

Need for modern plants in fish feeds

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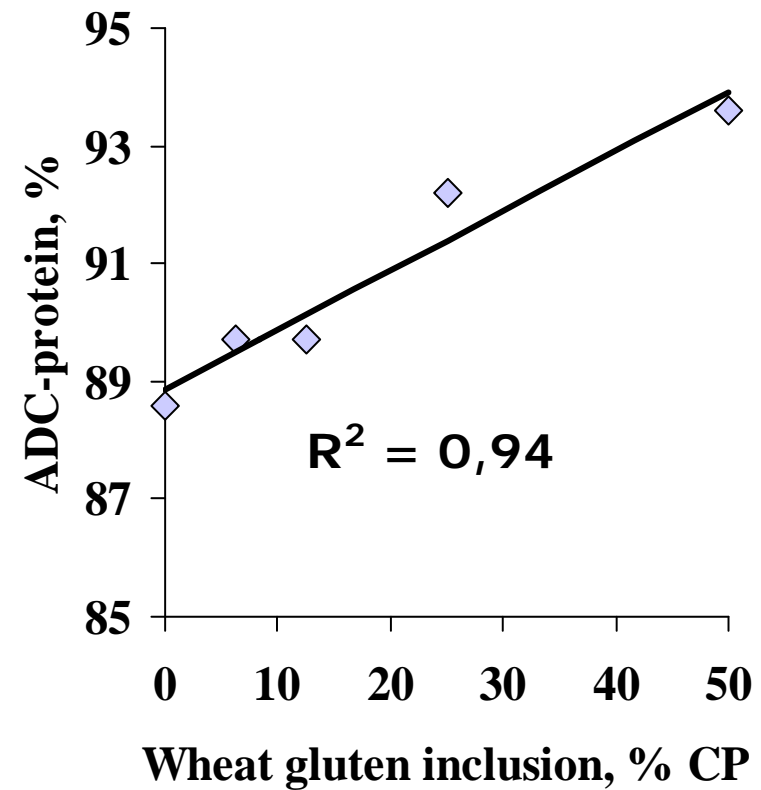
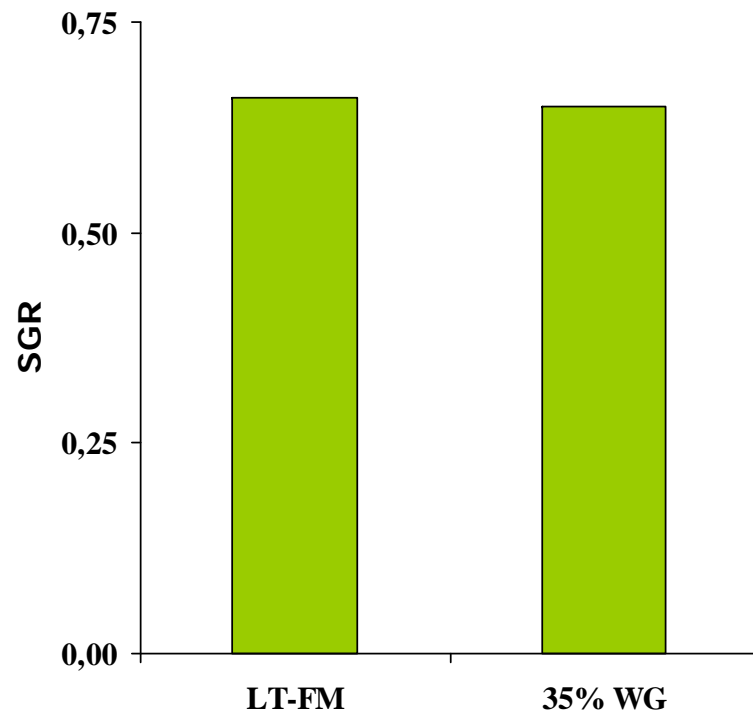
Lipids

- Lipids
 - EPA (20:5 *n*-3) and DHA (22:6 *n*-3) rather than linolenic acid (18:3 *n*-3) in feed for marine fish due to limited desaturation capacity
 - Canola oil rather than soy oil due to linoleic acid 18:2 *n*-6 (competition on desaturates and eicosanoid balance) and more monoenes (:1) (preferred for energy) in Canola
- Fish oil vs high *n*-3 plant oil
 - Annual fish oil production: Approx. 1 mill tons. More than $\frac{3}{4}$ used for aquaculture.
 - Need for more
 - Fish oil vs soy oil (January 2006): Price difference approx. 270 €/ton. Fish oil 150 g EPA+DHA/kg
 - 1,800 €/ton EPA+DHA

