NORWEGIAN UNIVERSITY OF LIFE SCIENCES

# *Plenty more fish in the forest*

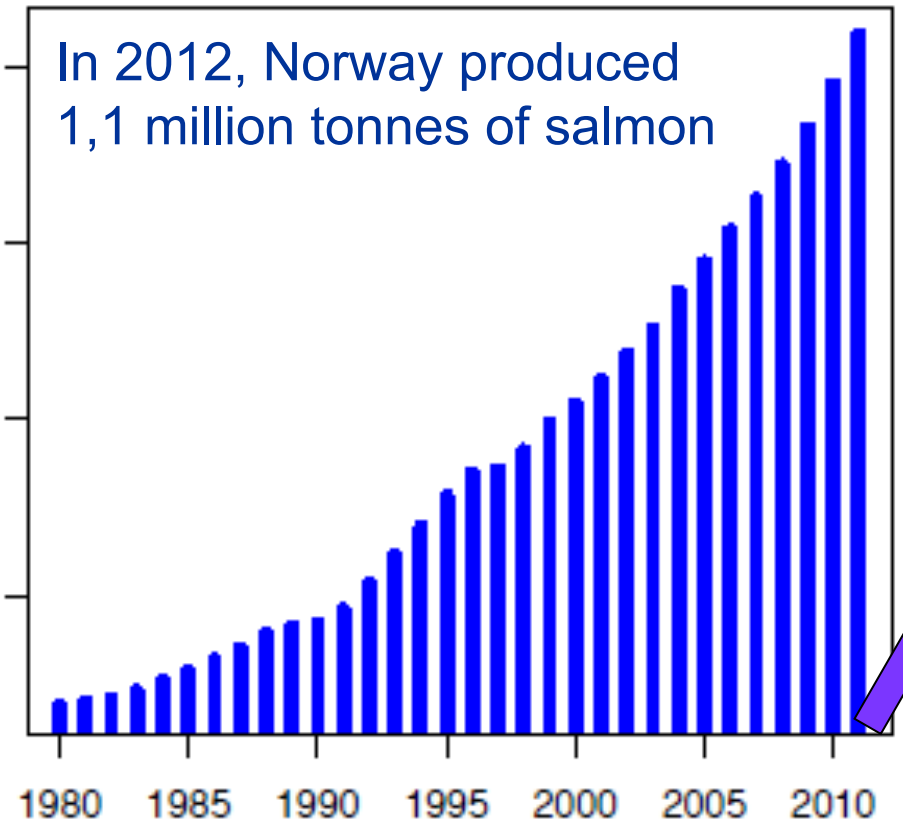
Margareth Øverland

MIC , September 24, 2013

# Prediction: Huge growth in aquaculture

(Verdiskapning basert på produktive hav i 2050)

