substrates:

- Methane or methanol (e.g. natural gas)
- Co-products from first-gen biofuel production
- Co-products from second-gen biofuel production
- Waste from wood and agricultural industry
- Sunlight + CO_2

Choosing the substrate:
non-toxic, abundant, totally re-generable and inexpensive, non-exotic, and able to support rapid growth of the microorganism….

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Nutrient content vs. growth rate of the microbe:

Chemical content*	Bacteria	Yeast/Fungi	Filamentous Fungi	Algae
Crude protein,%	60-85	50-70	30-50	25-60
Nucleic acids, %	8-20	5-15	5-8	4-6
Lipids, %	2-10	2-10	10-25	5-45
Growth rate	Very high	High	Intermediate	Low

* NB!!! Chemical content can vary a lot among species within a microbial group and is also related to differences in growth conditions.

Organism, type of cell	Approx doubling time for the biomass (minutes)
Bacteria	45 (from approx. 10)
Yeast	90 (from approx. 20)
Fungi / Moulds	160
Protozoa	260
Mammalian cells	630-1260
Plant cells	3600-6600

Production of bacterial meal

BM; (BioProtein) is produced from metanotroph bacteria grown on natural gas

Methylococcus capsulatus

Methane
Oxygen
Ammonia
Minerals

Fermentor

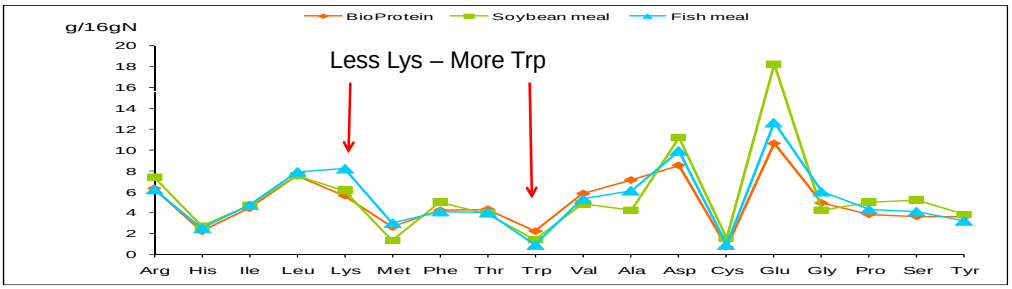
Bacterial meal

BM is produced from continuous aerobe fermentation in specially designed loop fermenters. The main bacteria is *Methylococcus capsulatus*. Natural gas is used as the energy and carbon source, ammonia as the N source. Also, oxygen and minerals are added to the process. The biomass is harvested, centrifuged and dried, all bacteria are killed in the process. The final product consists of a dry powder with a dry matter content of 95%.

Bacterial meal

Crude protein (10% nucleic acids)	**70%**
Crude lipids (phospholipids)	**10%**
Carbohydrates	**12%**
Minerals (high in Cu)	**7%**
Crude fiber	**1%**

> 90% Metylococcus capsulatus (Gram negative)



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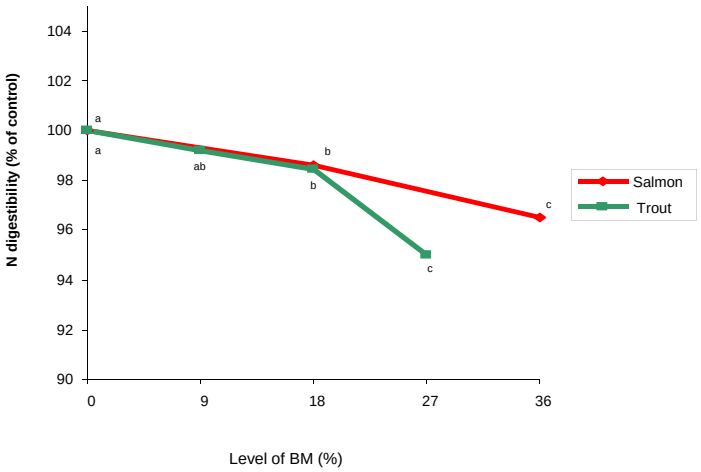
Crude protein digestibility in fish fed bacterial meal



