

# *Plenty more fish in the forest*

Margareth Øverland

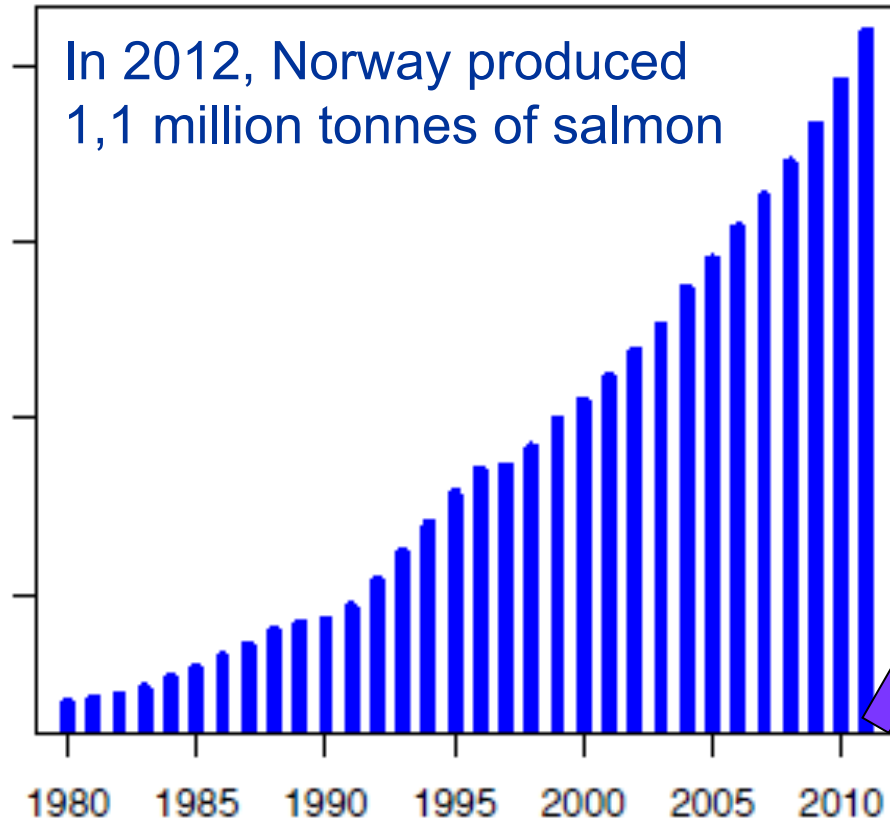
MIC , September 24, 2013



# Prediction: Huge growth in aquaculture

(Verdiskapning basert på produktive hav i 2050)

