

Plenty more fish in the forest

Margareth Øverland

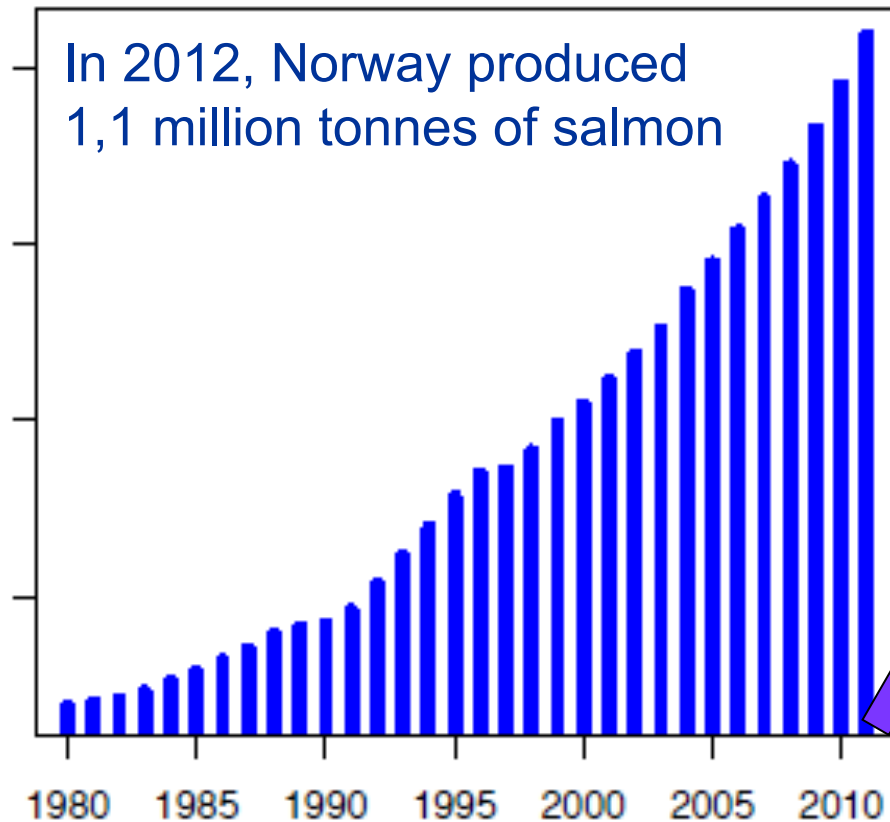
MIC , September 24, 2013



Prediction: Huge growth in aquaculture

(Verdiskapning basert på produktive hav i 2050)