Source: Aas 2006

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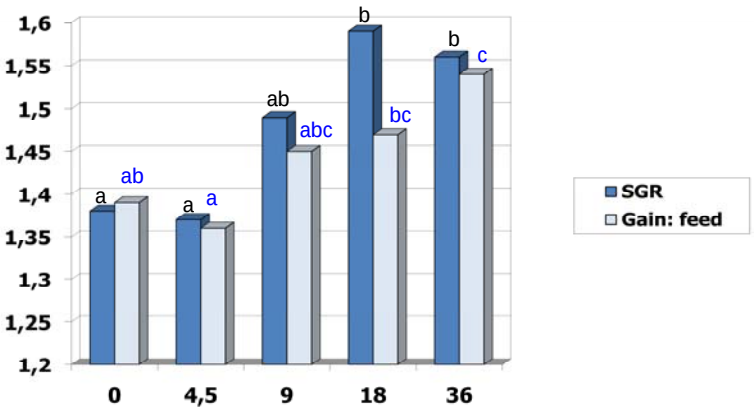
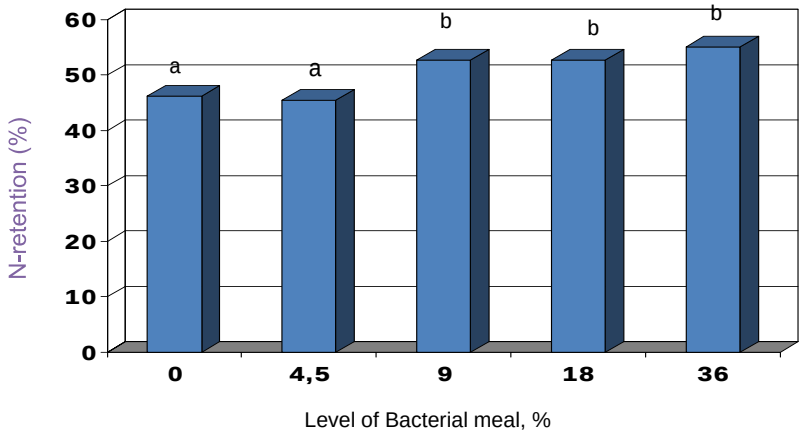
Growth performance in Atlantic salmon



Source: Aas et al. 2006

Nitrogen retention of salmon



Source: Aas et al. 2006

Bacterial meal and soy-induced enteritis in salmon

- 4 diets
- Atlantic salmon (130 g)
- 3 tanks per diet
- 2½ months feeding
- Salt water

Diet, %	FM diet	SBM diet	BM diet	BM-SBM diet
Fishmeal (FM)	59	41	31	13
Soybean meal (SBM)	0	20	0	20
Bacterial meal (BM)	0	0	30	30

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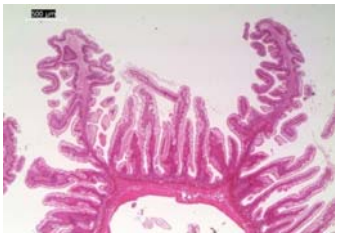
BM: effect on histology of distal intestine



Normal

Soy-induced enteritis

N= 15 fish per treatment

Diet	Fish meal	Soy bean meal	Bacterial meal	Soy & Bacteria
Normal tissue	**15**	0	**15**	**15**
Fish with soy-enteritis	0	**15**	0	0

Source: Romarheim et al., 2011.

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Graded levels of Bacterial meal and soy enteritis in salmon

- 8 diets
- Atlantic salmon (270g)
- 2 tanks per diet
- 1 ½ months feeding
- Salt water

Diets	1	2	3	4	5	6	7	8
Fishmeal (FM)	64	46	44	41	36	32	27	17
Bacterial meal (BM)	-	-	2.5	5	10	15	20	30
Soybean meal (SBM)	-	20	20	20	20	20	20	20