## Production of salmon in Norway



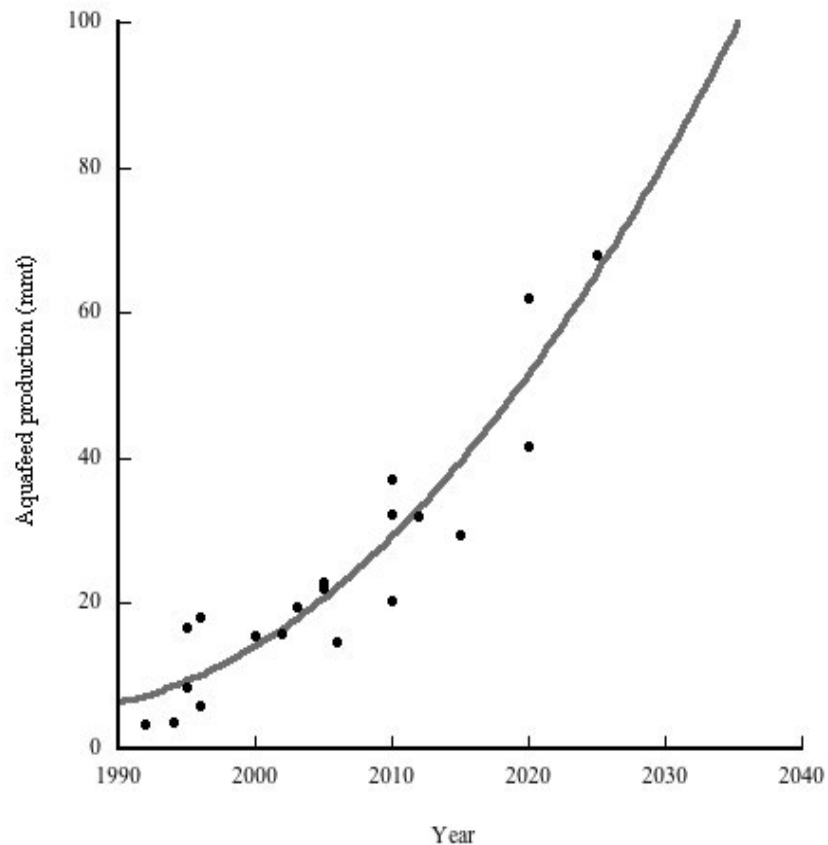
*I 2050 = 5 Mill tonn*

source: FAO.org



# Aquafeed production

Need for fish feed and prognoses until 2040

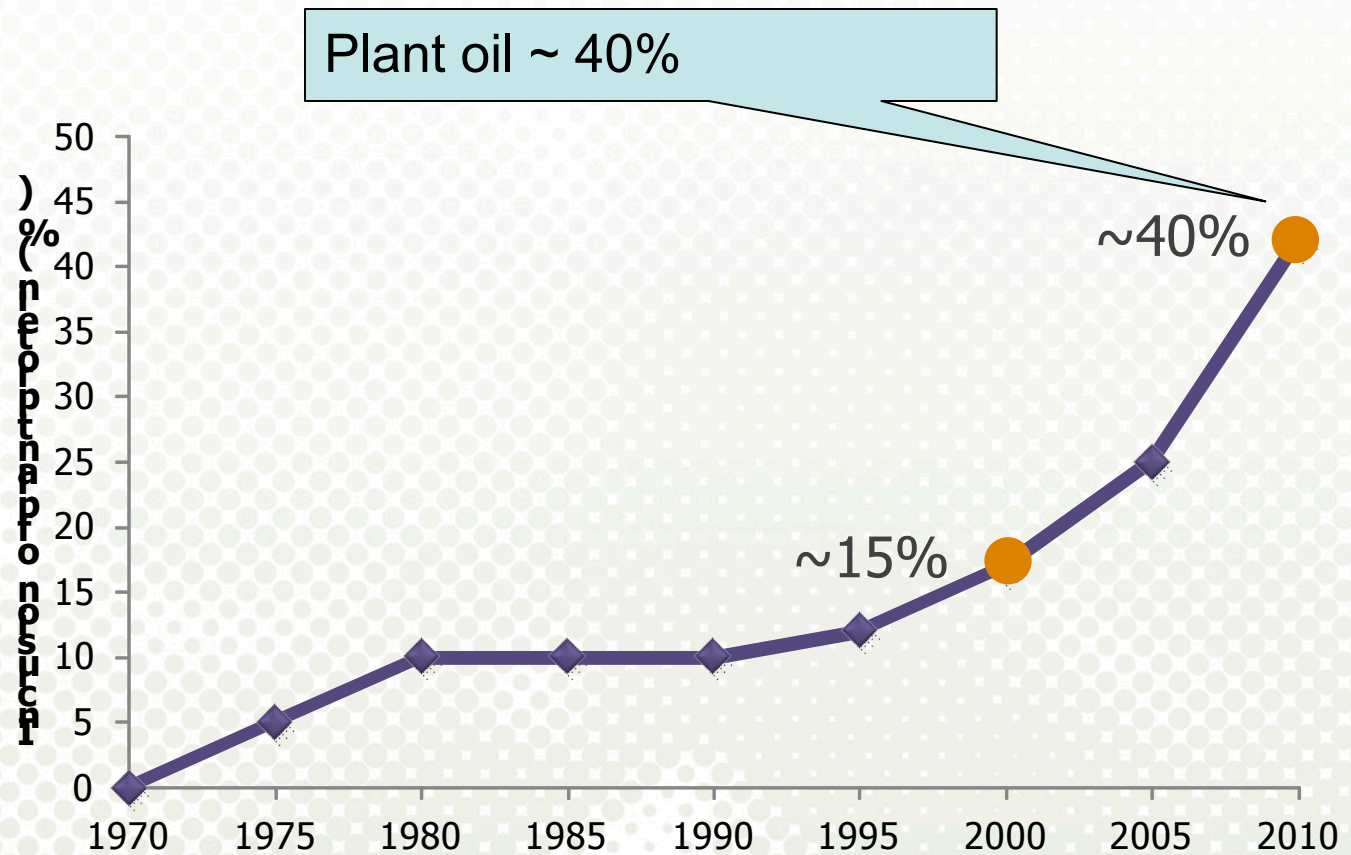


Global compound feed production:  
Total in 2011: 873 million tons  
Aquafeed: 28.7 million tons

From various sources



# Plant ingredients in Norwegian salmon feeds



Modified from Torrissen et al. (2011)

[www.umb.no](http://www.umb.no)