Production of salmon in Norway



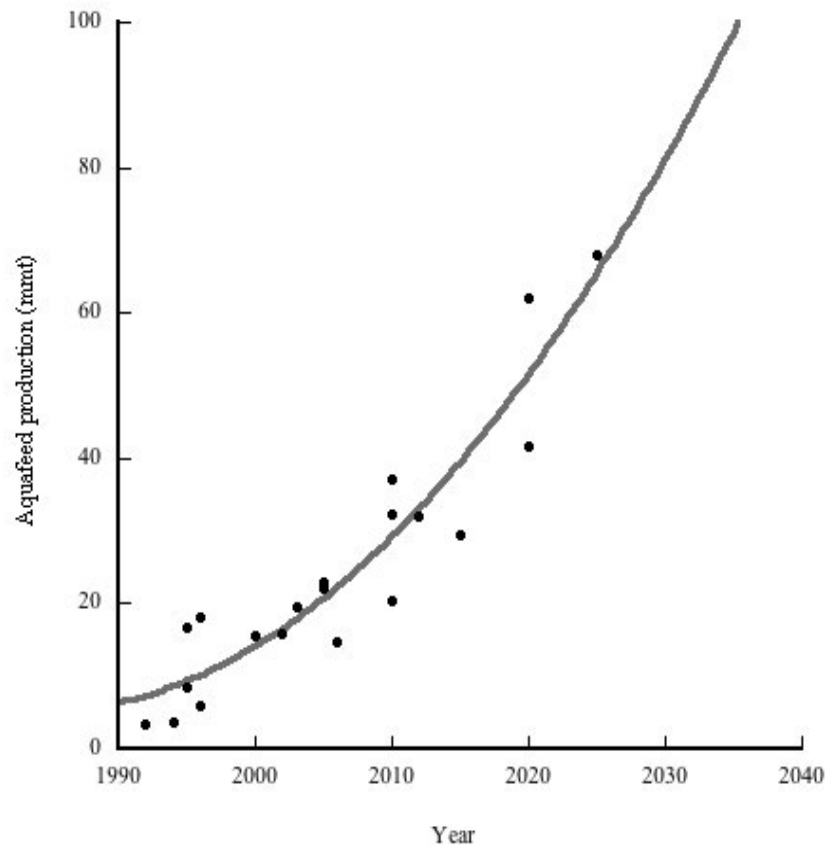
I 2050 = 5 Mill tonn

source: FAO.org



Aquafeed production

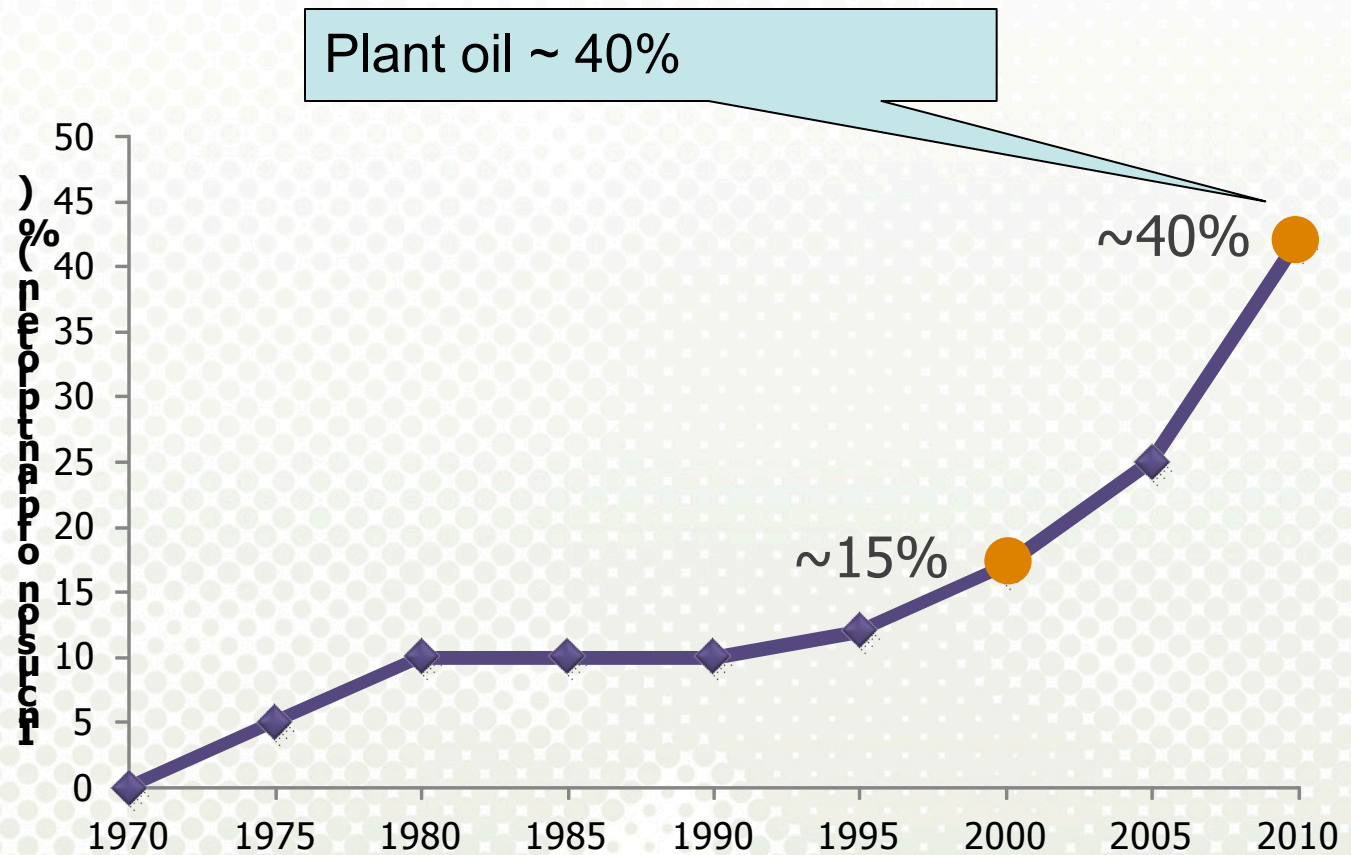
Need for fish feed and prognoses until 2040



Global compound feed production:
Total in 2011: 873 million tons
Aquafeed: 28.7 million tons

From various sources

Plant ingredients in Norwegian salmon feeds



Modified from Torrissen et al. (2011)

