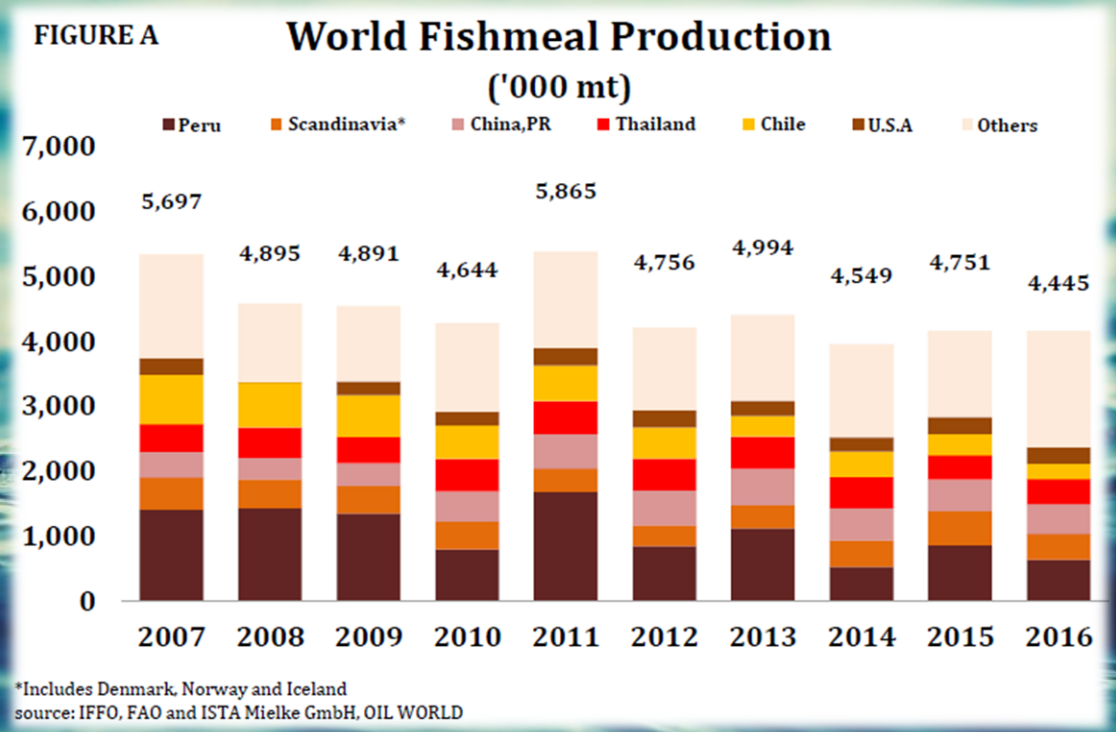
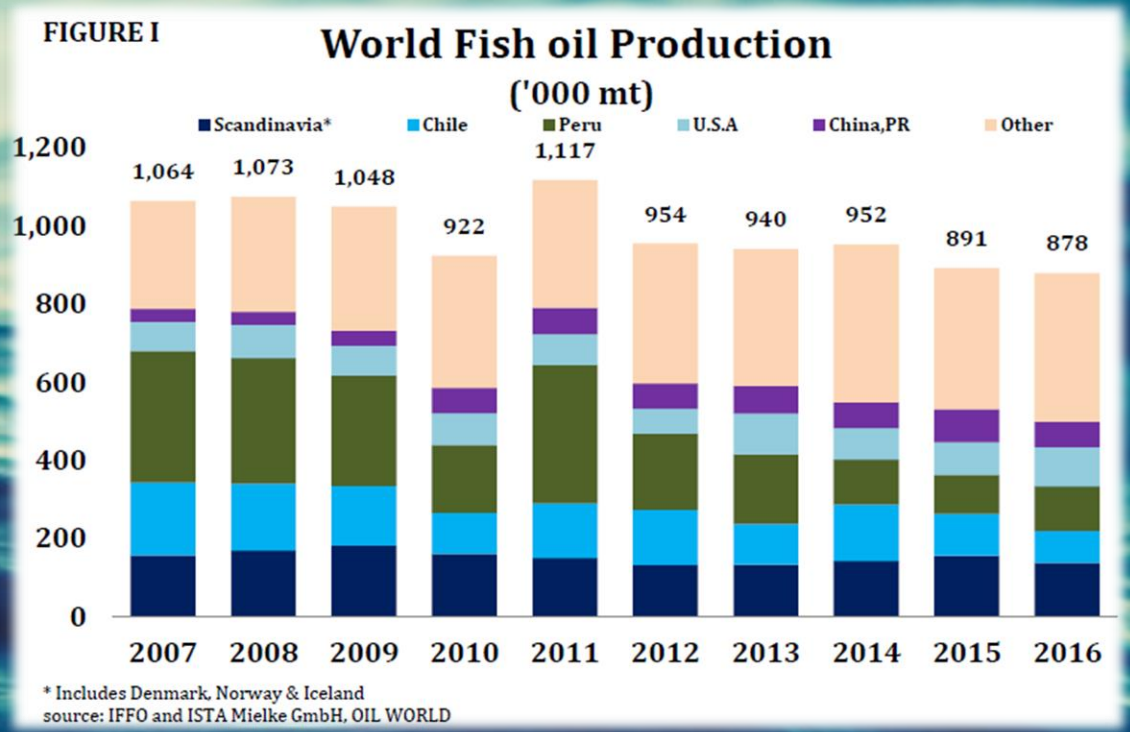
# “The continuing importance of fishmeal and fish oil in aquafeeds”