# Potentials and challenges with plant ingredients

## Advantages

- Availability and supply
- Environmental profile
- Low cost

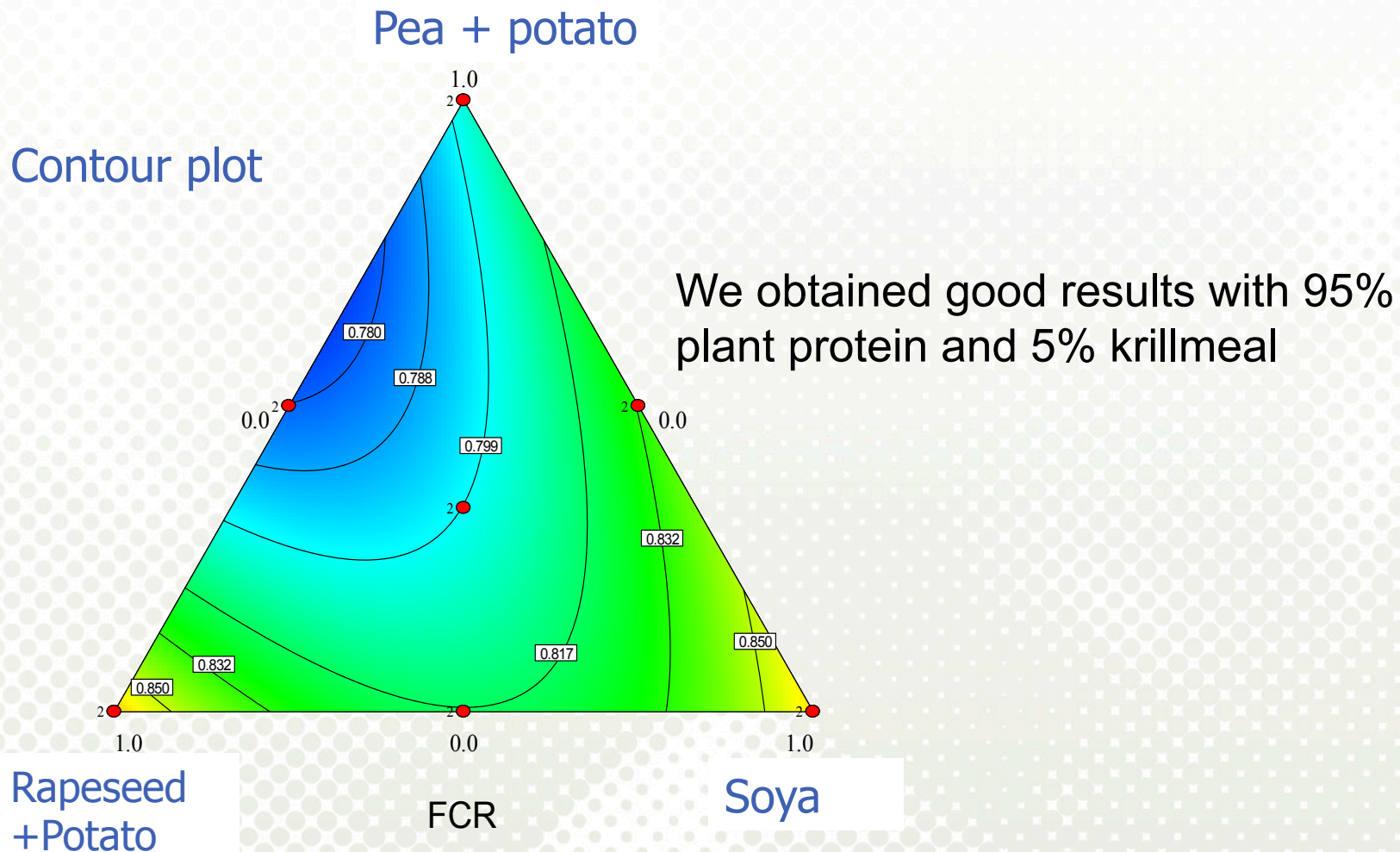
## Disadvantages

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



# Fishmeal-free diets for salmonids

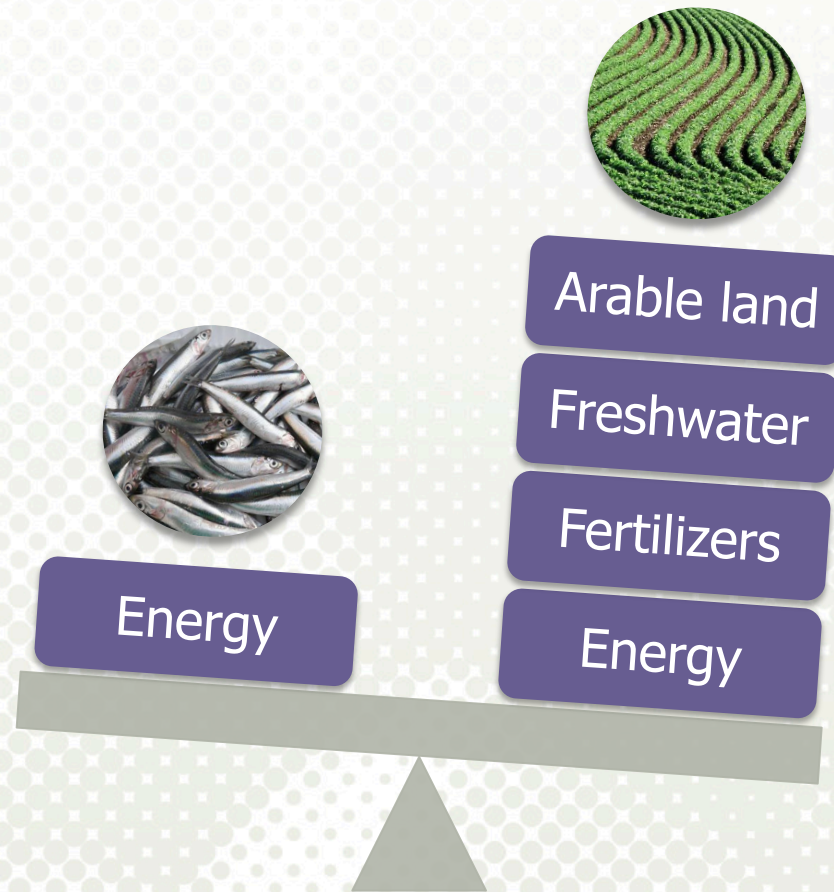
## Optimal combination for best performance





# How sustainable are plant ingredients?

## Should we be using human food to feed farmed fish?

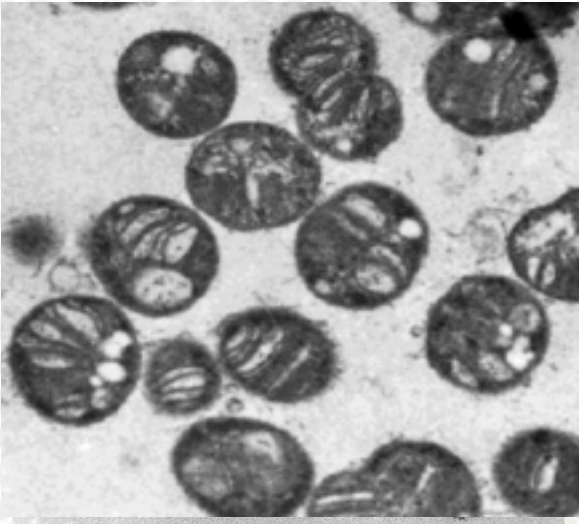




# Microbial ingredients in fish feeds

## Bacteria

*Methylococcus capsulatus*



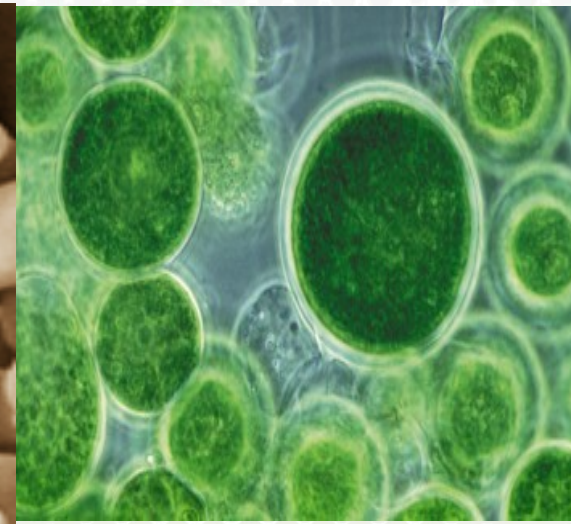
## Yeast/Fungus

*Kluyveromyces*



## Microalgae

*Phaeodactylum*, *Chlorella*,



# Production of protein from natural gas

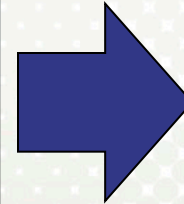
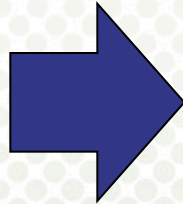