www.umb.no



Potentials and challenges with plant ingredients

Advantages

- Availability and supply
- Environmental profile
- Low cost

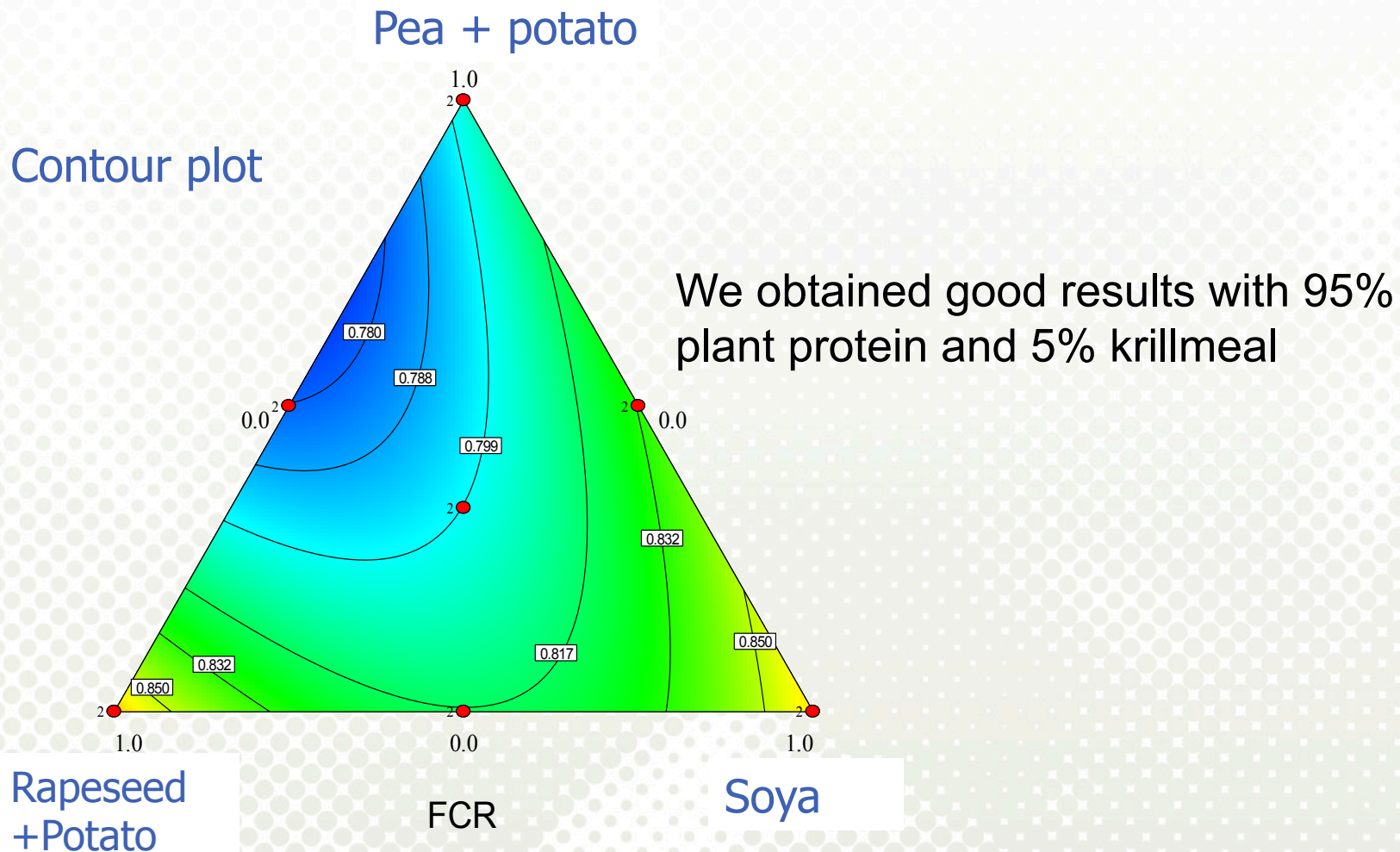
Disadvantages

- Low nutrient density
- Unbalanced AA profile
- Antinutrients
- No EPA or DHA



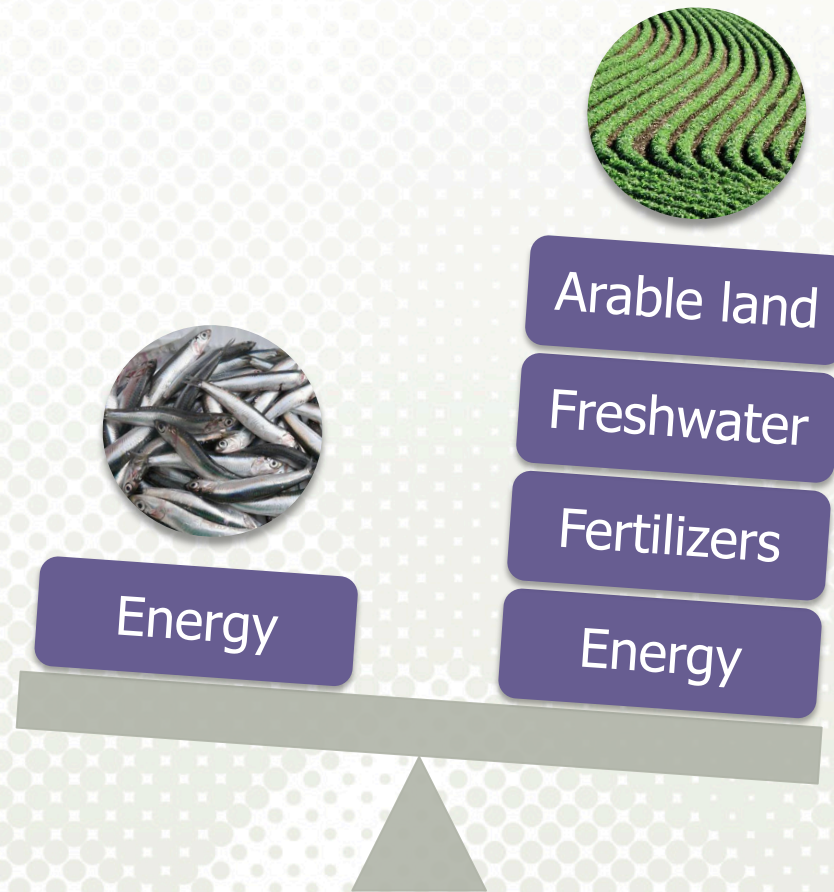
Fishmeal-free diets for salmonids

Optimal combination for best performance



How sustainable are plant ingredients?

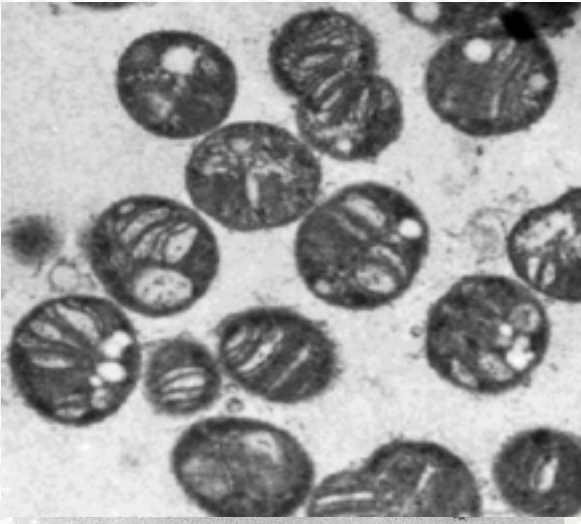
Should we be using human food to feed farmed fish?



Microbial ingredients in fish feeds

Bacteria

Methylococcus capsulatus



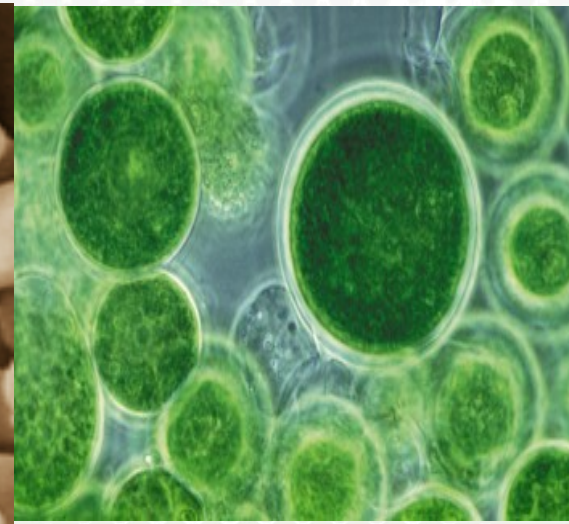
Yeast/Fungus

Kluyveromyces



Microalgae

Phaeodactylum, *Chlorella*,



Production of protein from natural gas

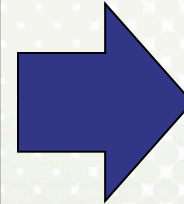
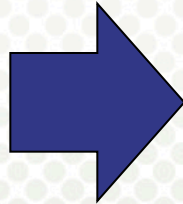


Natural gas

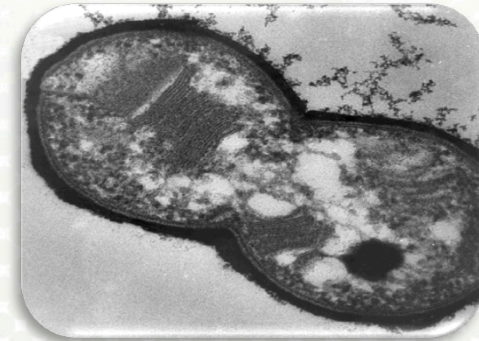
Oxygen

Ammonia

Minerals



Methylococcus capsulatus

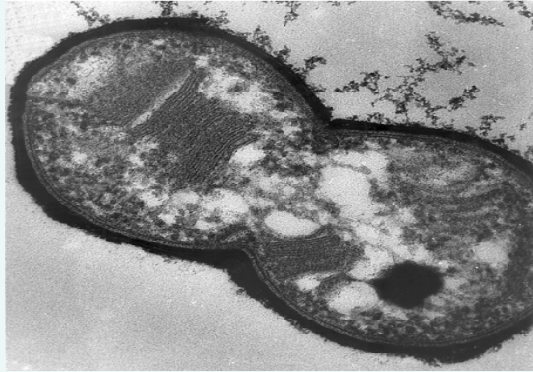


Bacterial meal

Only 1% of Norwegian natural gas exports are sufficient to meet the protein demand for the Norwegian aquaculture industry today