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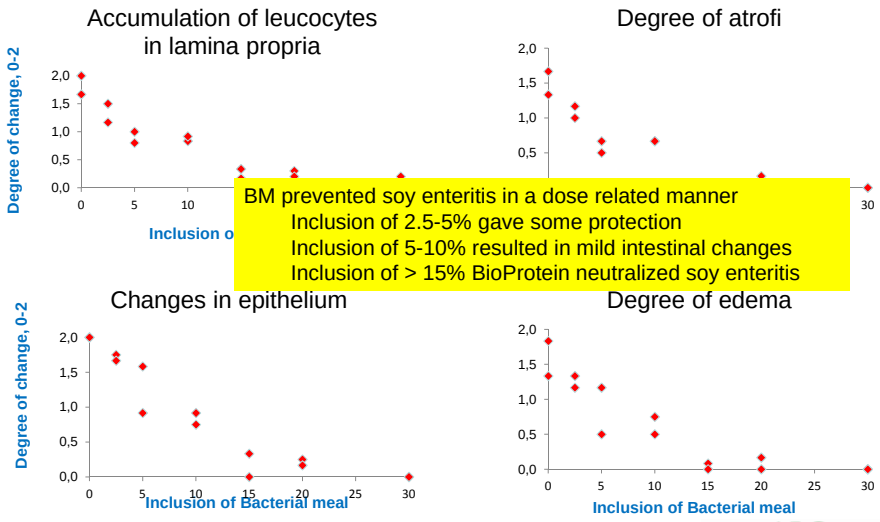
Histology in distal intestine



BM prevented soy enteritis in a dose related manner
- Inclusion of 2.5-5% gave some protection
- Inclusion of 5-10% resulted in mild intestinal changes
- Inclusion of > 15% BioProtein neutralized soy enteritis

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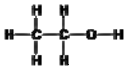
Production of yeast

Waste products from agriculture, wood and paper industry

- Pentoses
- Hexoses
- Oxygene
- Minerals



Ethanol

Yeast

Rhizopus oryzae, Pichia spp., Kluyveromyces spp

Chemical content	
Dry matter	96%
Crude protein	40-50%
Crude fat	10-20%

Production of microalgae

Omega-3

Sunlight →
Water →
CO_2 →
Minerals →

Chemical content	
Dry matter	96%
Crude protein	25-50%
Crude fat	10-25%

Nannochloropsis oceania
Isochrysis galbana
Phaeodactylum tricornutum
Chlorella vulgaris

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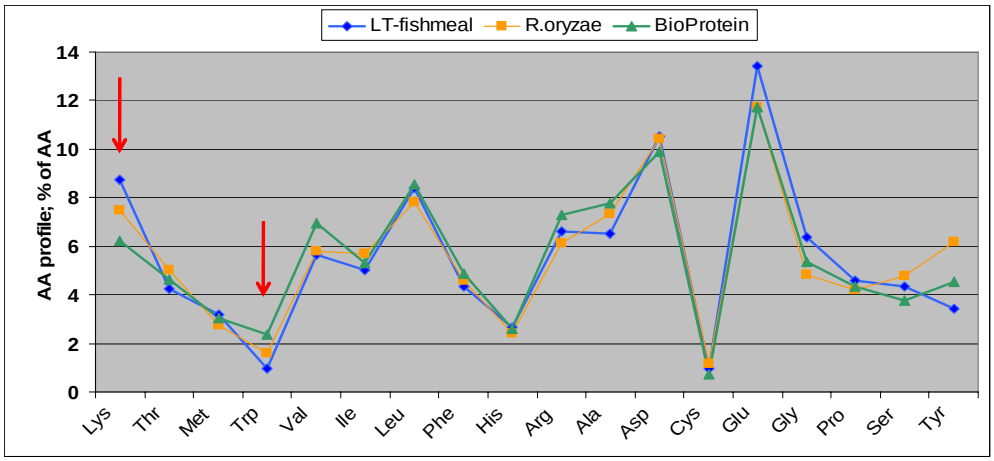
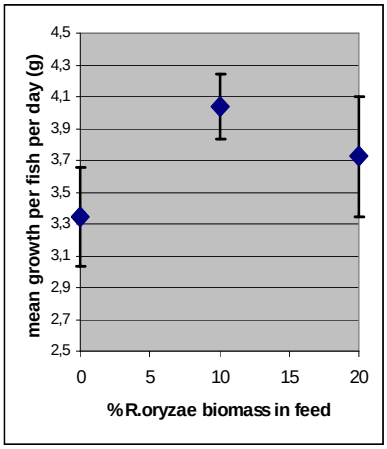
Amino acid composition in *Rhizopus oryzae*