Protein sources

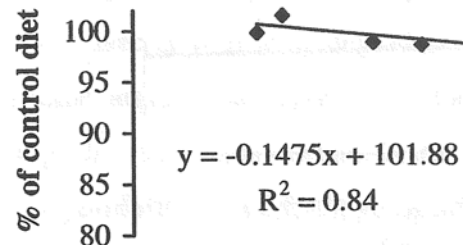
- Needed
 - Safe for fish and humans
 - Antinutrients
 - Toxins
 - Accepted by the fish
 - Taste and flavour
 - High-quality fish product
- Wanted
 - Low price
 - Available in the market in sufficiently high amounts
 - Can be used at a low degree of processing
 - Balanced protein
 - Does not reduce utilisation of other nutrients
 - Feed technological quality
 - Sustainable production

Highly processed plant proteins have high nutritional value in feed for salmon (Storebakken m. fl., 2000)

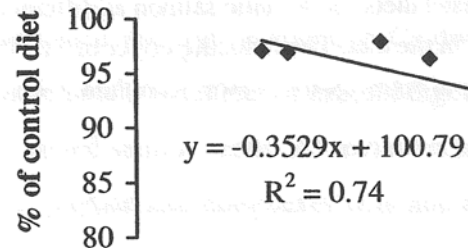


Effect of soybean meal on nitrogen, lipid and energy digestibility

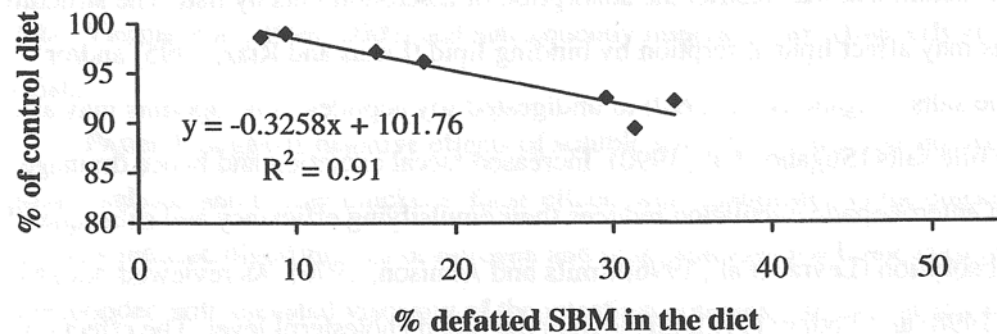
Nitrogen digestibility



Lipid digestibility

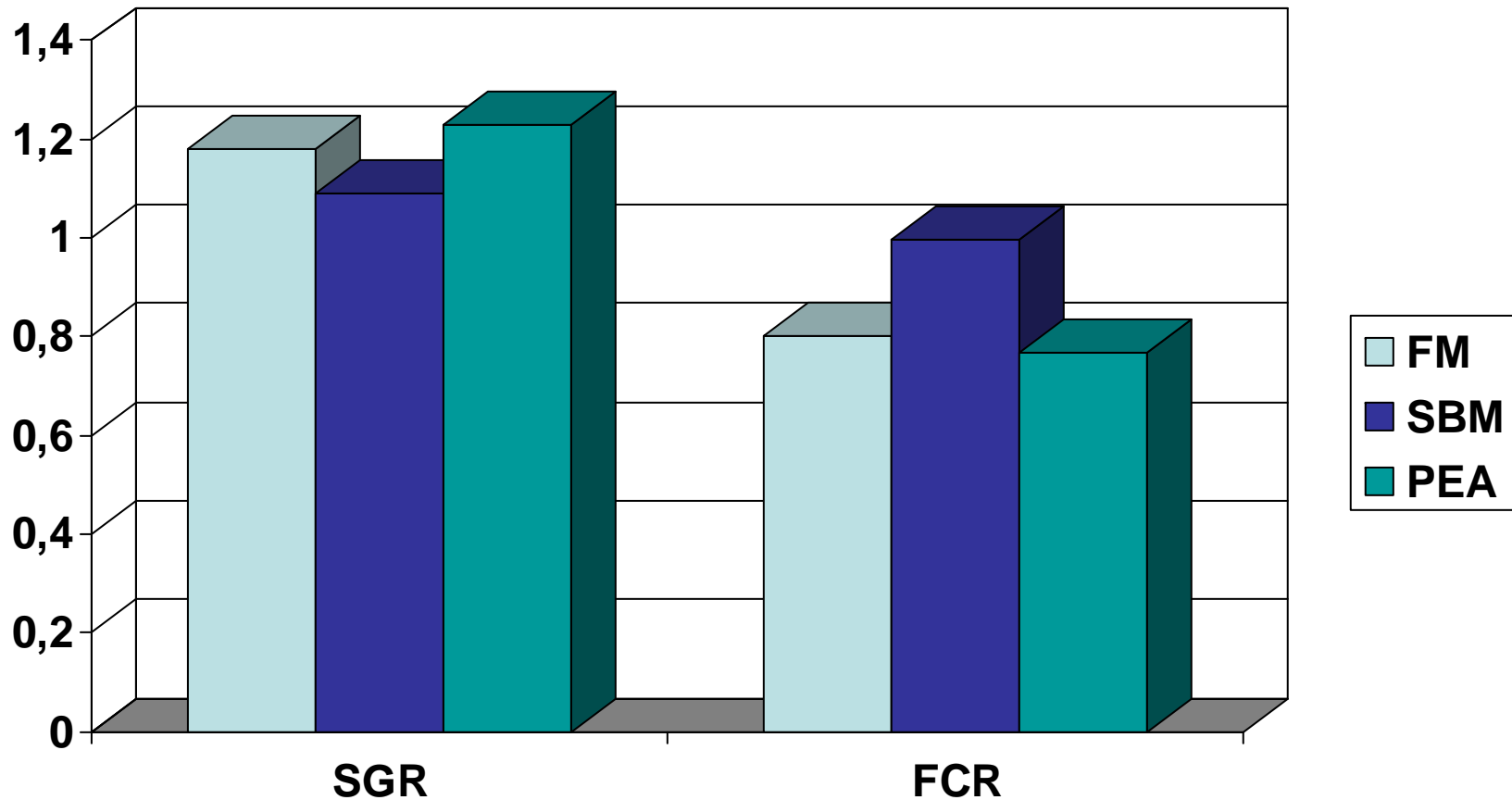


Energy digestibility



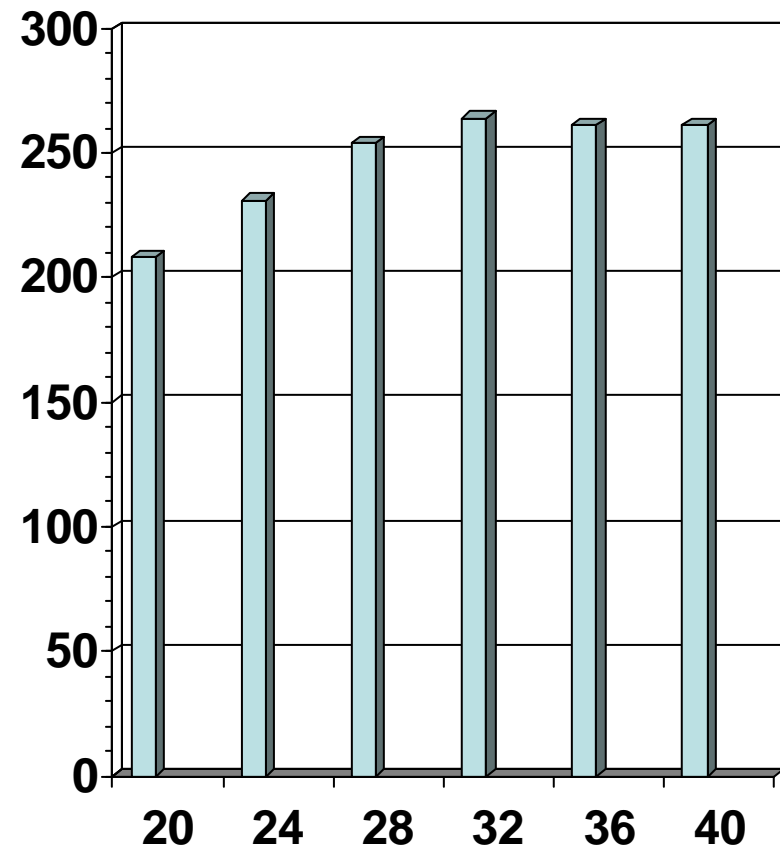
Peas are good!