Bacterial meal

Methylococcus capsulatus



- Methanotroph bacteria
- High protein content

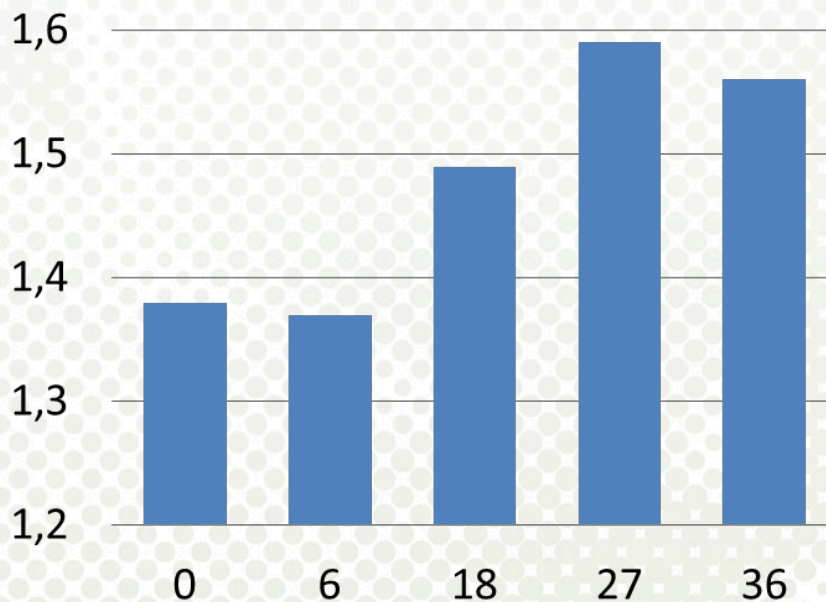
Protein	70%
Fat	10%
Carbohydrates	12%
Ash	7%

Other traits:

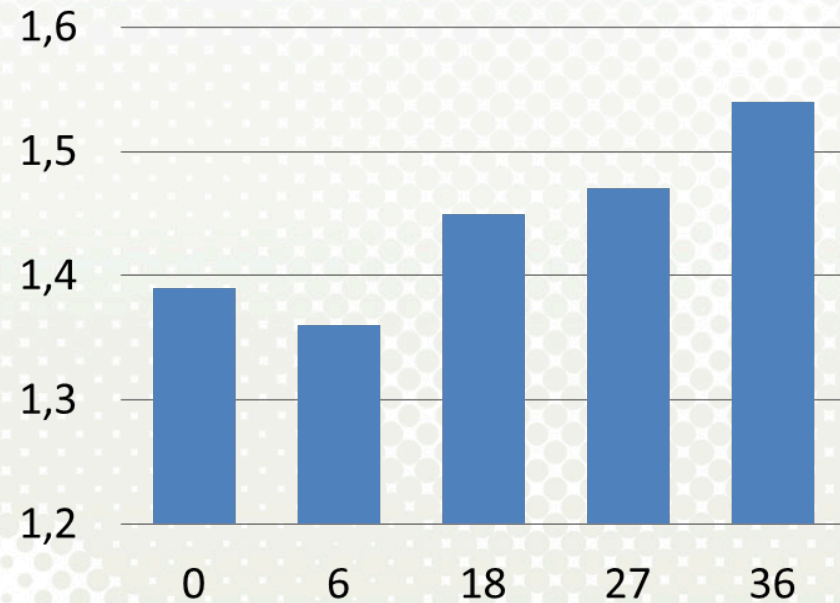
- favorable amino acid composition
- 10 % nucleic acids
- Bioactive components

Growth and feed efficiency of salmon fed increasing levels of bacterial meal

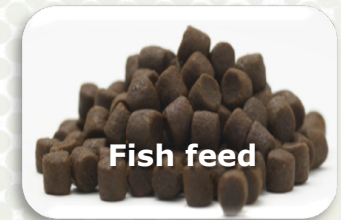
Specific growth rate, %/day



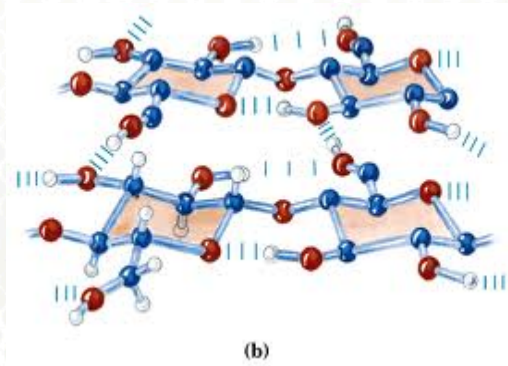
Feed efficiency, gain:feed



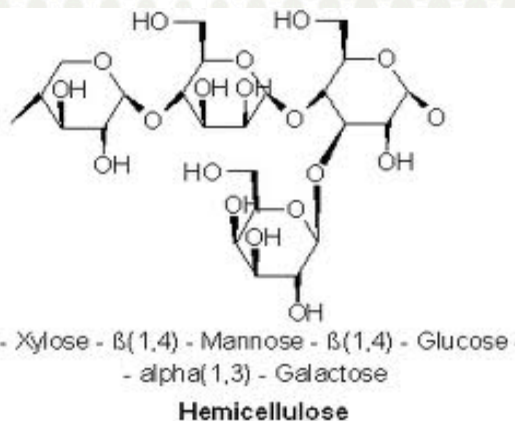
Fish feed from low-value biomass



Production of yeast from forest biomass



Cellulose



Mechanical treatment



Thermo-chemical treatment



Enzymatic hydrolyzes



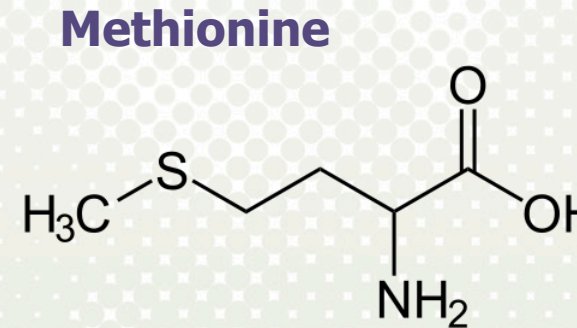
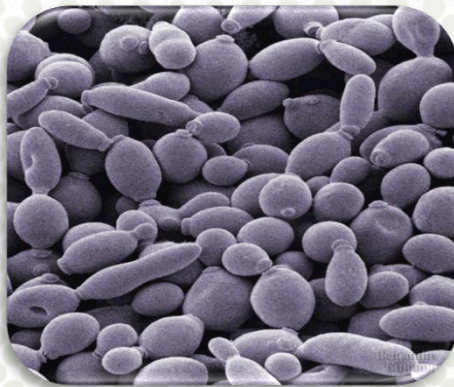
Fermentation