Natural gas

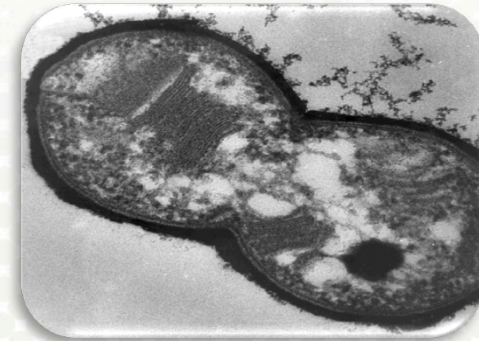
Oxygen

Ammonia

Minerals



*Methylococcus capsulatus*



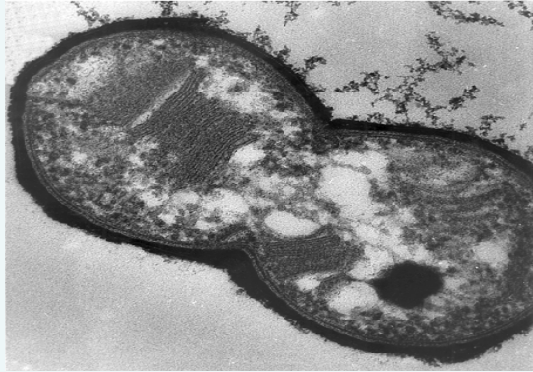
Bacterial meal

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%

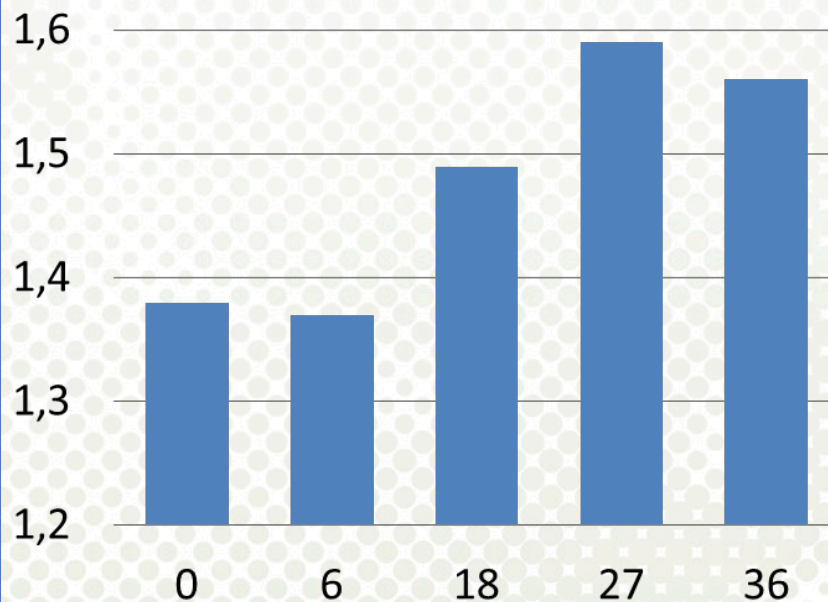
### Other traits:

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

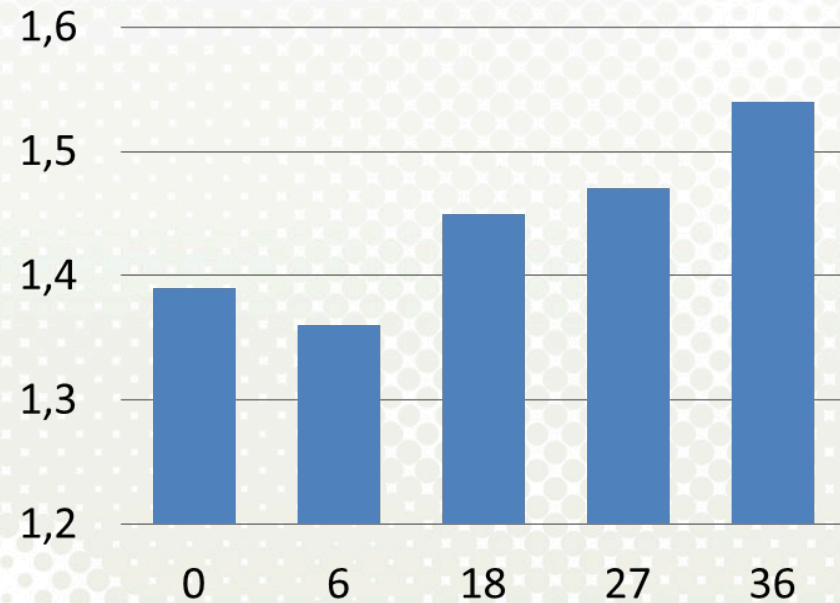


# Growth and feed efficiency of salmon fed increasing levels of bacterial meal

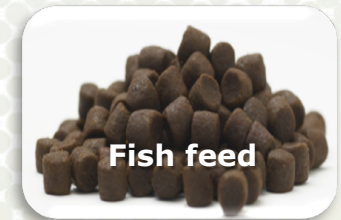
Specific growth rate, %/day



Feed efficiency, gain:feed

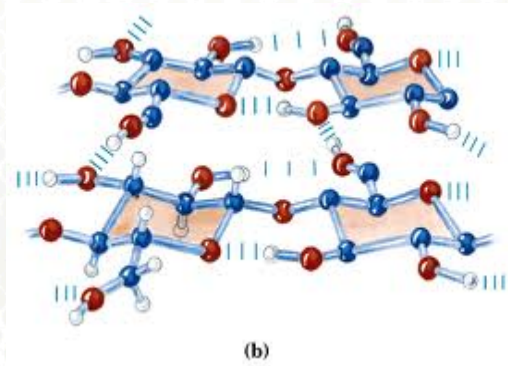


# Fish feed from low-value biomass

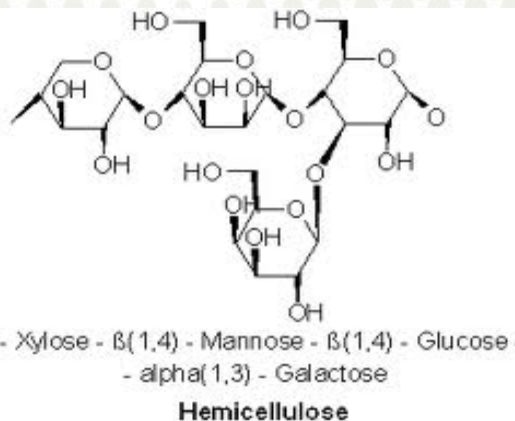




# Production of yeast from forest biomass



**Cellulose**



Mechanical treatment



Thermo-chemical treatment



Enzymatic hydrolyzes



Fermentation

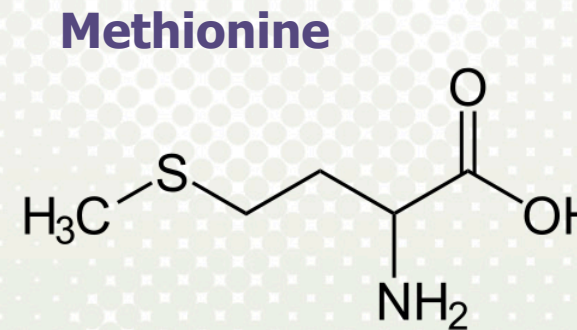
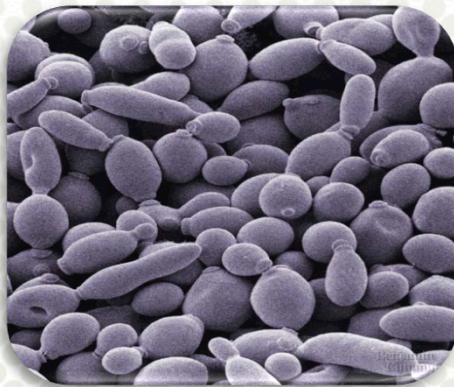