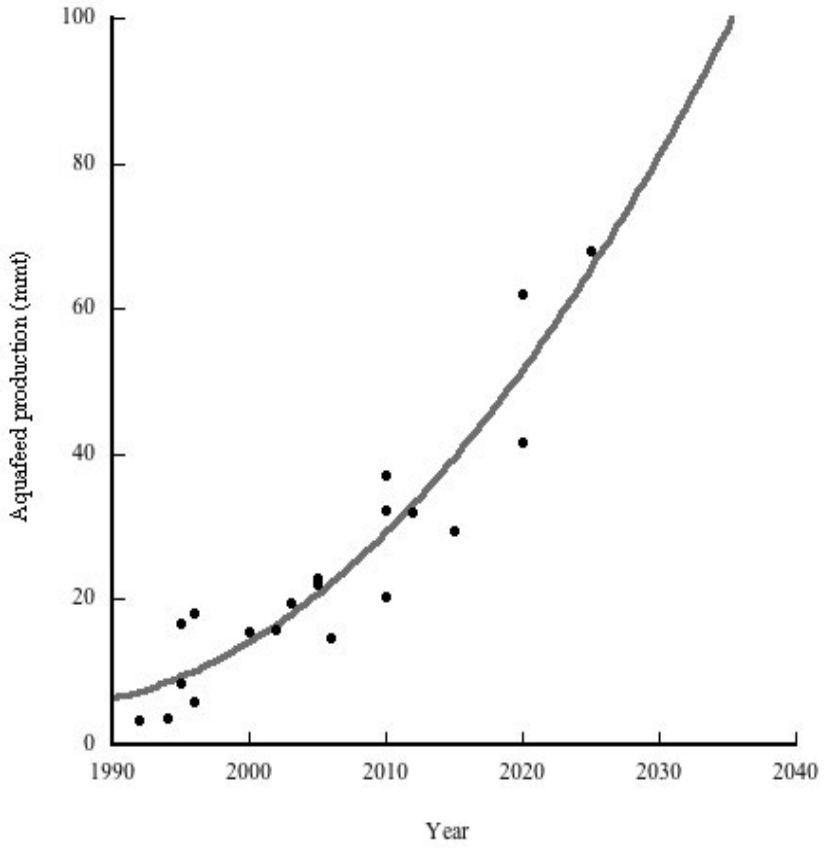
## Production of salmon in Norway




I 2050 = 5 Mill tonn

# Aquafeed production

## Need for fish feed and prognoses until 2040



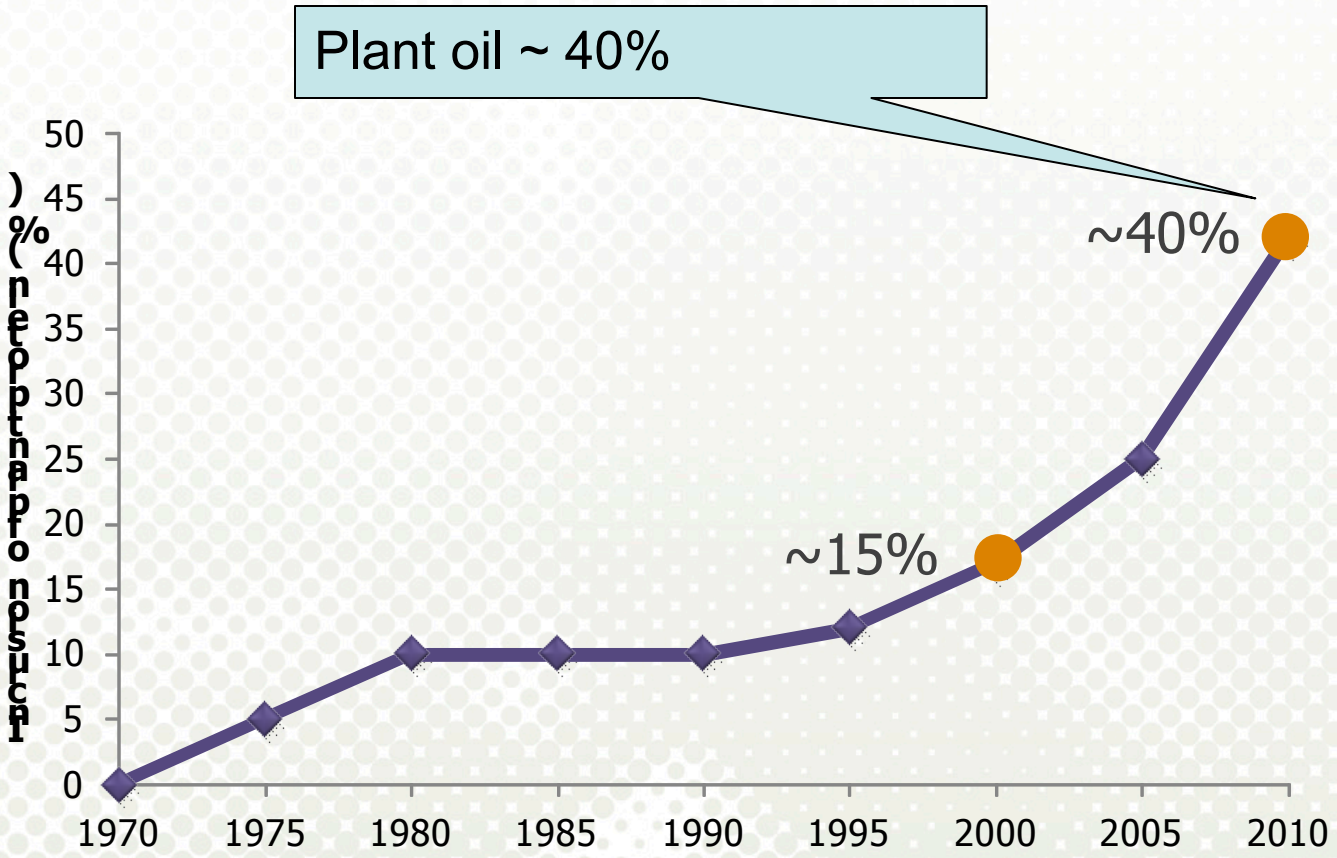

Global compound feed production:

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)

# Potentials and challenges with plant ingredients

## Advantages

- Availability and supply
- Environmental profile
- Low cost

## Disadvantages

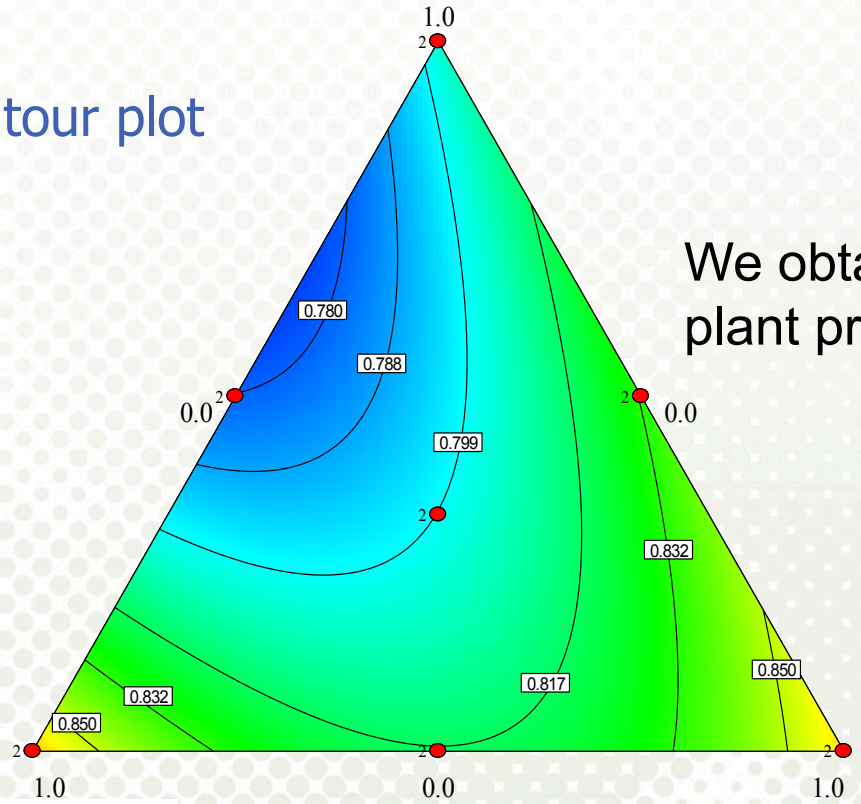
- Low nutrient density
- Unbalanced AA profile
- Antinutrients
- No EPA or DHA