Yeast produced from forest biomass –a potential high-value feed resource

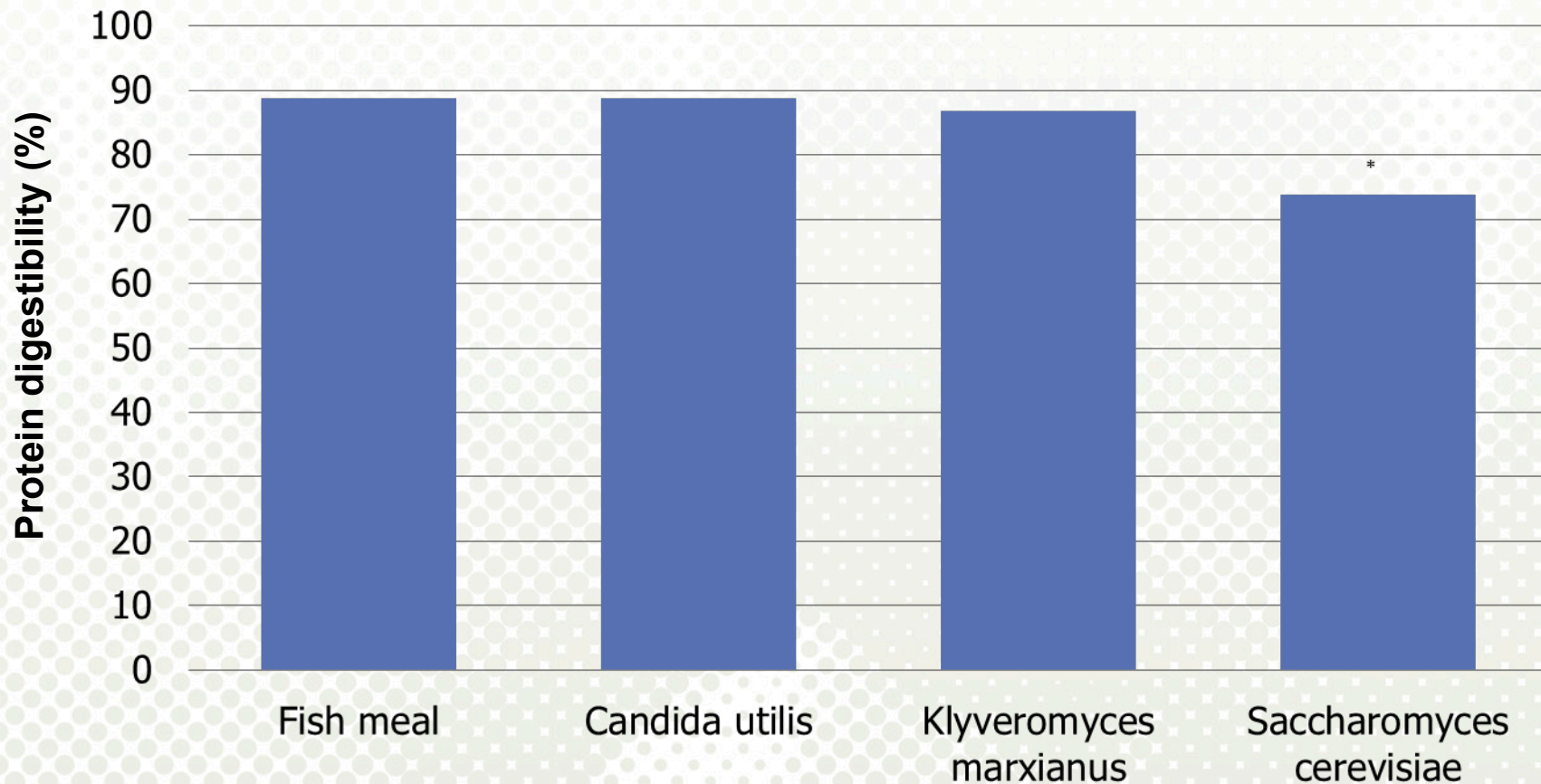


Yeast:

- ~ 50% protein, 2-10% lipids
- High protein value

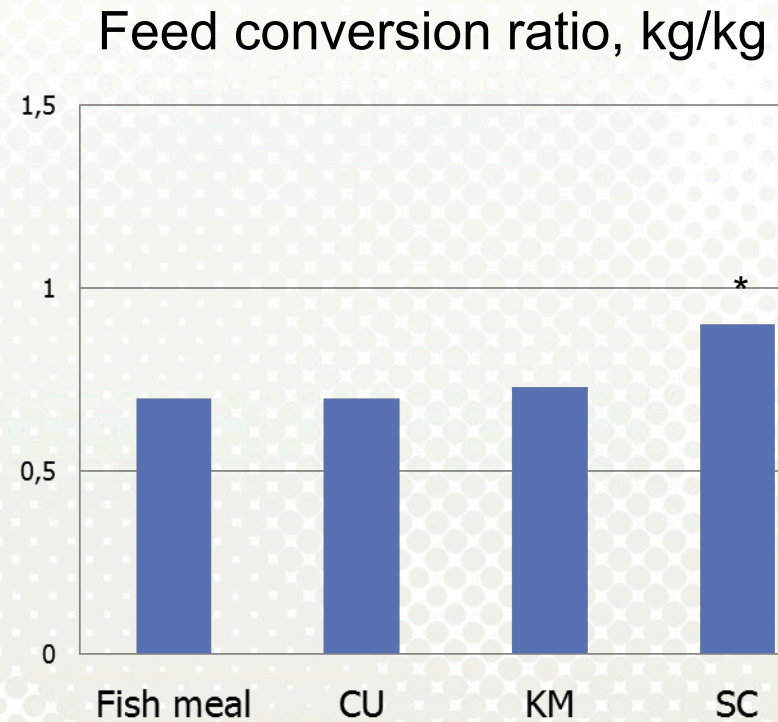
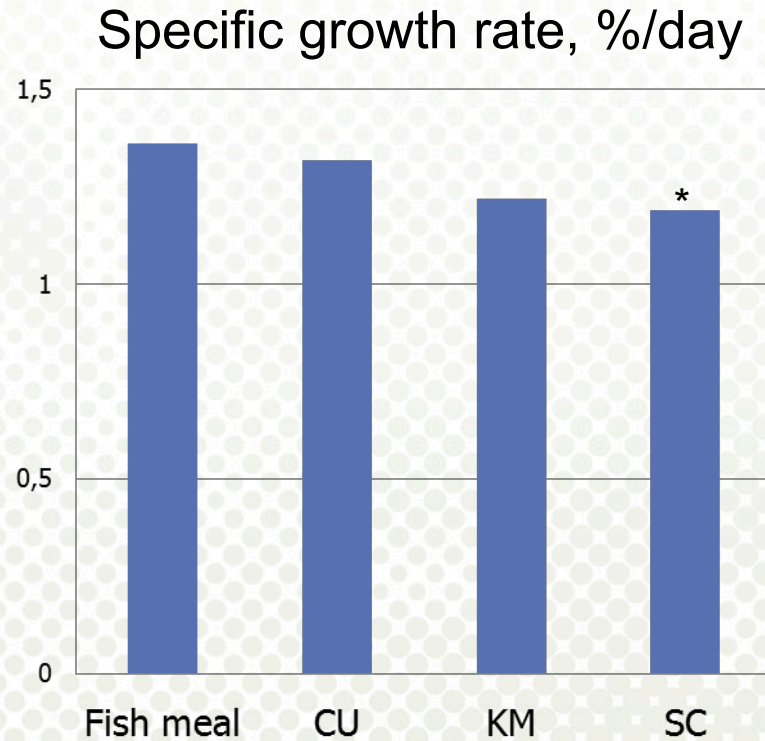