Dr Neil Auchterlonie,
IFFO
February 16th 2018

# Annual Global Production of FM & FO



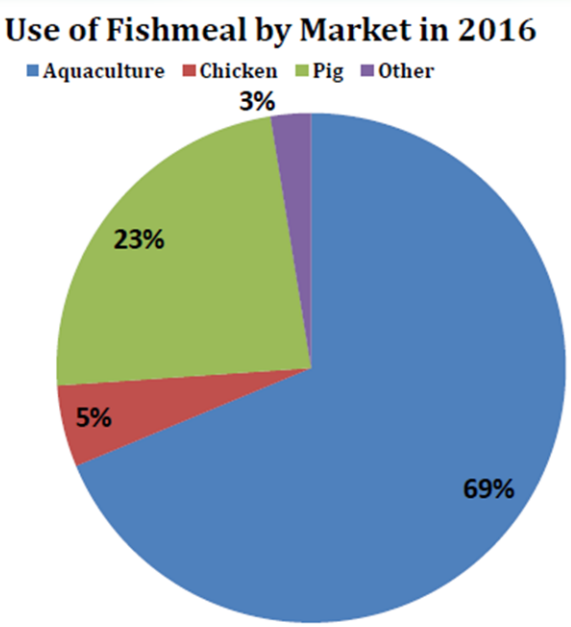




**Fishmeal**
**c.5 million tonnes *p.a.***

**Fish Oil**
**c.1 million tonnes *p.a.***

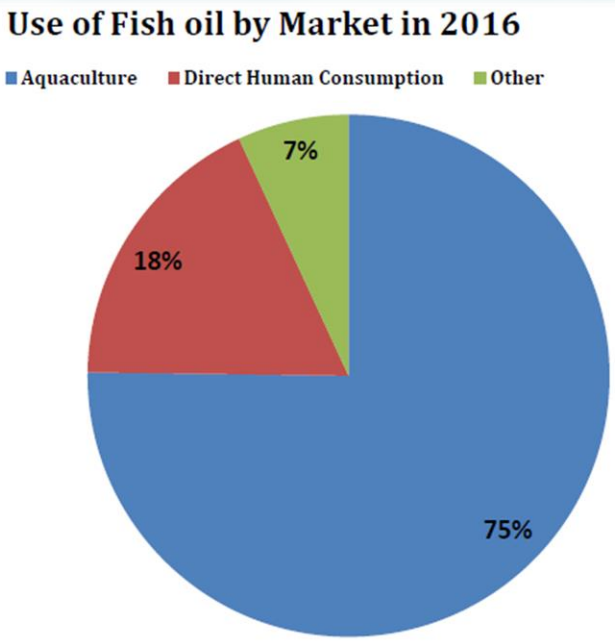