# Fishmeal-free diets for salmonids
## Optimal combination for best performance

Pea + potato

Contour plot




We obtained good results with 95% plant protein and 5% krillmeal

Rapeseed +Potato

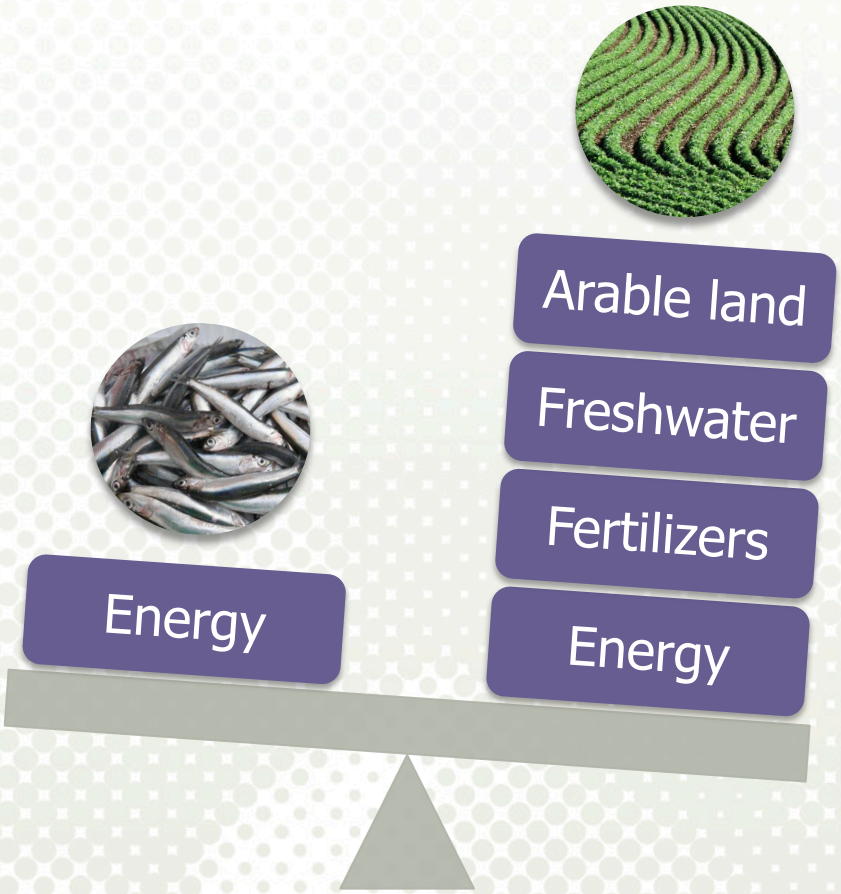
FCR

Soya

Source: Zhang et al., 2012, Aquaculture

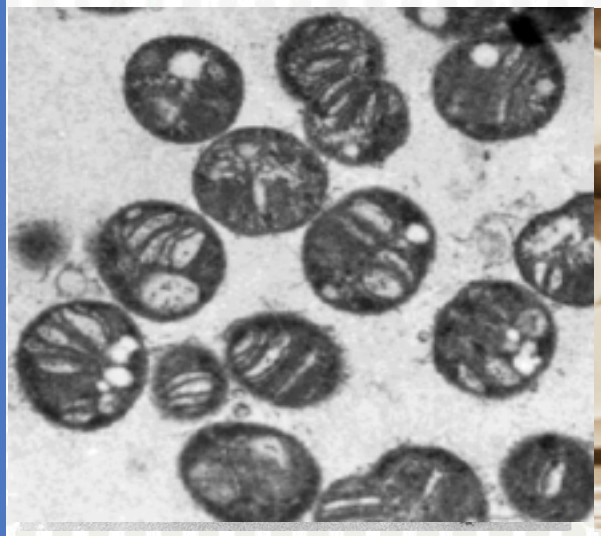
# How sustainable are plant ingredients?

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



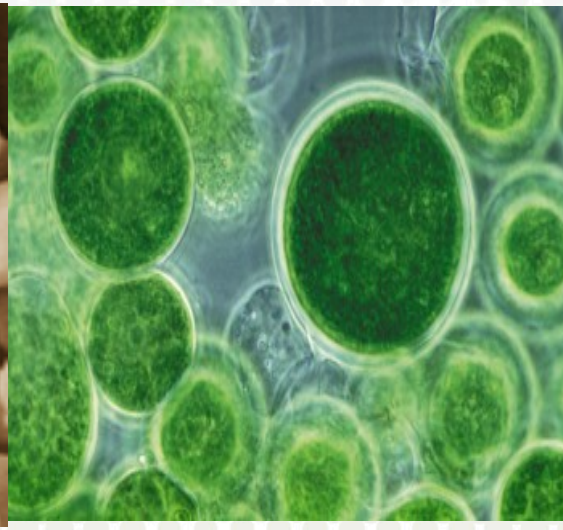
# Microbial ingredients in fish feeds

Bacteria
*Methylococcus capsulatus*



Yeast/Fungus
*Kluyveromyces*

Microalgae
*Phaeodactylum, Chlorella,*



# Production of protein from natural gas

Natural gas

Oxygen

Ammonia

Minerals

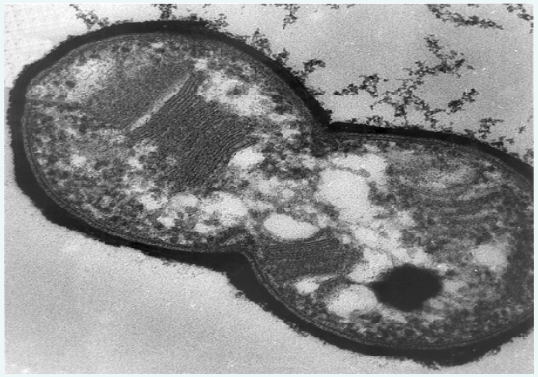
*Methylococcus capsulatus*

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% |

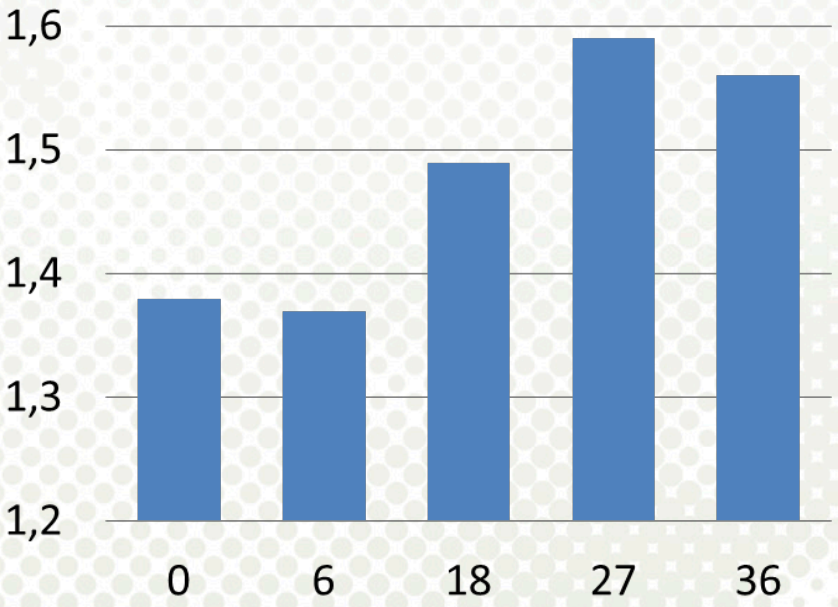
Other traits:

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

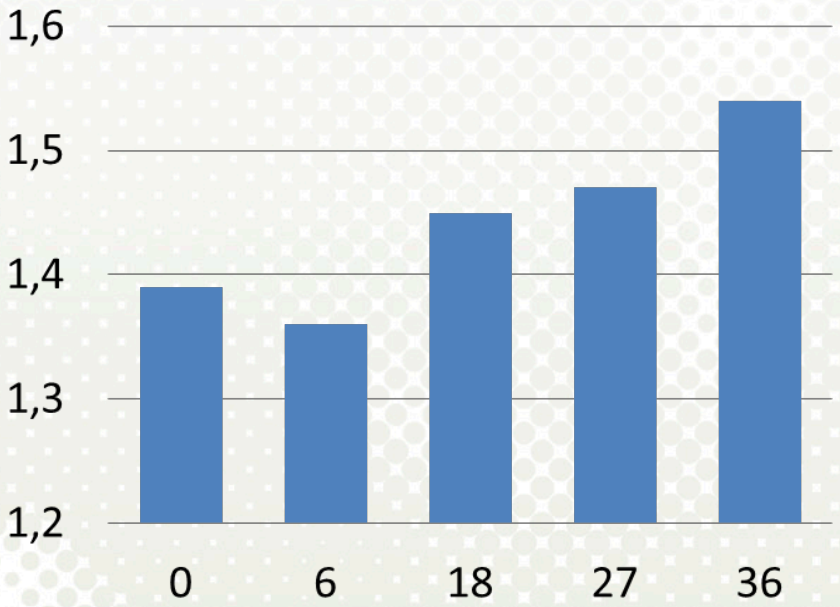
Source: Øverland et al., 2011, Archives of Anim. Nutr