FM, Fish meal; SBM, soybean meal 20% of feed;
Pea (50% protein), 20% of feed



Essential amino acid balance in ingredients is not a major challenge

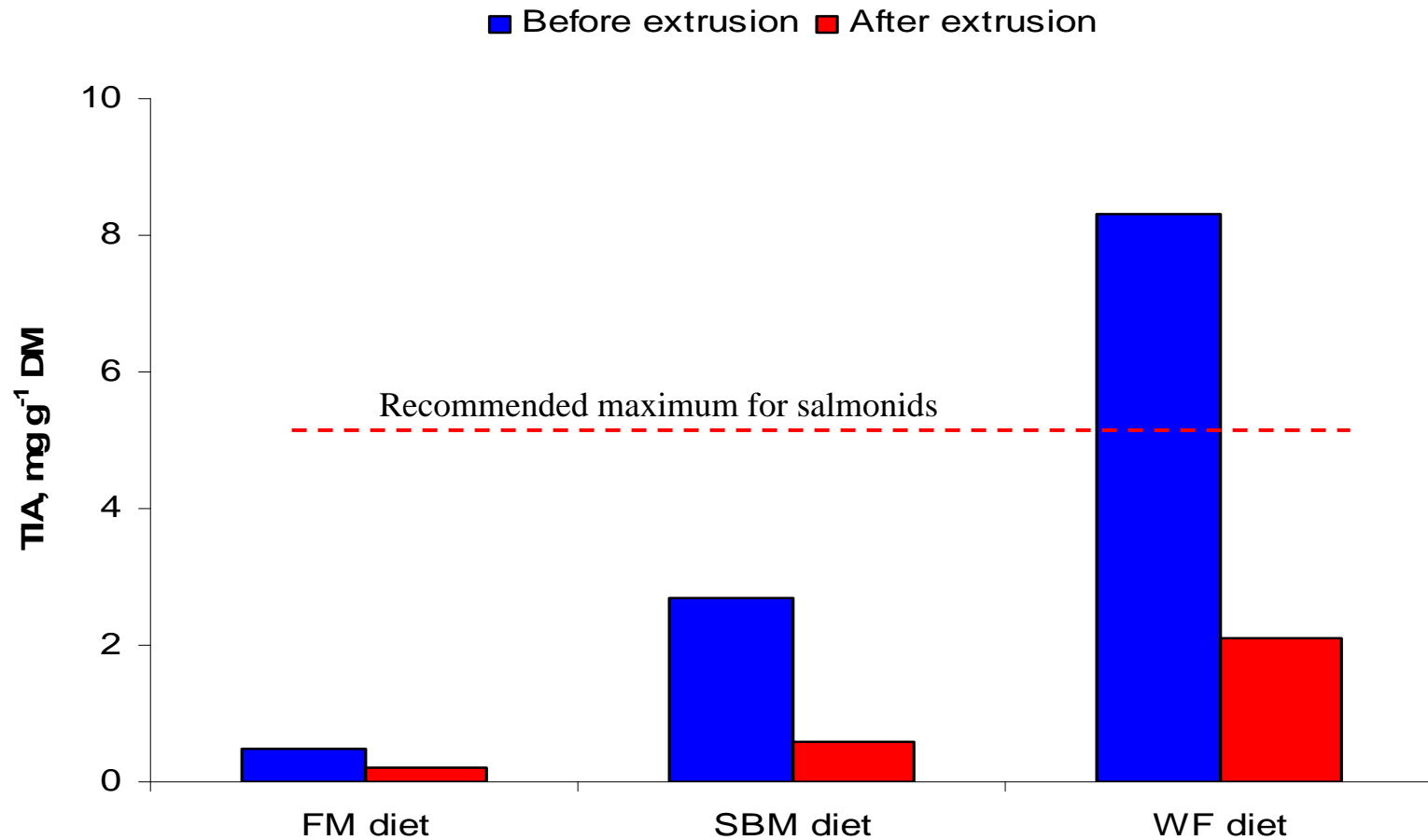
- Fish with stomachs utilise crystalline *L*-amino acids efficiently, like other monogastric animals
- Example: Growth (% of initial wt) in response to dietary lysine (g/kg) in juvenile grouper (Luo et al., 2006)