# FMFO by Market

FIGURE R




source: IFFO

FIGURE T




source: IFFO and FAO

# FMFO in Aquaculture

FIGURE Q

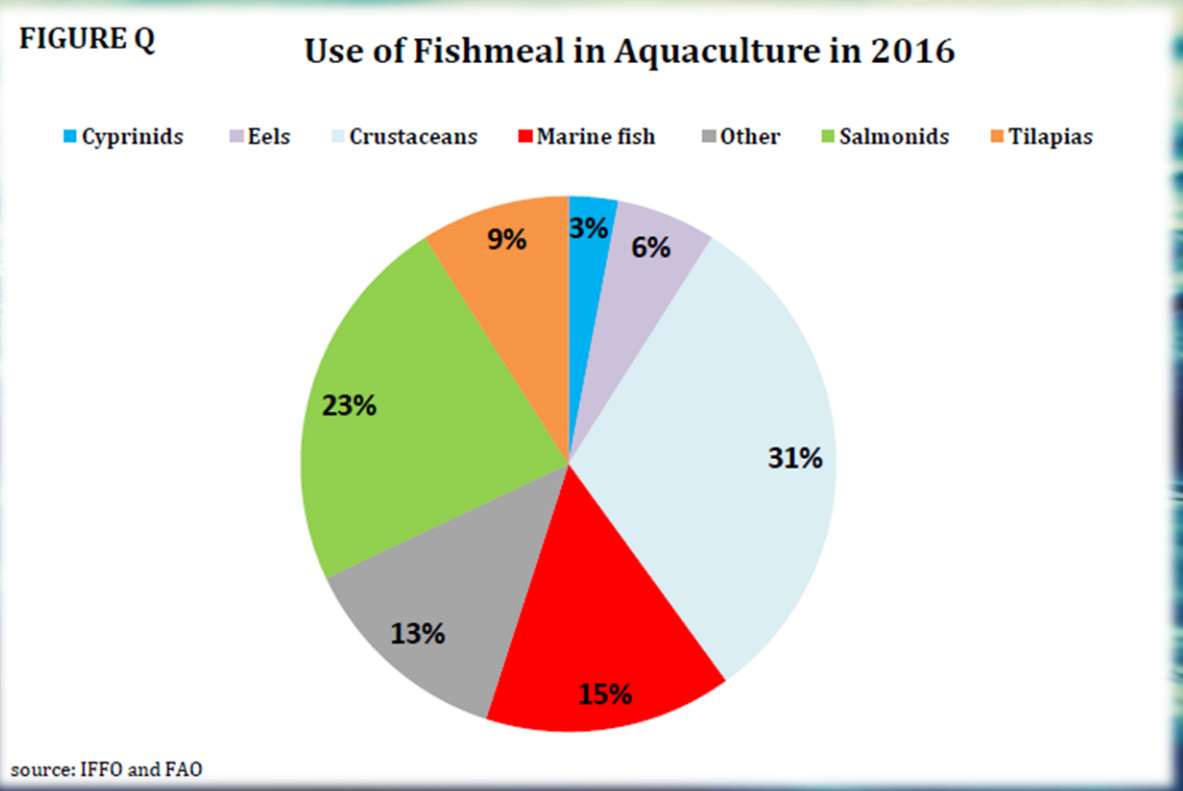
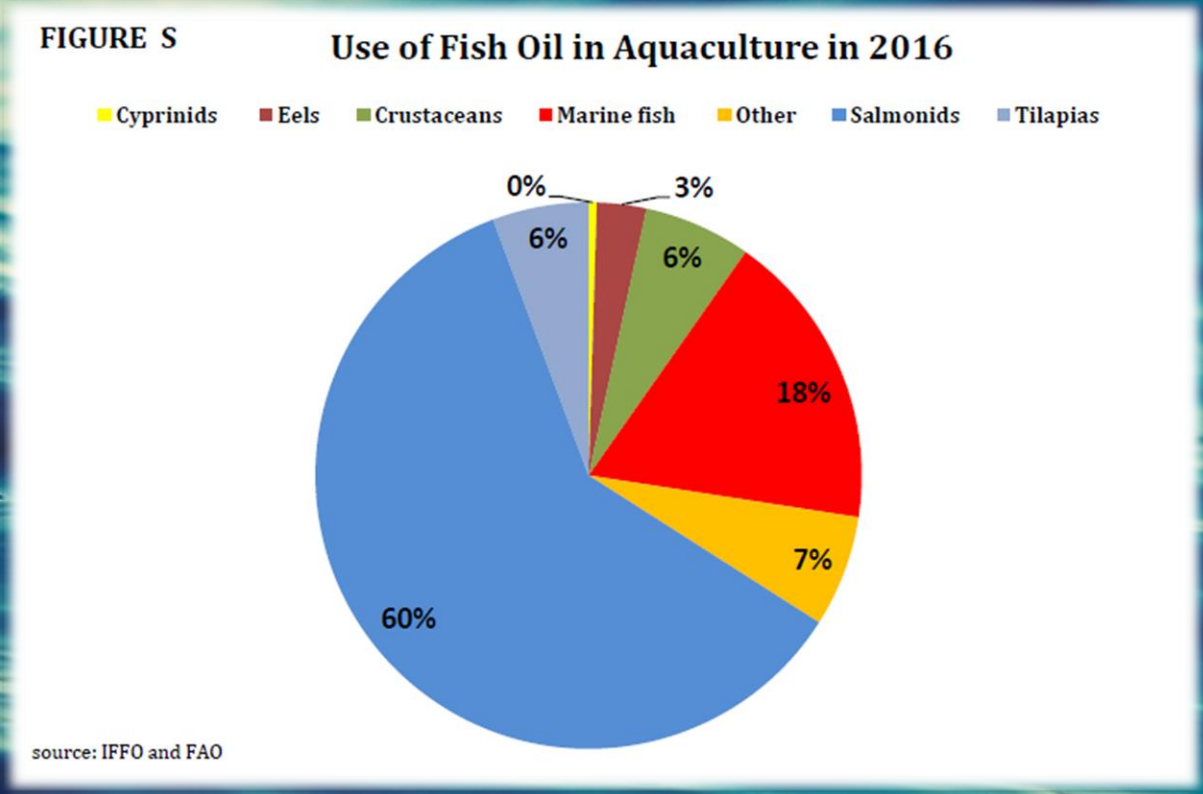