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

Specific growth rate, %/day




Feed efficiency, gain:feed




Source: Aas et al. 2006, Aquaculture

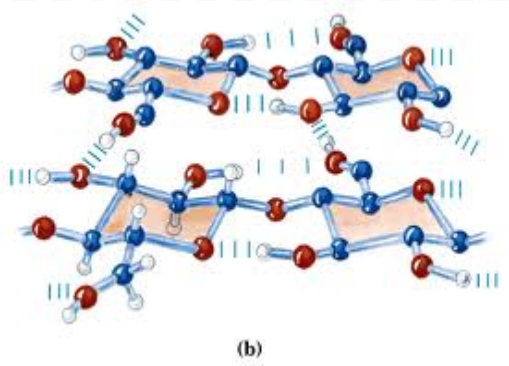
# Fish feed from low-value biomass



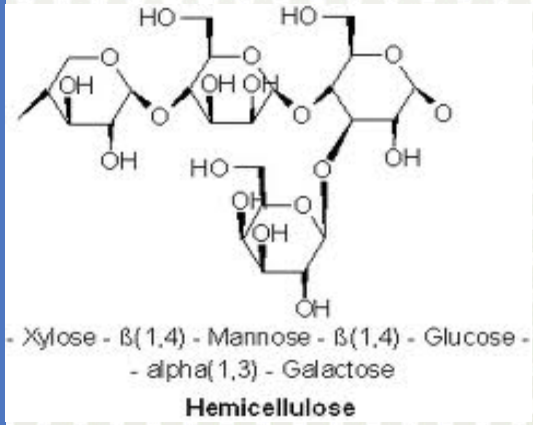

**Bioraffinery**



# Production of yeast from forest biomass




**Cellulose**




**Hemicellulose**

Mechanical treatment

↓

Thermo-chemical treatment

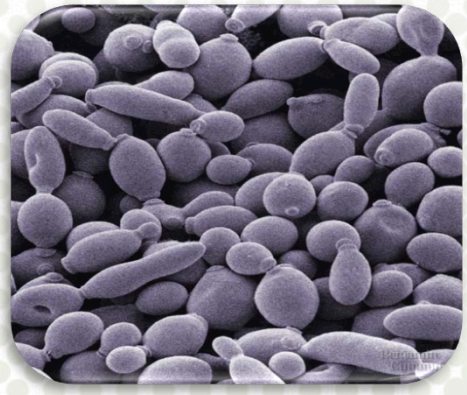
↓

Enzymatic hydrolyzes

↓

Fermentation

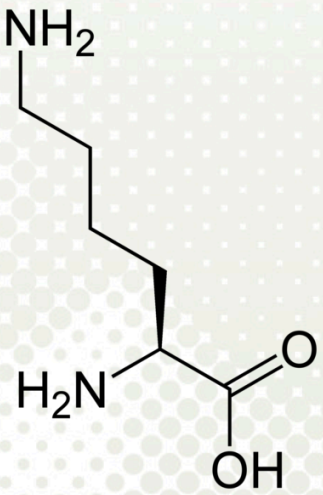
# Yeast produced from forest biomass –a potential high-value feed resource



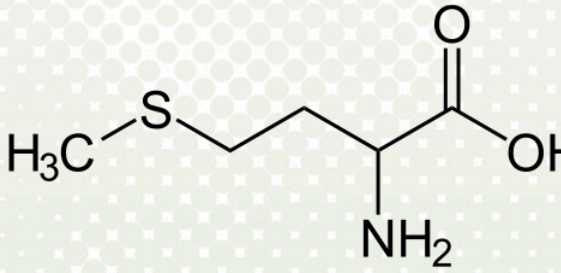
Yeast:

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

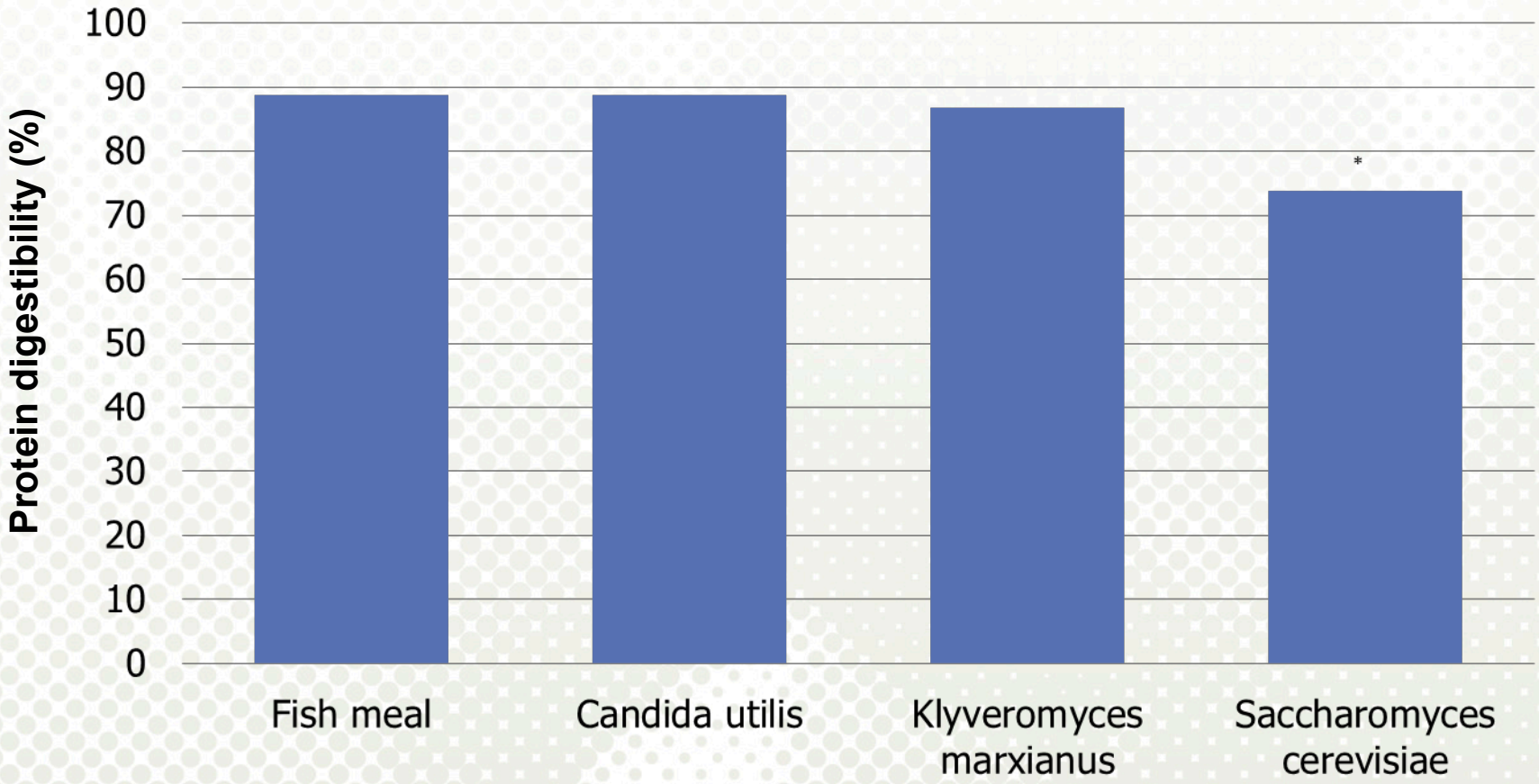
**Lysine**




**Methionine**

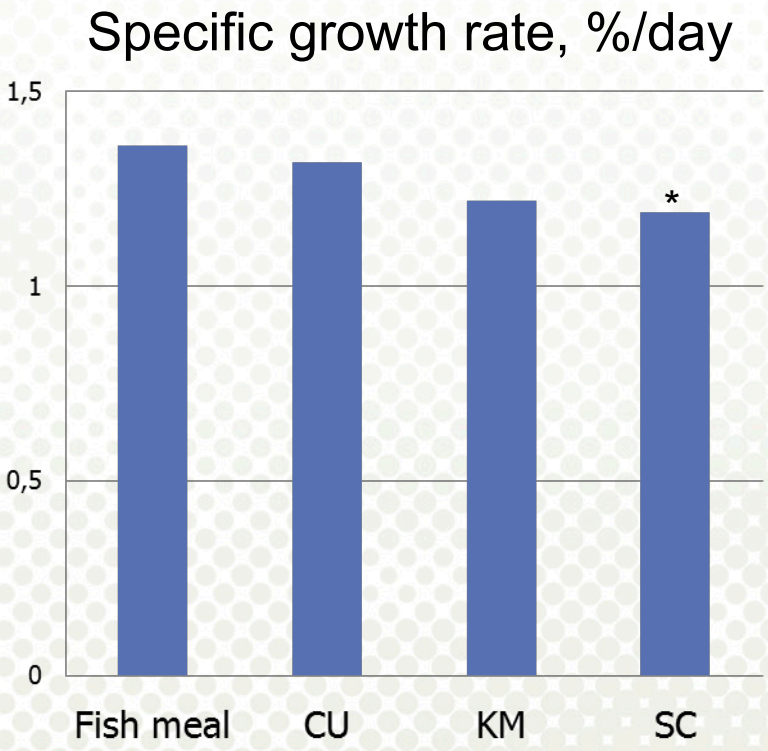


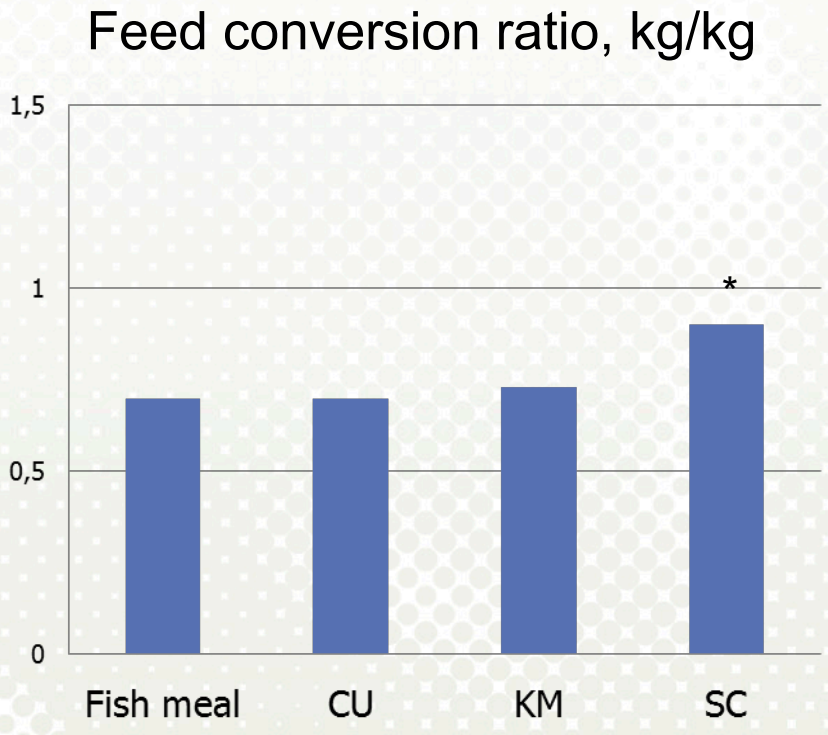
# Digestibility of protein in salmon fed 30% yeasts