Rhizopus oryzae

- 3 month growth trial with Atlantic salmon in freshwater
- No significant difference in growth rate or feed conversion ratio
- Best performance was reached with 10% yeast inclusion



	0 %	10 %	20 %	SEM
DM intake , g	55	46	51	2.0
Weight gain, g	54	61	56	6.1
Growth rate, %/day	1.2	1.4	1.2	0.12
Feed efficiency, kg/kg	1.0	1.3	1.1	0.11

Source: unpubl. res. SLU, Sweden & APC, Norway.

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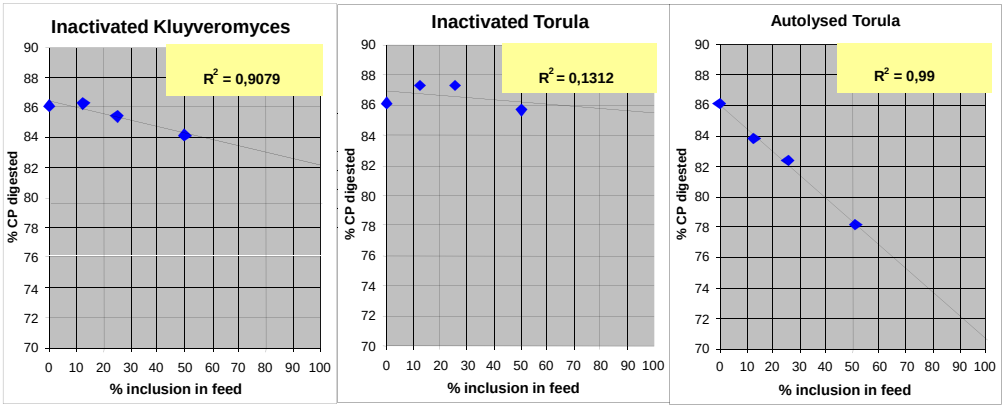
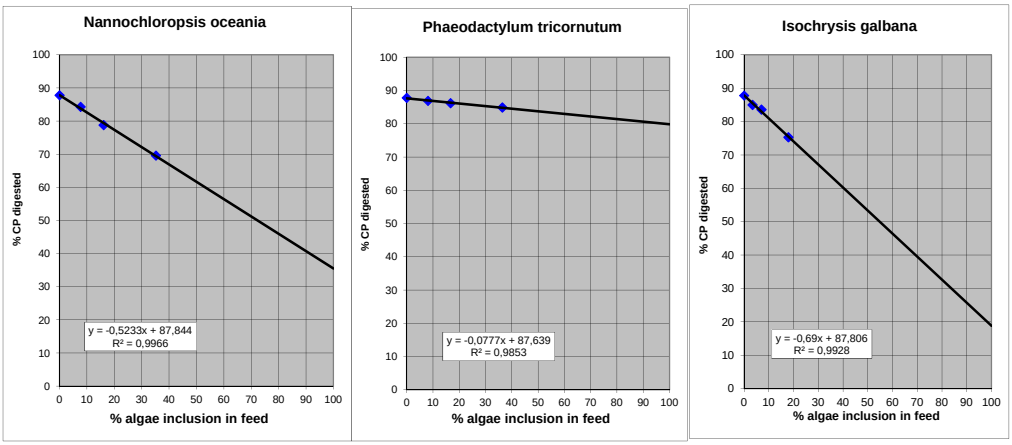
Digestibility of Crude Protein in various yeast products (using mink as a model for fish)



Source: APC, Mydland et al., unpublished

Digestibility of Crude Protein in various algae products (using mink as a model for fish)



Source: Skrede et al. 2011.

Conclusion

- Microbes represent a promising fish feed ingredient.
- They are sustainable feed resources - they don't require agricultural land, use little water and can be made from non-food raw materials.
- To be successful, microbial ingredients must have a high nutritional value and be produced economically.
- Many interesting bioactive components that may give positive health effects.
- Recent revisions of EU regulations on microbial protein sources (Regulation (EC) No 767/2009) will facilitate development and use of such products as feed ingredients.