FIGURE S



# Process:

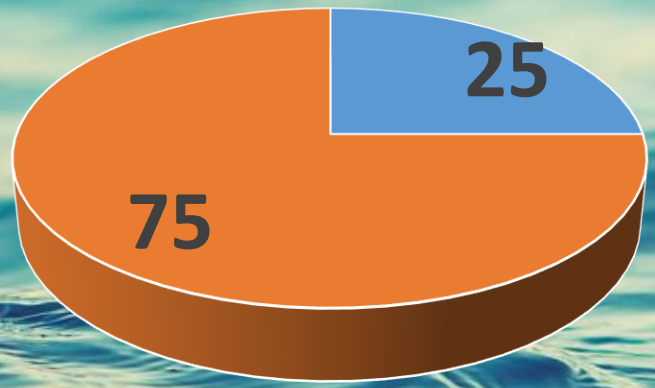

Mass Balance Marine Ingredients production (2010)

# Whole fish raw material sources:

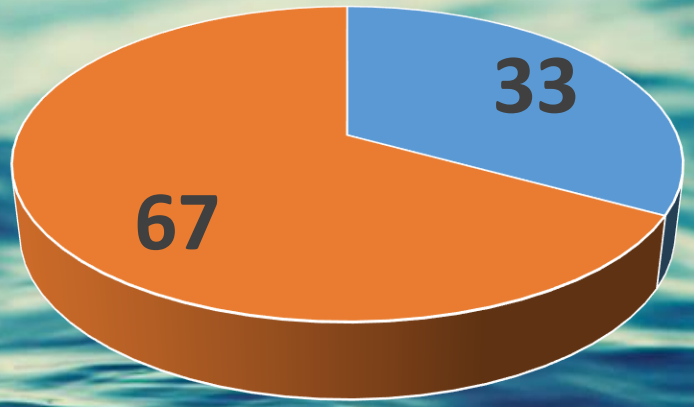
| INDUSTRIAL GRADE FORAGE | Landings tonnes |
|---|---|
| Gulf menhaden (*Brevoortia patronus)* | 479,000 |
| Atlantic menhaden *(Brevoortia tyrannus)* | 212,000 |
| Sand-eel (*Ammodytes spp.)* | 486,500 |
| **Total 1,175,000 tonnes of which 100% converted** | |
| **FOOD GRADE FORAGE** | |
| Peruvian anchovy (*Engraulis ringens*) | 8,468,000 |
| Japanese anchovy *(Engraulis japonicus*) | 1,567,000 |
| South African anchovy (*Engraulis encrasicolus*) | 228,000 |
| Sprat *(Sprattus sprattus)* | 262,000 |
| Blue whiting *(*Micromesistius poutassou) | 678,500 |
| Capelin *(Mallotus villosus*) | 958,500 |
| **Total 12,162,000 tonnes of which an estimated 90% was converted** | |
| **PRIME FOOD FISH** | |
| Atlantic herring (*Clupea harengus)* | 656,500 |
| European sardine *(Sardina pilchardus)* | 639,000 |
| Chilean jack mackerel (*Trachurus murphyii*) | 1,870,000 |
| Japanese jack mackerel *(Trachurus japonicas)* | 320,000 |
| Chub mackerel *(Scomber japonicus)* | 1,403,500 |
| Californian sardine (*Sardina sagax caerulea*) | 556,000 |
| South African sardine (*Sardina sagax)* | 263,000 |
| **Total 5,708,000 tonnes (average landings 2001 – 2006) of which an unknown percentage was converted** | |

**after Wijkström, 2011**

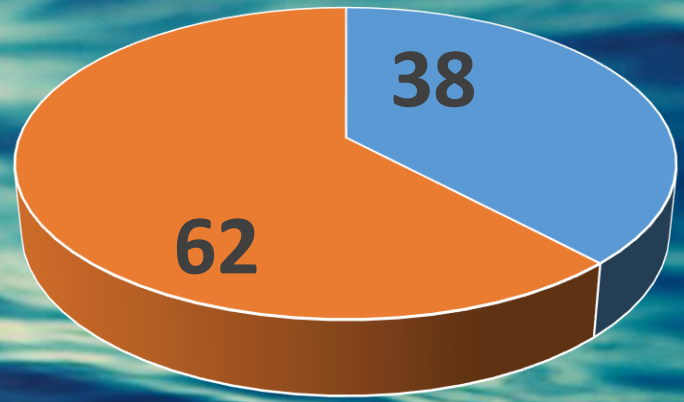
# Raw material: Whole fish & Byproduct proportions




Estimated by Shepherd, 2012




Calculated by Jackson & Newton, 2016




Predicted by FAO for 2025 (2016)