# Yeast produced from forest biomass –a potential high-value feed resource

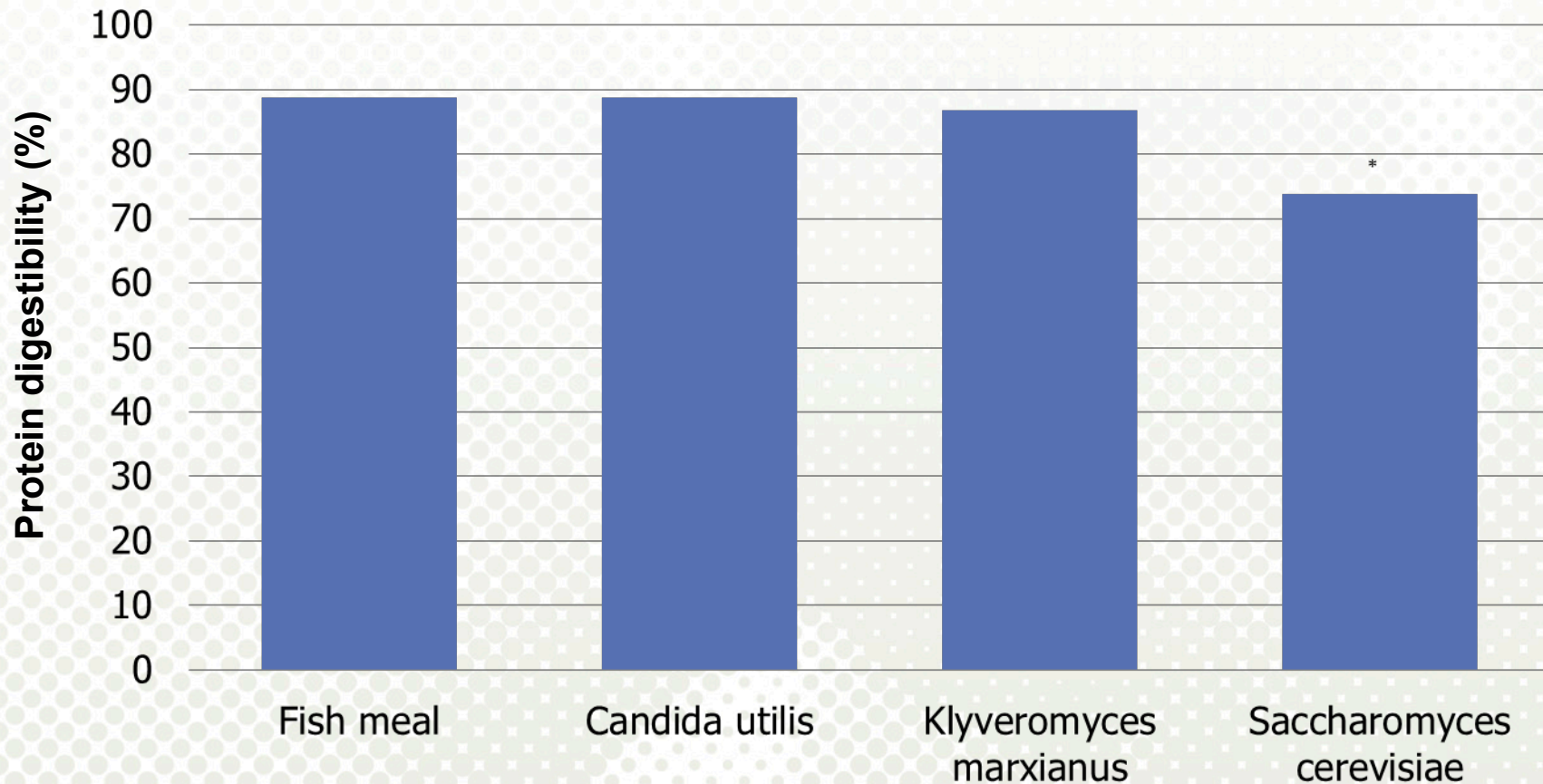


## Yeast:

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



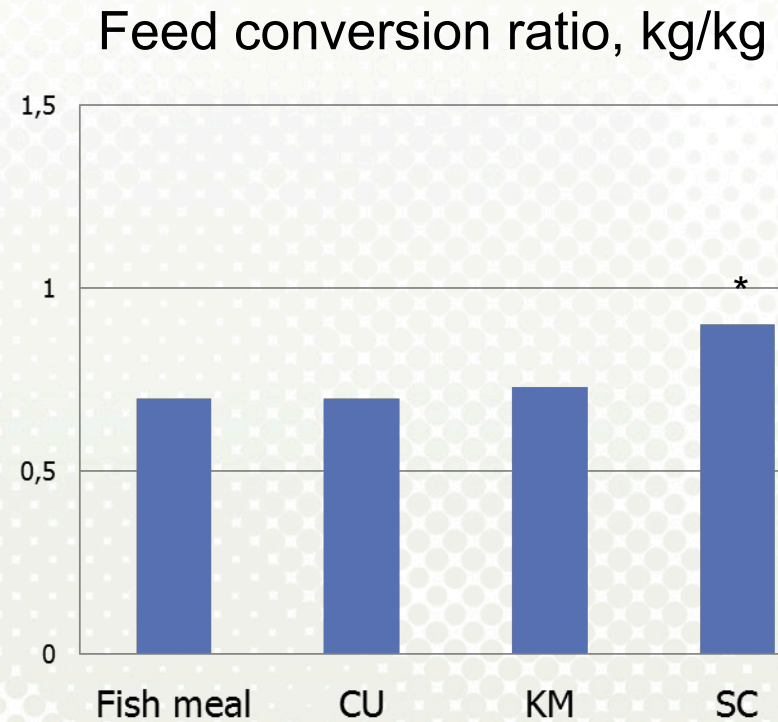
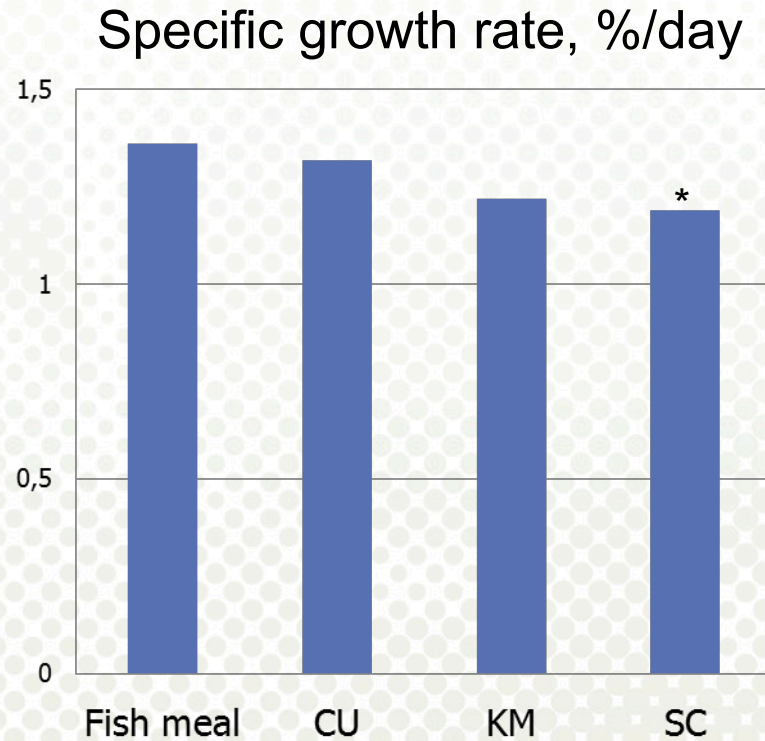
# Digestibility of protein in salmon fed 30% yeasts