Source: Øverland et al., 2013, Aquaculture

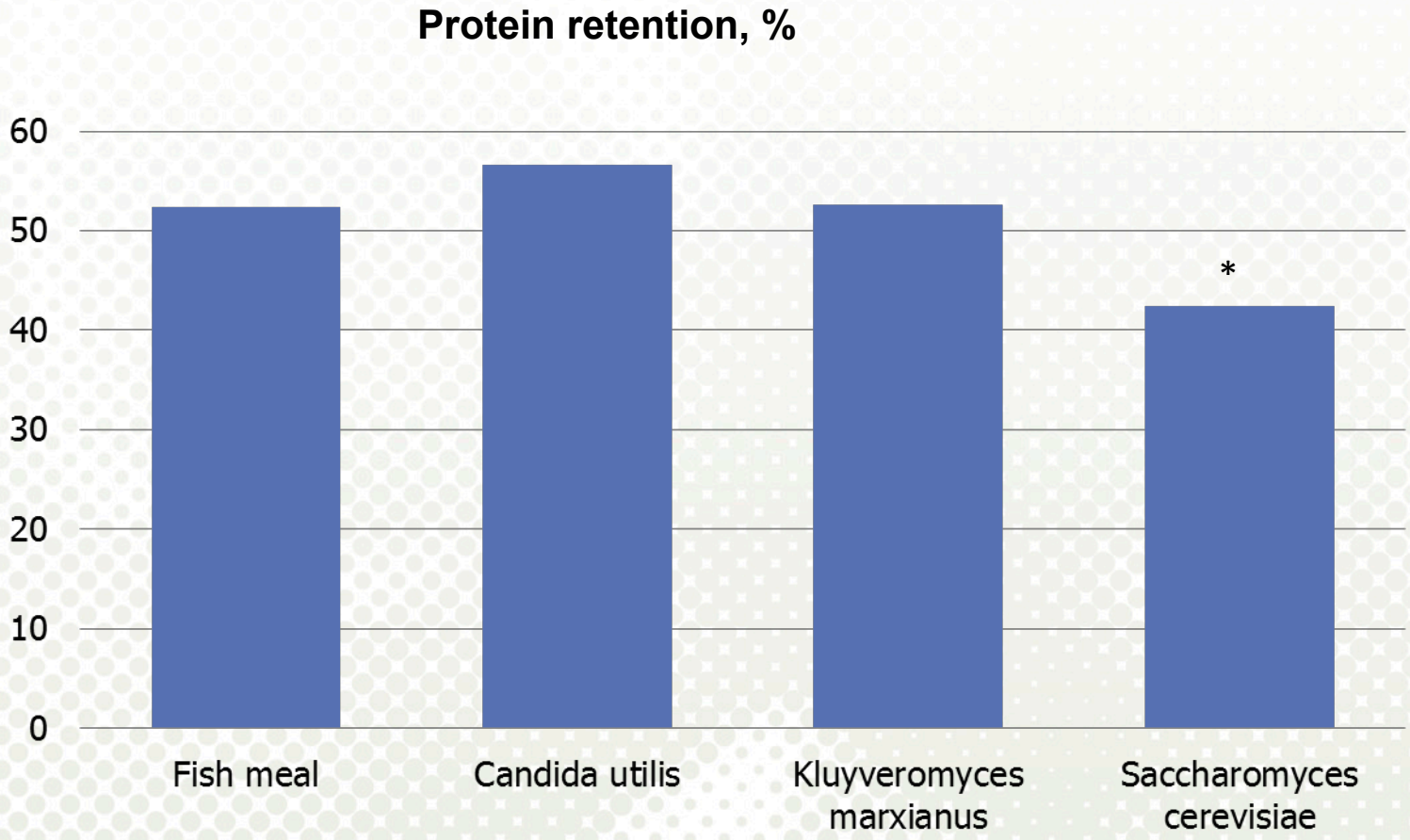
# Growth rate and feed conversion ratio of salmon fed 30% yeast




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

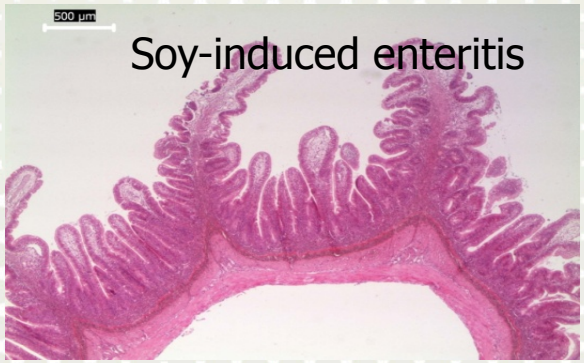
# Protein retention in salmon fed 30% yeast




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

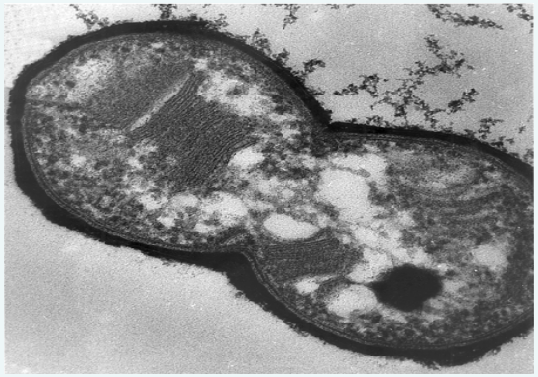
# Plant ingredients increase risk of gut health disorders in fish


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

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

## *Methylococcus capsulatus*



- Methanotroph bacteria
- High protein content

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- 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:

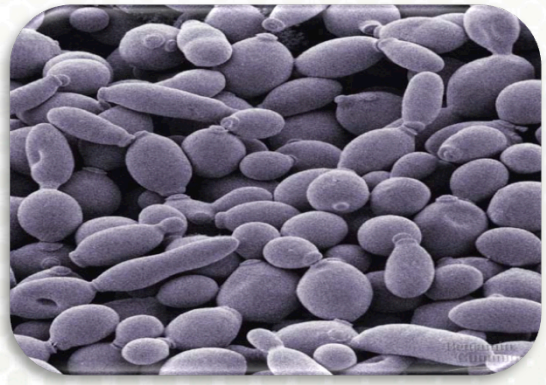
Yeast

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

Microalgae

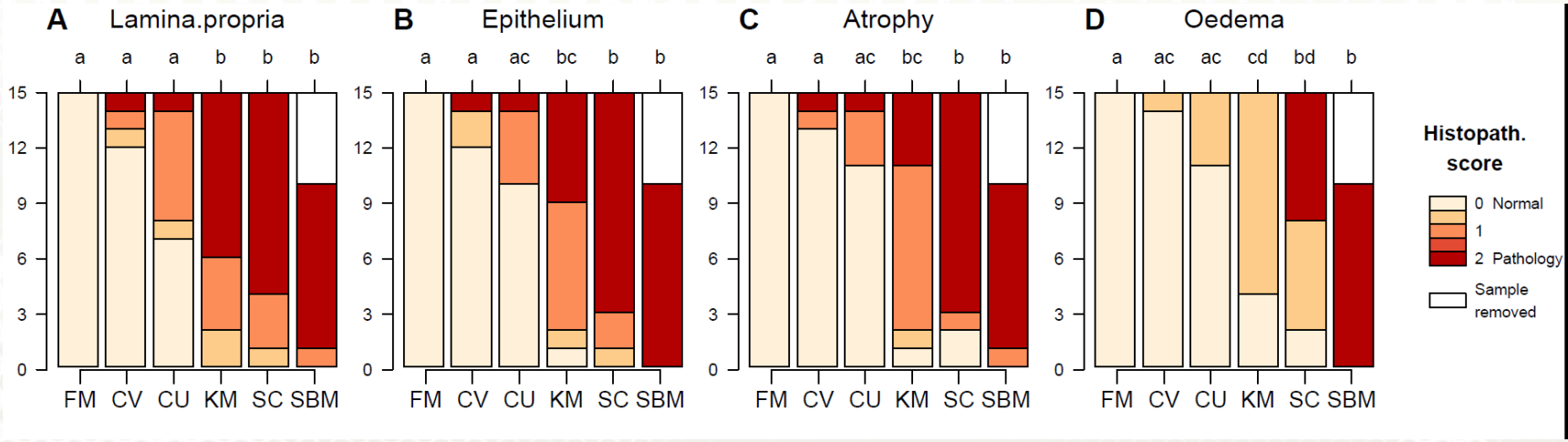
4. *Chlorella vulgaris*

# 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,

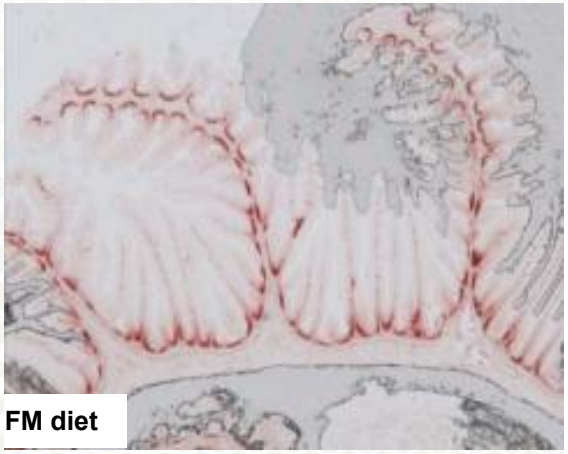
2 = full enteritis, red,

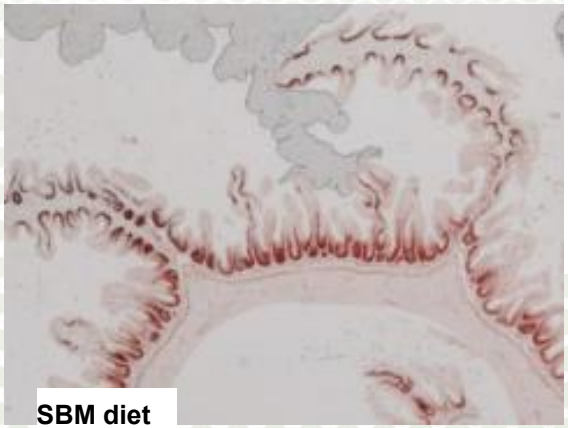
0 = normal, beage.