# Marine ingredients are the foundation for modern fed aquaculture & facilitated technological development

Fig. 25 Square timber framed floating cages

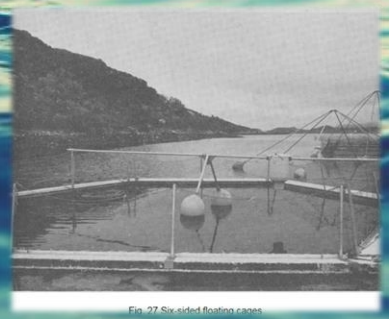
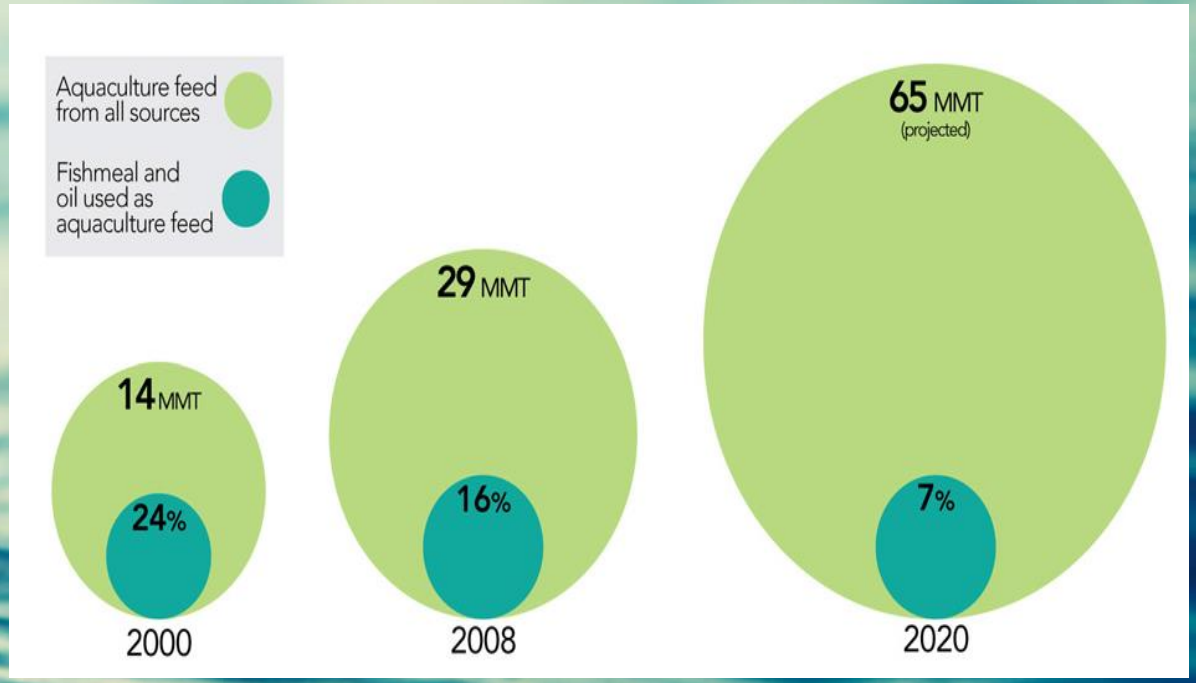


Fig. 27 Six-sided floating cages

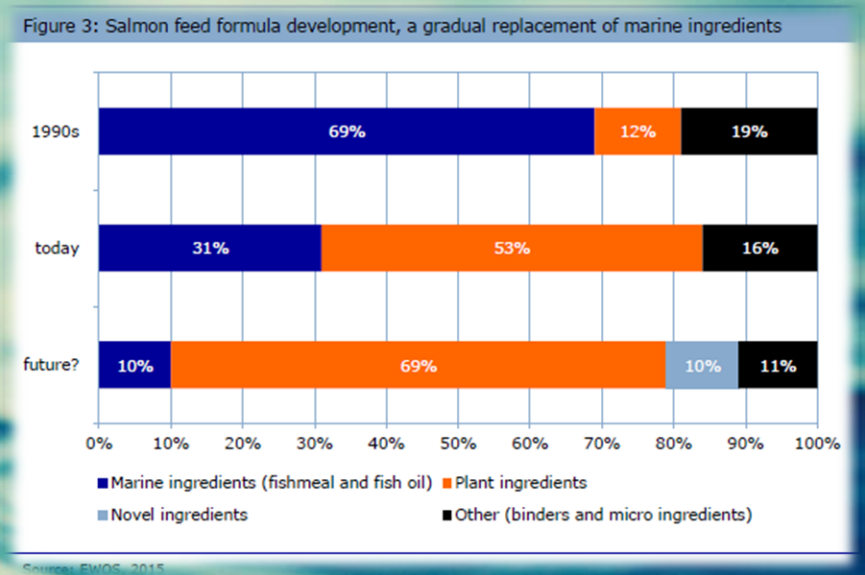
# Aquaculture continues to grow….