Digestibility of protein in salmon fed 30% yeasts



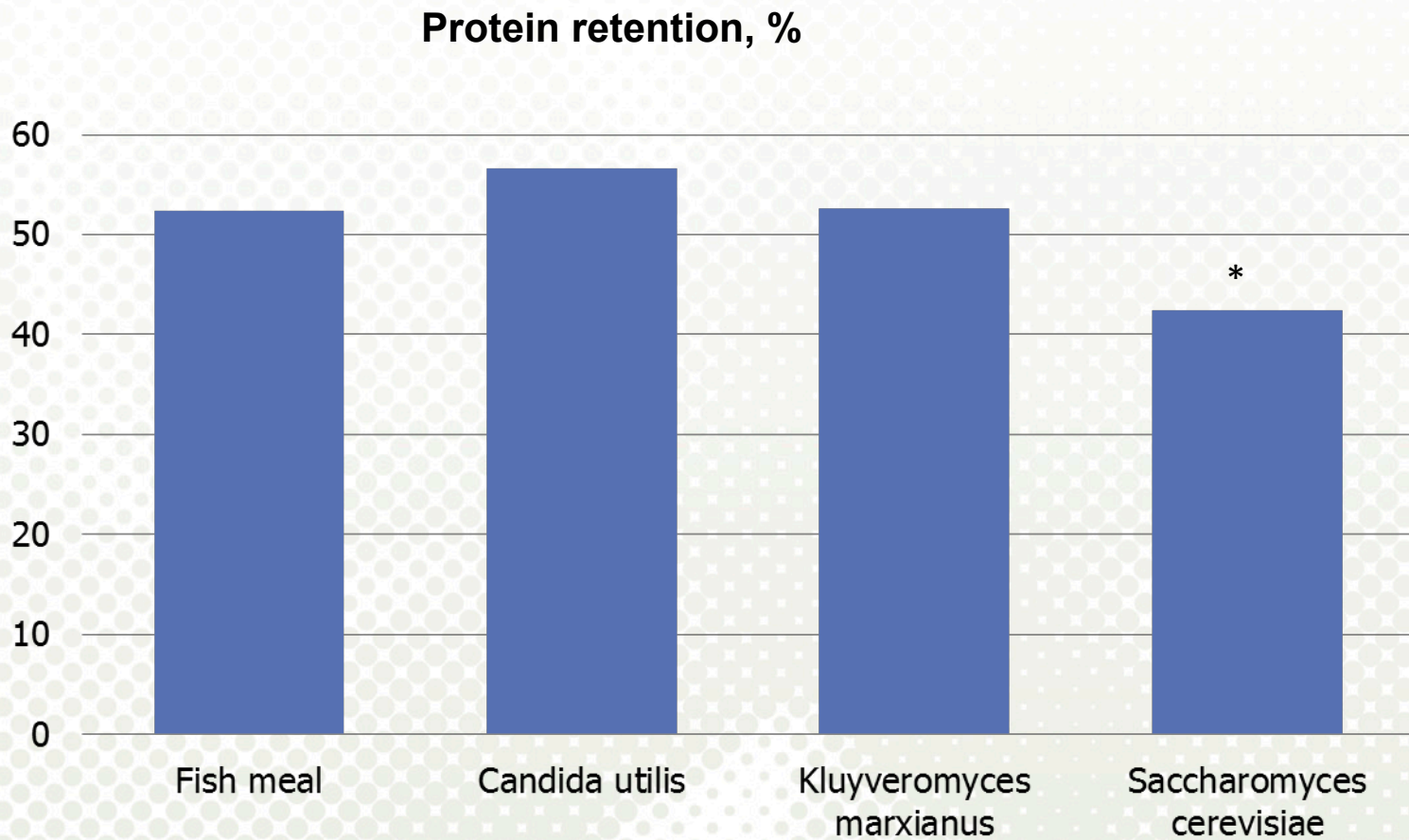
Source: Øverland et al., 2013, Aquaculture

Growth rate and feed conversion ratio of salmon fed 30% yeast



Source: Øverland et al., 2013, Aquaculture, 402–403 1–7

Protein retention in salmon fed 30% yeast



Source: Øverland et al., 2013, Aquaculture, 402–403 1–7

Plant ingredients increase risk of gut health disorders in fish

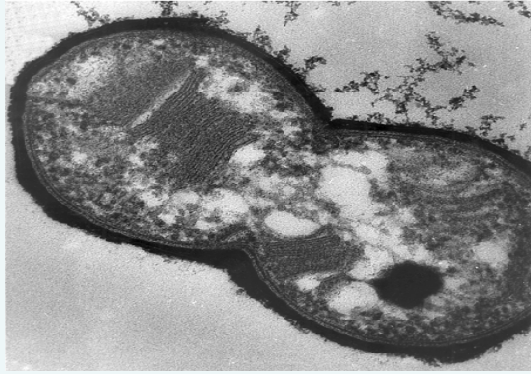


Soybean meal in feed for Atlantic salmon induces a dose-dependent inflammation (enteropathy) in the distal intestine



Feeding bacterial meal prevented soybean meal induced enteritis (SBMIE) in Atlantic salmon

Methylococcus capsulatus



- ❑ Methanotroph bacteria
- ❑ High protein content

Protein	70%
Fat	10%
Carbohydrates	12%
Ash	7%

- ❑ Romarheim OH, Øverland M, Mydland LT, Skrede A, Landsverk T Bacteria grown on natural gas prevent soybean meal(SBM) induced enteritis in Atlantic salmon. The Journal of Nutrition (2011) vol. 141 (1) pp. 124-30
- ❑ Romarheim OH, Hetland DL, Skrede A, Øverland M, Mydland LT, Landsverk T Prevention of soya-induced enteritis in Atlantic salmon (*Salmo salar*) by bacteria grown on natural gas is dose dependent and related to epithelial MHC II reactivity and CD8+ intraepithelial lymphocytes. The British journal of nutrition (2012) pp. 1-9
- ❑ Romarheim OH, Landsverk T, Mydland LT, Skrede A, Øverland M Cell wall fractions from *Methylococcus capsulatus* prevent soybean meal-induced enteritis in Atlantic salmon (*Salmo salar*). Aquaculture (2013) vol. 402-403 pp. 13-18

Hypotheses:

Microbial ingredients like yeast and microalga could have similar health-beneficial properties

Microbial products tested:

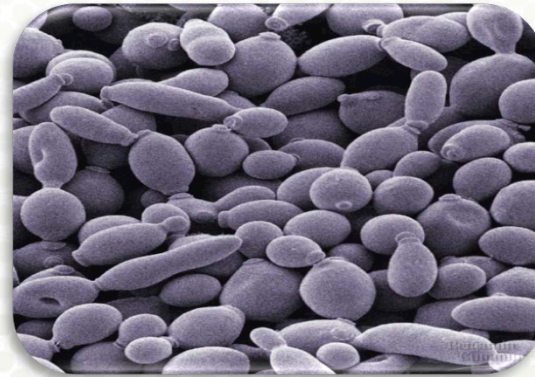
Yeast

1. *Candida utilis*
2. *Kluyvermyces marxianus*
3. *Saccharomyces cerevisiae*

Microalgae

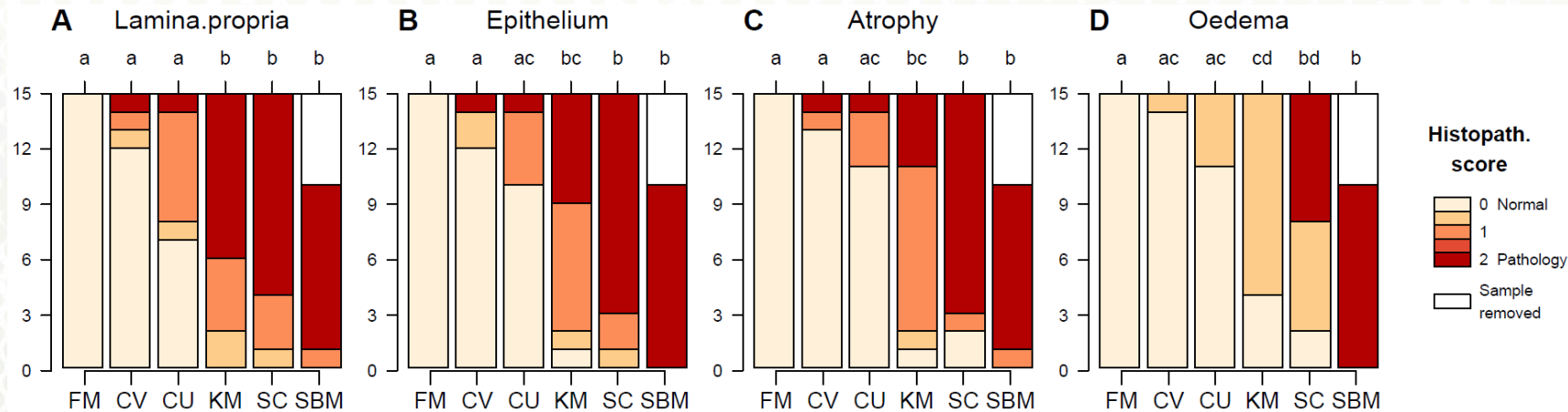
4. *Chlorella vulgaris*

Effect of yeast in diets with 20% soybean meal on gut health (SBMIE)



Feed, %	Fishmeal	Soy	Single cell
Fishmeal	71	51	30
Soybean meal	-	20	20
Yeast, microalgae	-	-	20

Effect of microbial ingredients on distal gut histology in salmon



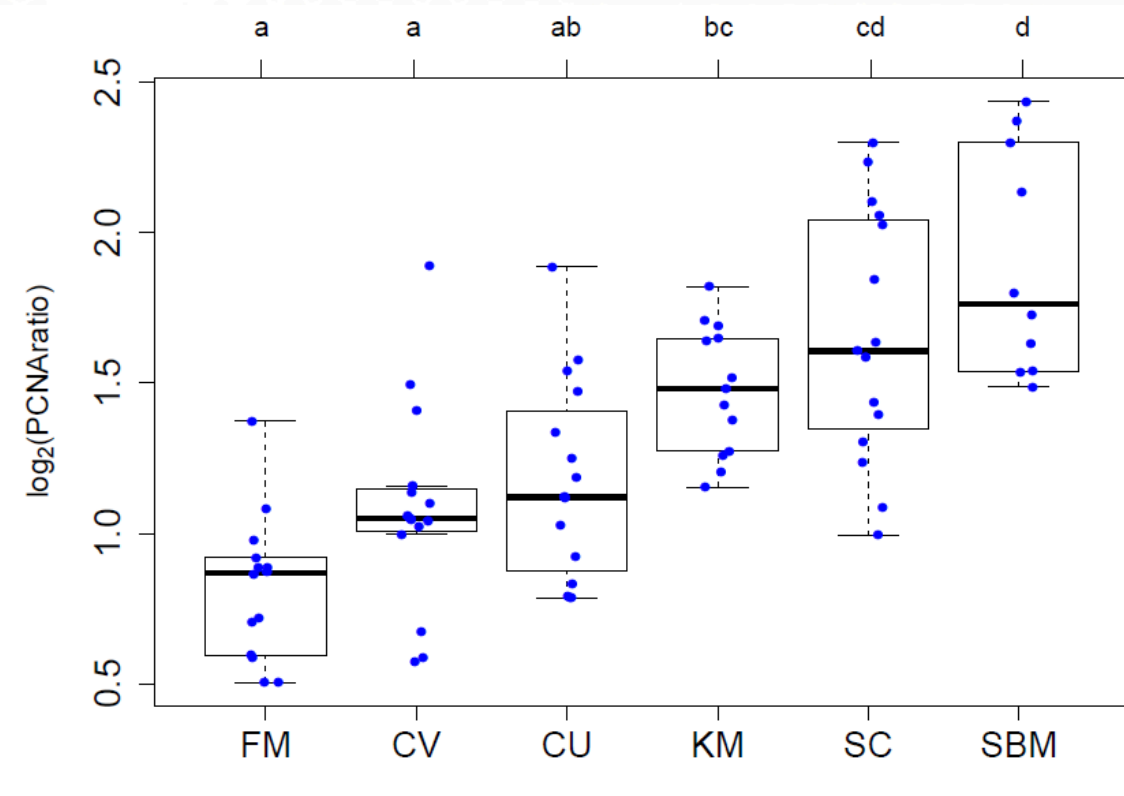
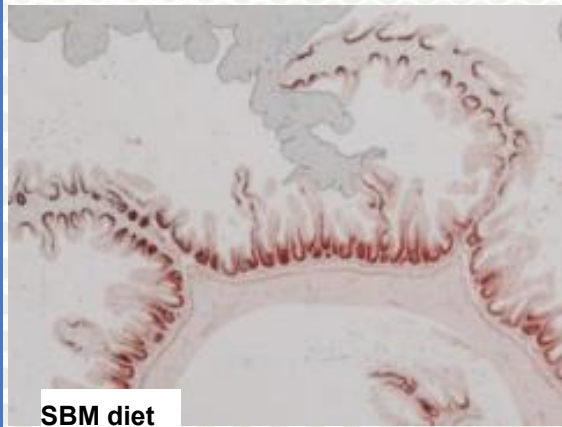
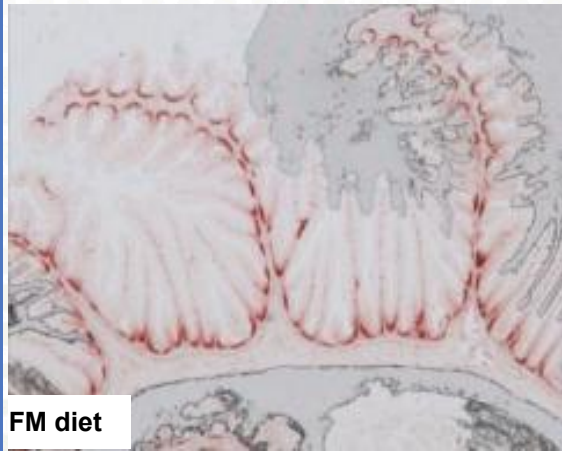
❑ Outlier from one tank in the SBM group was removed