Antinutrients

- Labile when heated
 - Protease inhibitors
 - Lectins
 -
- Stable when heated
 - Indigestible carbohydrates
 - Oligosaccharides
 - Non-starch polysaccharides
 - Glycosinolates
 - Phytic acid
 - Saponines
 - Tannins
 -

Heat labile antinutrients is not a major problem due to the high amounts of heat applied during extrusion (Romarheim et al., 2005)



Carbohydrates

- Indigestible oligosaccharides
 - Reduced water content of faeces
 - Microbial selection
 - Effects under investigation
- Starch
 - Salmonids have limited ability for starch digestion and utilisation
 - mainly used for feed technological purposes
- Non-starch polysaccharides
 - Compete with starch for gelatinisation water
 - Insoluble – just fillers
 - Soluble, polar
 - Lipid digestibility

- Feed enzyme supplementation doesn't work for fish reared in cold water:

Phosphorus content in the vertebral column of Atlantic salmon fed diets with:

fish meal (FM),

or 60% of protein from soy-protein-concentrate (SPC),

or SPC with enzyme addition (SPC-E),

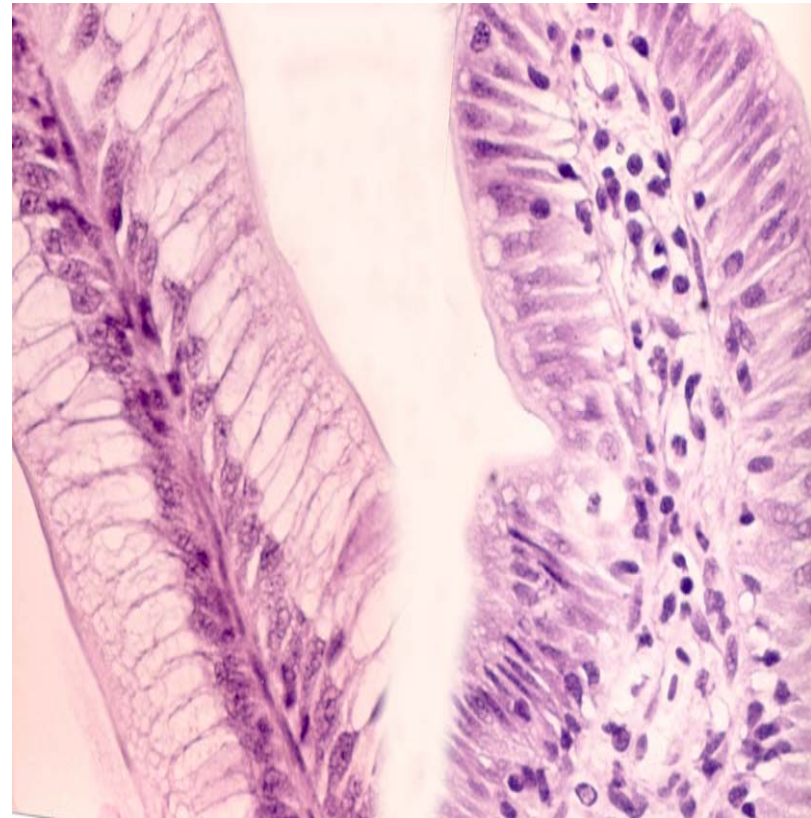
or SPC that has been incubated with phytase (**SPC-I**)

| | FM | SPC | SPC-E | SPC-I |
|-----------------------|-----------------|-----------------|-----------------|-----------------------|
| P, g kg ⁻¹ | 23 ^a | 17 ^c | 16 ^c | 20^b |

•(Denstadli et al., 2007)

Unexpected serious effects of plant proteins

- Example: Soybean-meal induced enteritis in the distal intestine of salmonids fed soybean meal (Ingh et al., 1991)
- Causes still not known:
 - Heat stabile
 - Extractable
 - Not all species
 - Only found for soy



Priorities

- Most suitable plants?
 - Oil (modified for EPA and DHA): Also keep monoenes high
 - Protein:
 - High yield
 - Starch rather than NSP
 - Low level of heat stable antinutrients
 - PEAS and BEANS?
 - Protein up
 - Oligosaccharides down
 - Reduce selected heat-stable antinutrients if necessary