# More feed is required




Source: Fry, J.P. et al., 2016. Environmental health impacts of feeding crops to farmed fish. *Environment International*, 91, pp.201–214. Available at: http://dx.doi.org/10.1016/j.envint.2016.02.022

# FMFO inclusion rates declining



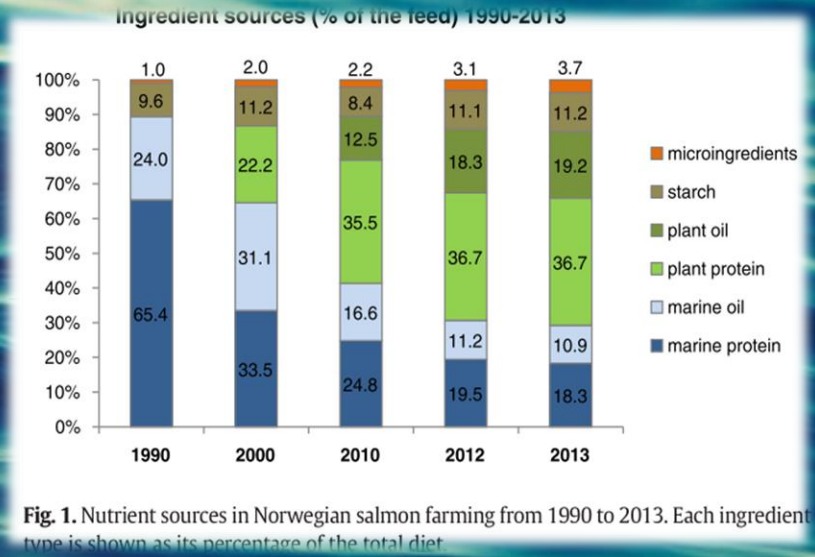




**Fig. 1.** Nutrient sources in Norwegian salmon farming from 1990 to 2013. Each ingredient type is shown as its percentage of the total diet.

**Ytrestoyl, et al. (2015) Aquaculture 448 365–374**
**http://dx.doi.org/10.1016/j.aquaculture.2015.06.023**

# Nutritional importance:

- Fishmeal
  - Protein
  - Digestibility
  - Amino acid profile
  - Micronutrients
- Fish oil
  - Energy
  - LC polyunsaturated fatty acids (EPA & DHA)
- Important factors for:
  - Growth
  - Quality
  - Health

# Amino acid profile

*"All finfish studied to date have been shown to require the same 10 amino acids which are considered essential for most animals. These include arginine, histidine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine."*

From: Robert P. Wilson, "Amino Acids and Proteins, in Fish Nutrition, 2nd Edition, 1989, Ed. John E. Halver.

Table 3. Percentage of essential amino acids (EAA)[1] in fishmeal (FM), rendered meat meal (MM), poultry by-product meal (PBM), blood meal (BM), soybean meal (SBM). Percentage of crude protein in the meal (in parenthesis).

| Essential Amino Acid | FM (64.5%)[2] | MM (55.6%)[2] | PBM (59.7%)[2] | BM (8… | |
|---|---|---|---|---|---|
| Arginine | 3.82 | 3.60 | 4.06 | | |
| Histidine | 1.45 | 0.89 | 1.… | | |
| Isoleucine | 2.66 | 1.64 | | | |
| Leucine | 4.48 | 2.85 | | | |
| Lysine | 4.72 | | | | 3.08 |
| Methionine + Cystine[3] | 2.31 | | | | 1.43 |
| Phenylalanine + Tryosine[4] | | | | 8.47 | 4.20 |
| Threonin… | | | .94 | 3.76 | 1.89 |
| Try… | | | 0.46 | 1.04 | 0.69 |
| | | 52 | 2.86 | 7.48 | 2.55 |

…he EAA composition of each feedstuff we… …93 NRC (National Research Council, Nutrient Requ… …l, National Academy of Sciences, Washington, DC).

[2]Percent… …f total crude protein in feedstuff.

[3]Cystine can be synthesized from methionine.

[4]Tyrosine can be synthesized from phenylalanine.