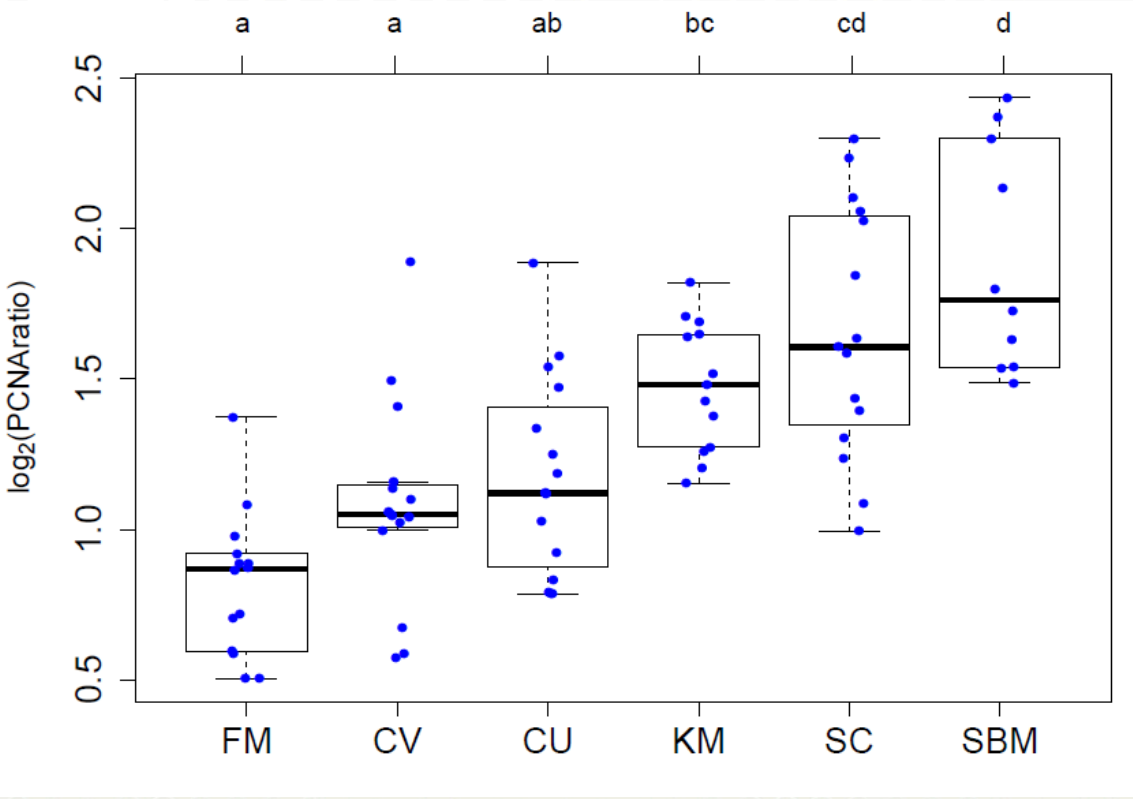
1 = slight to moderate enteris

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

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



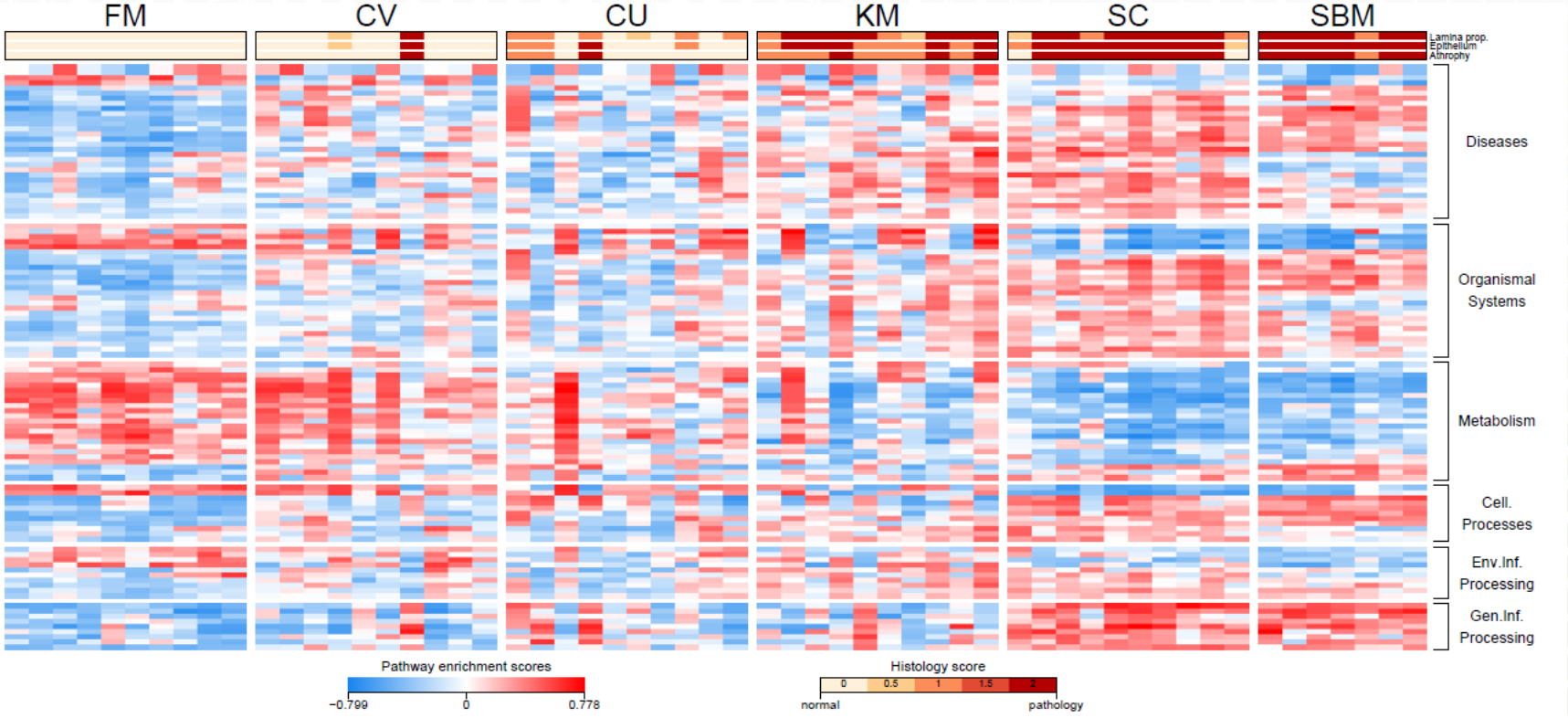




Source: Grammes et al., 2013; Submitted, to Plos One

# Effect of microbial ingredients on gene expression in distal intestine

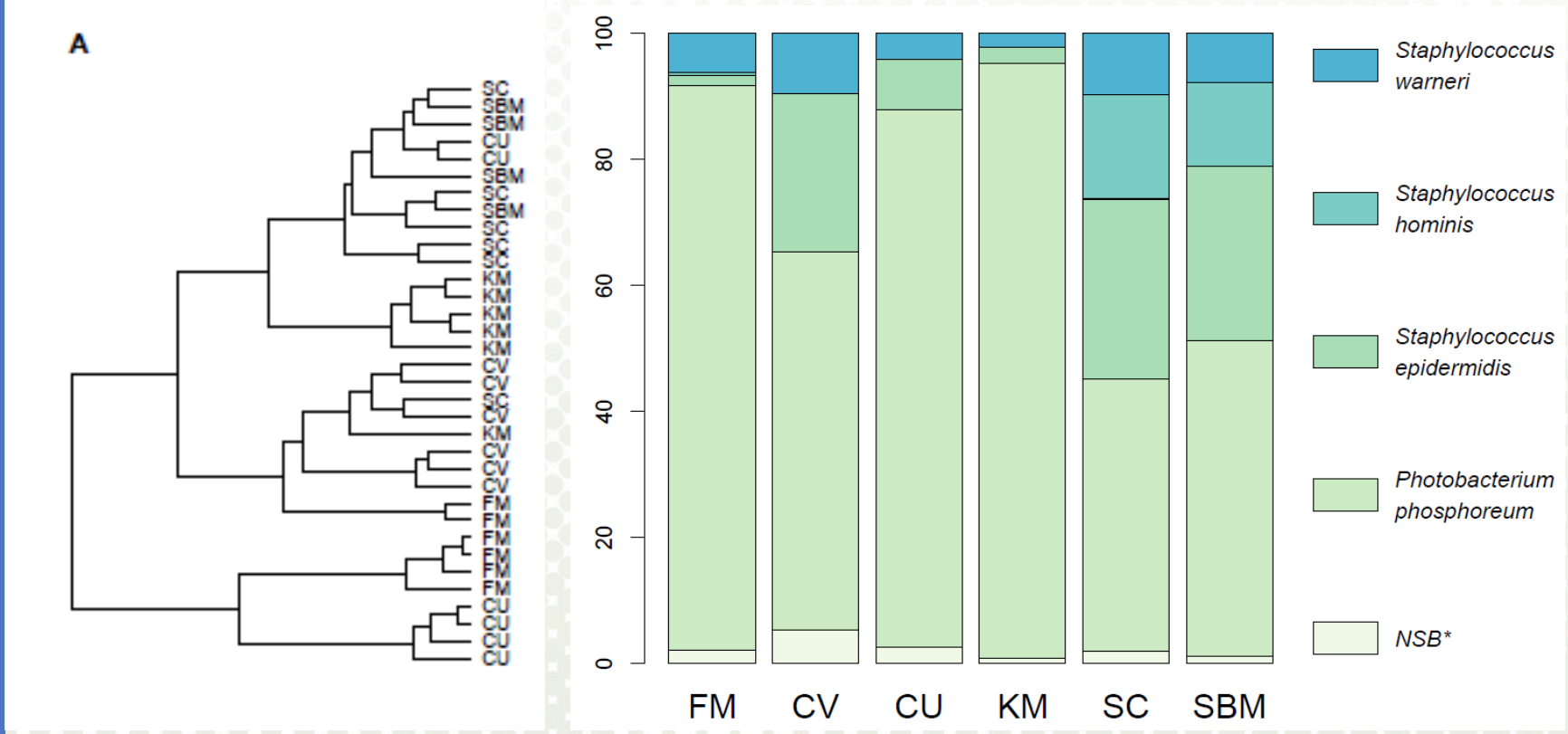
## Heat map - Gene expression – pathways - KEGG




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

# Effect of microbial ingredients on gut microbiota in salmon

Relative abundance of bacteria in distal intestine




Source: Grammes et al., 2013; PlosOne, in press



DGGE profiles 16 S rRNA; V6-8

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# 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