Source: Øverland et al., 2013, Aquaculture



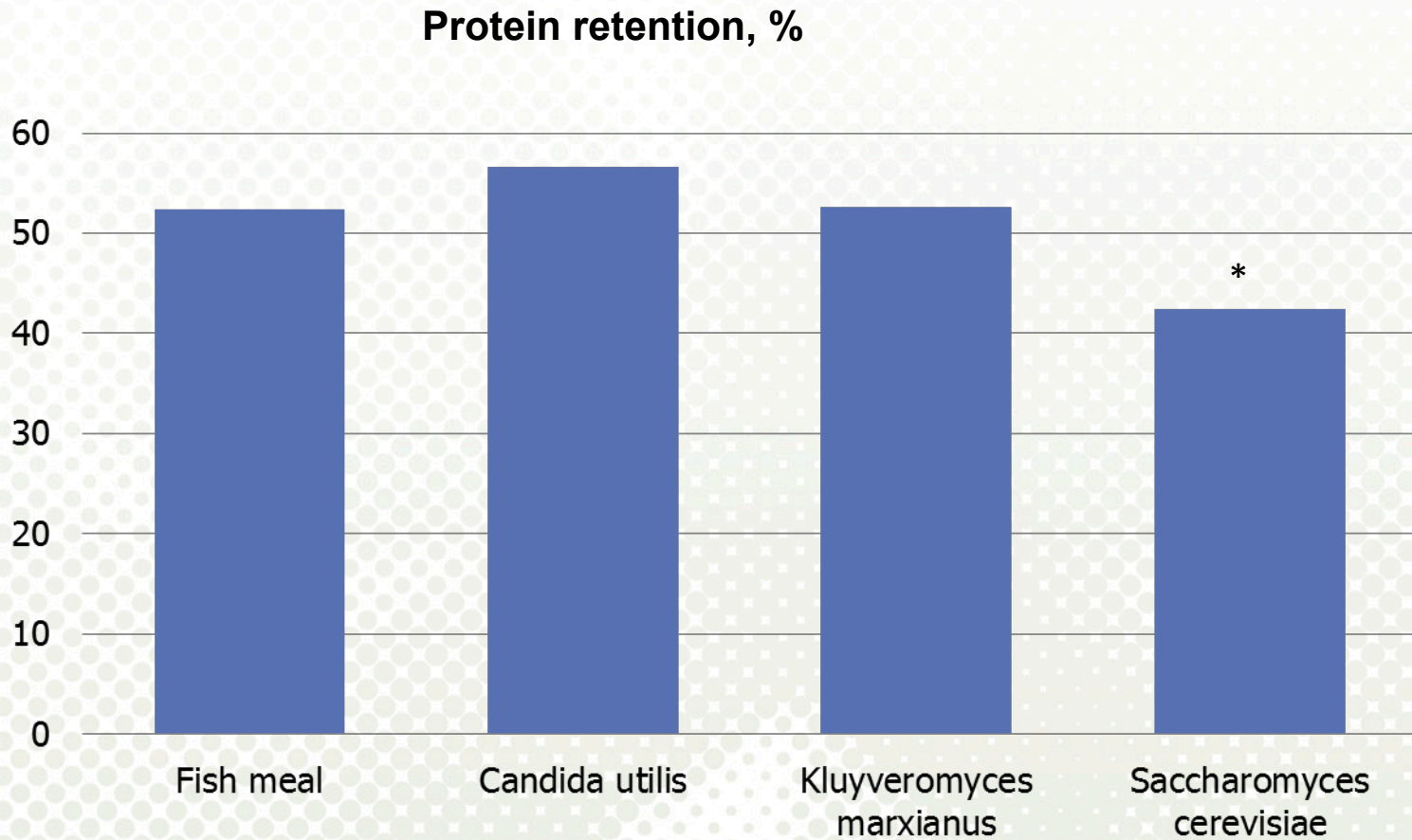
# Growth rate and feed conversion ratio of salmon fed 30% yeast



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



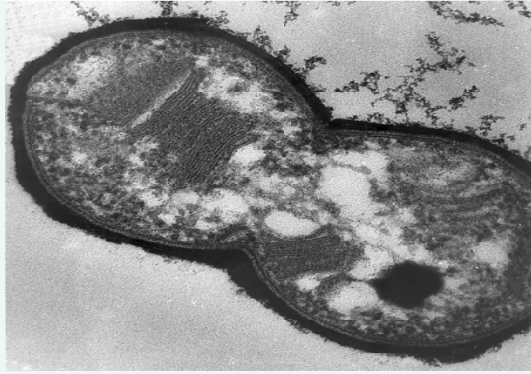
Soybean meal in feed for Atlantic salmon induces a dose-dependent inflammation (enteropathy) in the distal intestine