Histology scores

Scale from 0 to 2,
 2 = full enteritis, red,
 0 = normal, beige.
 1 = slight to moderate enteritis

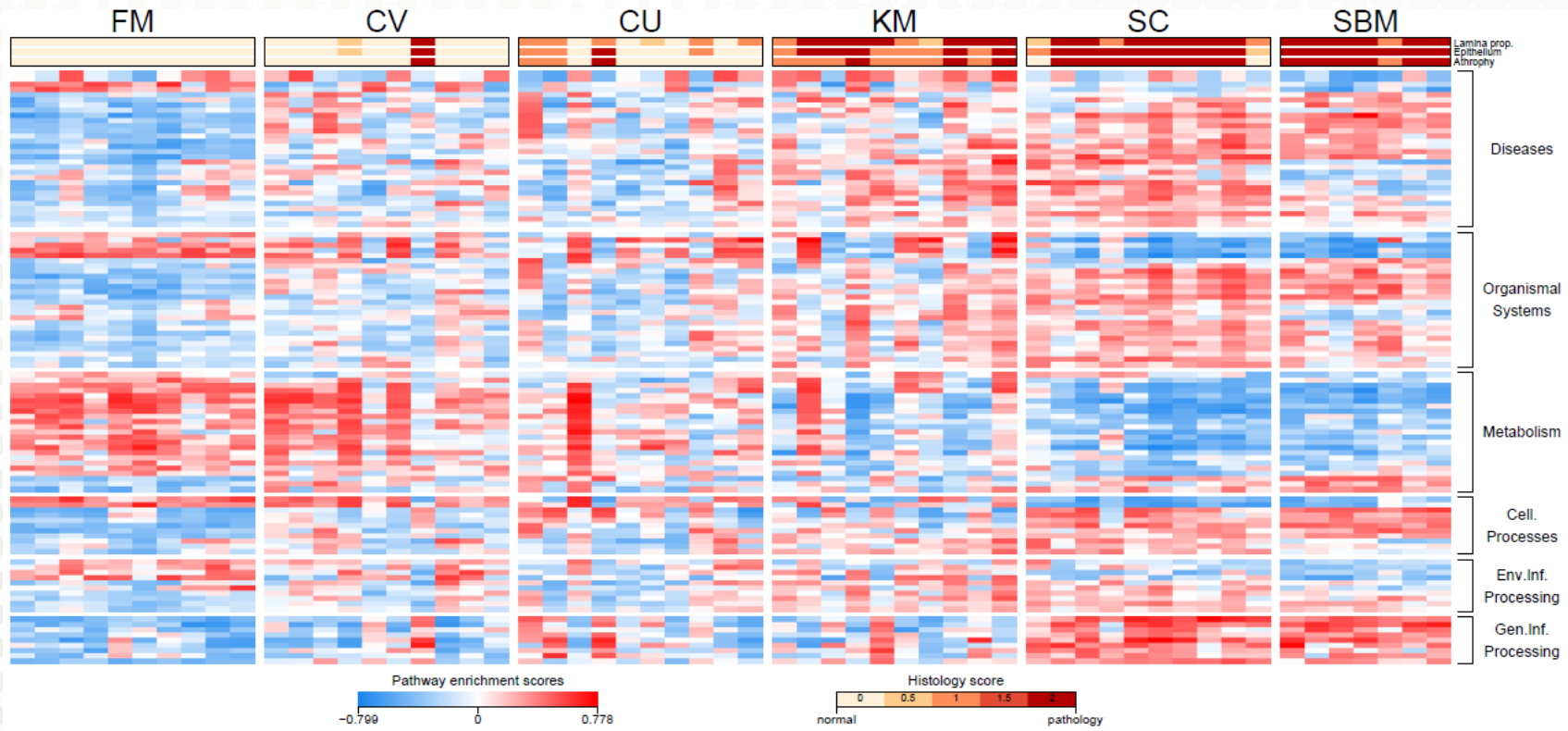


Effect of microbial ingredients on PCNA in distal intestine of salmon



Effect of microbial ingredients on gene expression in distal intestine

Heat map - Gene expression – pathways - KEGG



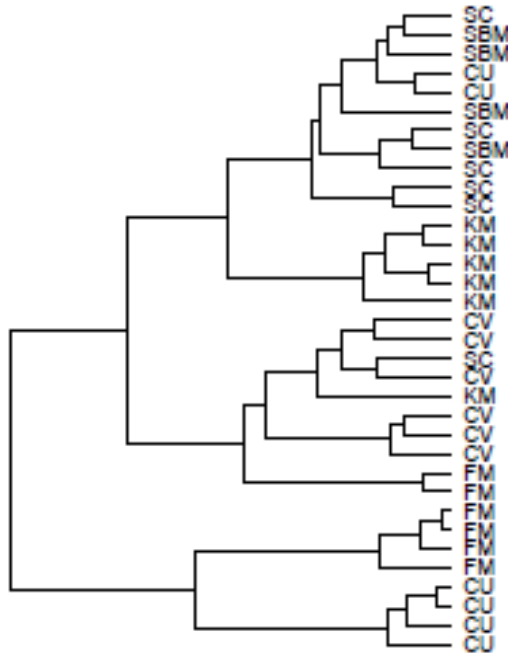
Source: Grammes et al., 2013, PlosOne In press



Effect of microbial ingredients on gut microbiota in salmon

Relative abundance of bacteria in distal intestine

A



Forest –a new blue-green value chain



Conclusion

- The rapid growth in the aquaculture industry puts large demand on feed resources
- Aquafeeds are under rapid development
 1. More use of plant ingredients
 2. Lower proportion of marine ingredients
 3. **Non-food ingredients become feasible**

Microbes represent promising feed ingredients. They do not require agricultural land, use little water and can be made from non-food raw materials