# 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

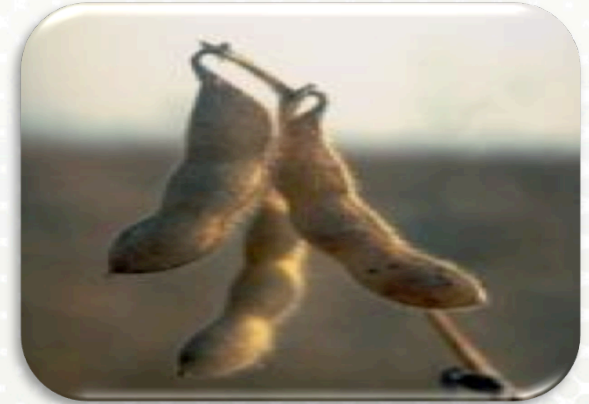
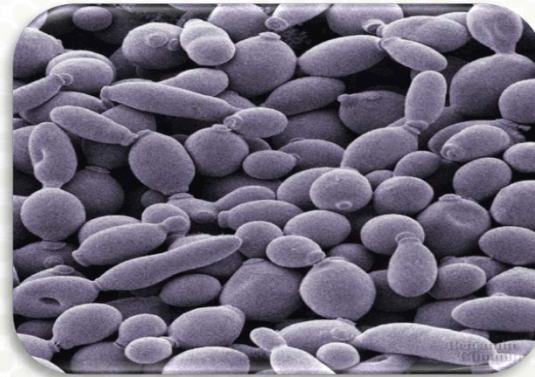
1. *Candida utilis*
2. *Kluyvermyces marxianus*
3. *Saccharomyces cerevisiae*

### Microalgae

4. *Chlorella vulgaris*

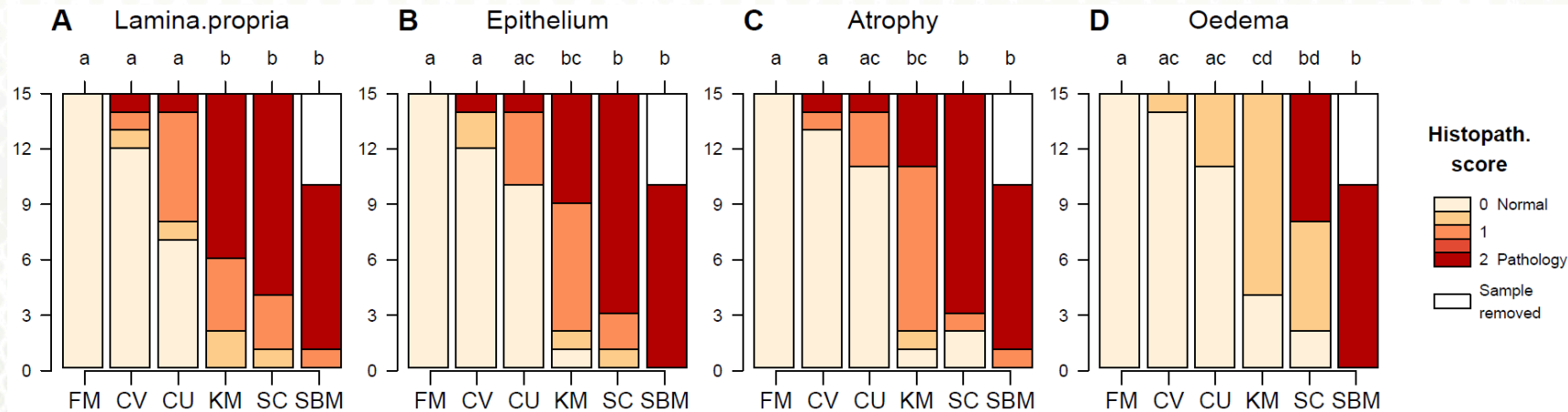


# Effect of yeast in diets with 20% soybean meal on gut health (SBMIE)



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

# Effect of microbial ingredients on distal gut histology in salmon



❑ Outlier from one tank in the SBM group was removed

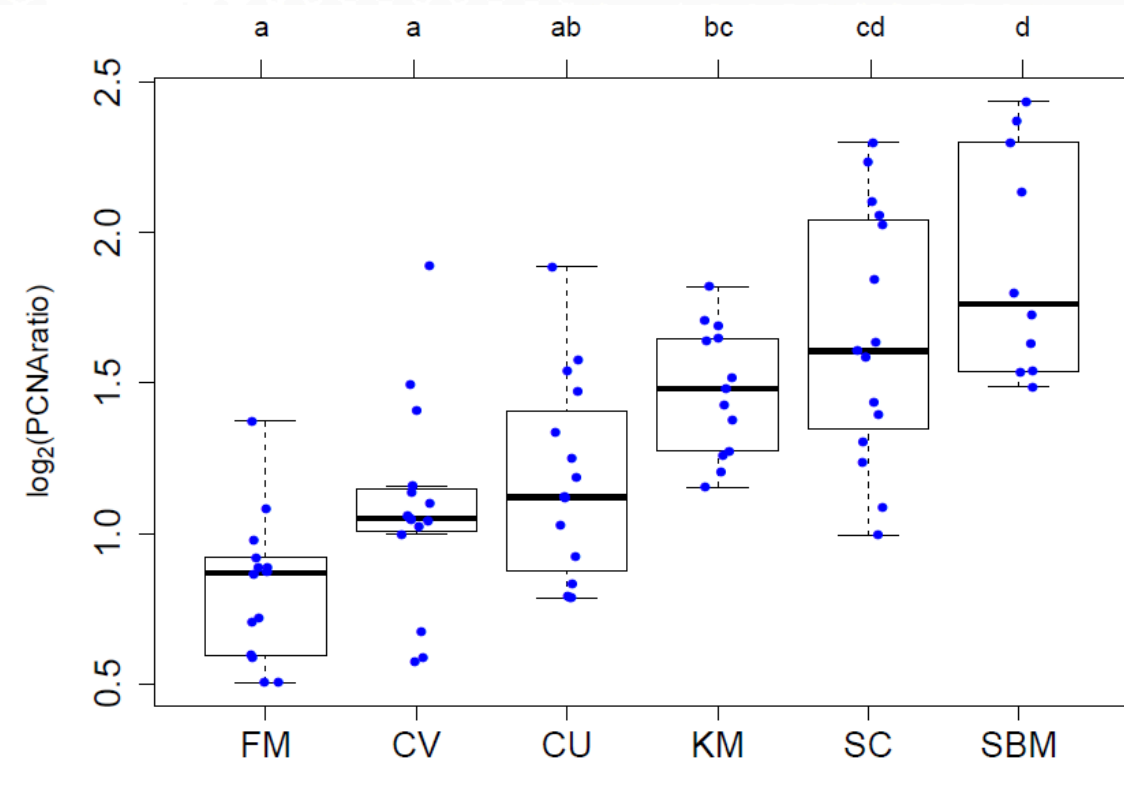
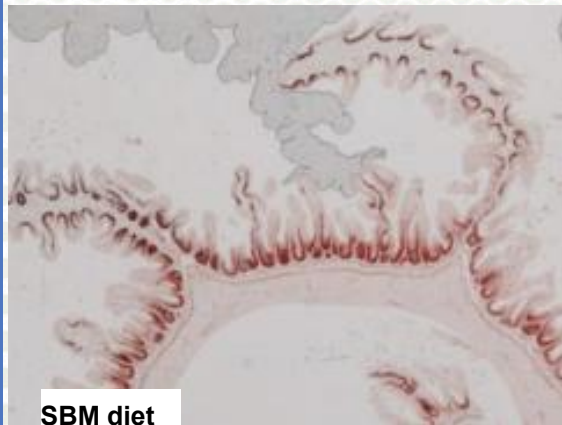
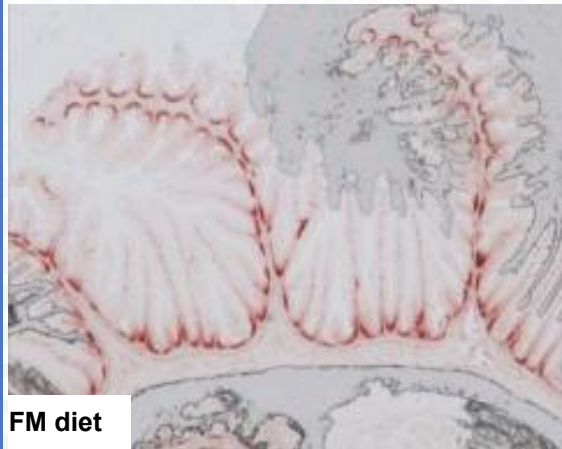
## Histology scores

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



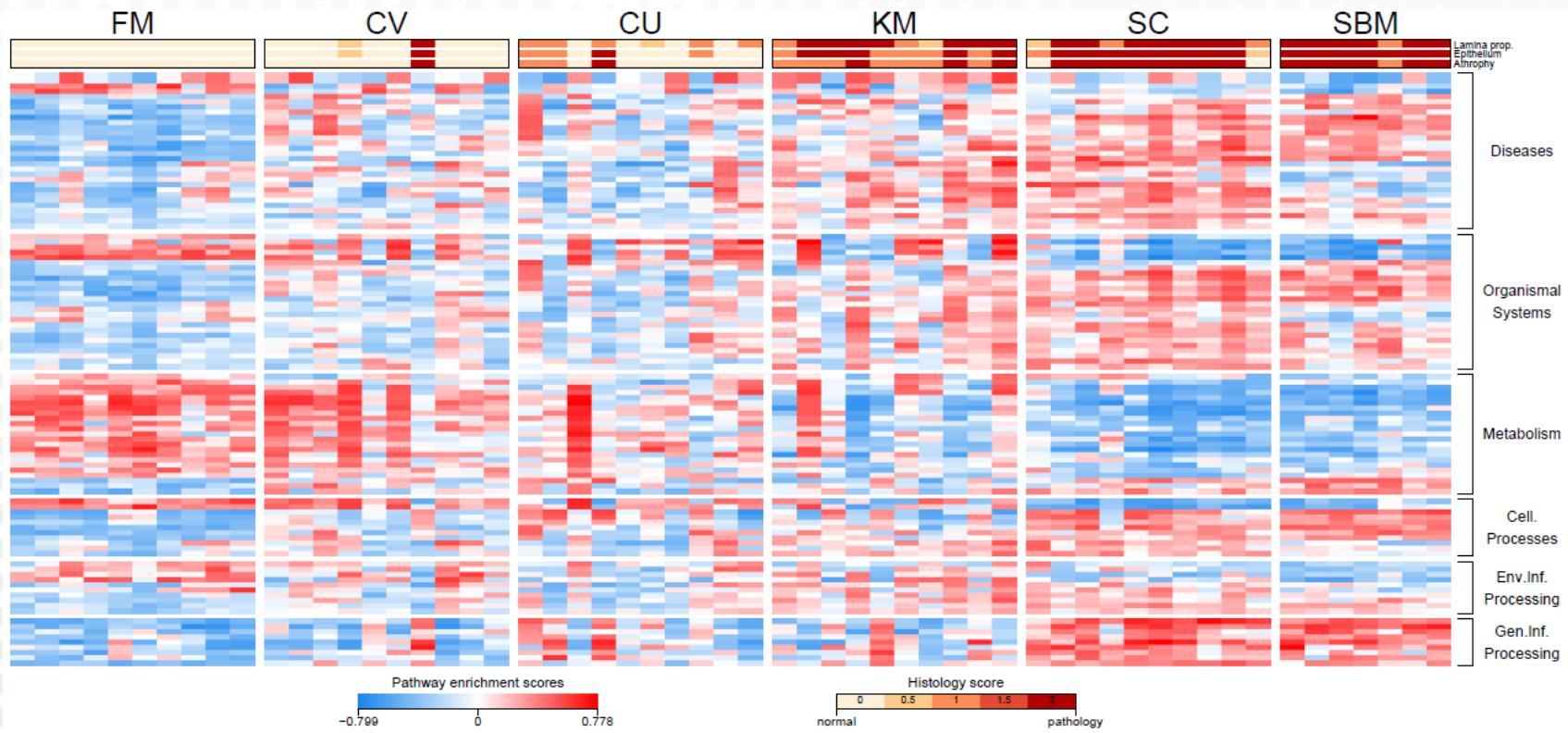


# Effect of microbial ingredients on PCNA in distal intestine of salmon



# Effect of microbial ingredients on gene expression in distal intestine

Heat map - Gene expression – pathways - KEGG



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







# 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