UF | IFAS Extension UNIVERSITY of FLORIDA

**The Benefits of Fish Meal in Aquaculture Diets**

R. D. Miles and F. A. Chapman[2]

**"Fishmeal contains the profile of amino acids that most closely meets the amino acid requirements of fish."**

# Importance of micronutrients – Minerals

## Mineral requirements of fish

| Macrominerals (g/kg diet) | Microminerals (mg/kg diet) (trace elements) |
|---|---|
| Calcium | Iron |
| Phosphorus* | Manganese* |
| Sodium | Copper |
| Potassium* | Zinc* |
| Chlorine | Cobalt |
| Magnesium* | Selenium* |
| Sulfur | Iodine* |
| | Molybdenum |

* Required in the diet, but not always supplemented in practical feeds

Extract from: Ronald W. Hardy, University of Idaho, Fish Nutrition Research Differences and similarities with livestock nutrition and what the future holds. Part I.: http://www.pitt.edu/~super4/33011-34001/33021.ppt

**Table 3:** The mineral and trace element contents of feed meals

| | Anchovy | | Herring | | Menhaden | | Tuna | | Salmon | Jack Mackerel | White fish | Sandeel | Soya | Canola/ rapeseed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | | | Mean | Mean | Mean | Mean |
| **Calcium %** | 3.89 | 2.79-5.60 | 2.05 | 1.32-3.54 | 5.23 | 3.94-6.82 | 8.36 | 5.82-12.6 | 3 – 4 | | 7.66 | 2.8 | 0.29 | 0.17 |
| **Chlorine %** | 1.41 | | 1.01 | | 0.55 | | 1.01 | | | | 1.25 | | 0.03 | 0.04 |
| **Magnesium %** | 0.25 | 0.16-0.33 | 0.12 | 0.09-0.13 | 0.15 | 0.13-0.17 | 0.23 | 0.16-0.30 | 0.15 – 2.0 | | 0.17 | 0.2 | 0.29 | 0.41 |
| **Phosphorus (total) %** | 2.54 | 1.85-3.55 | 1.90 | 1.01-2.29 | 2.93 | 2.39-3.67 | 4.44 | 3.28-6.59 | 2 - 3 | | 4.80 | 2.2 | 0.60 | 1.17 |
| **Phosphorus (available) %** | | | 1.90 | | | | | | | | 4.80 | | 0.24 | |
| **Potassium %** | 0.75 | 0.39-0.84 | 1.16 | 0.84-1.38 | 0.71 | 0.60-1.10 | 0.73 | 0.58-0.84 | 2 - 3 | | 0.87 | 0.2 | 1.97 | 1.39 |
| **Sodium %** | 0.95 | 0.48-1.49 | 0.57 | 0.29-1.03 | 0.38 | 0.25-0.44 | 0.74 | 0.52-1.17 | 0.4 – 0.5 | | 1.04 | 1.0 | 0.03 | 0.04 |
| **Sulphur %** | 0.54 | | 0.46 | | | | 0.68 | | | | 0.48 | | | 0.30 |
| **Aluminum** mg/kg | 77.2 | 48.0-190 | 33.0 | 22.5-97.5 | 352 | 161-615 | 150 | 98.0-180 | | | | 82 | | |
| **Barium** mg/kg | 5.40 | 2.00-10.9 | 3.00 | 2.0-15.0 | 20.4 | 4.9-51.5 | 4.52 | 2.0-6.5 | | | | | | |
| **Boron** mg/kg | 13.7 | 9.00-19.8 | 6.30 | 4.45-8.45 | 14.1 | 12.2-19.8 | 16.4 | 11.1-21.5 | | | | | | |
| **Chromium** mg/kg | 10.2 | 6.6-23 | 4.20 | 3.0-6.2 | 11.0 | 8.5-13.1 | 17.6 | 11.9-21.5 | | | | | | |
| **Copper** mg/kg | 8.30 | 5.0-13.8 | 5.40 | 4.6-8.8 | 10.9 | 6.6-17.5 | 10.6 | 8.00-15.4 | 2 - 3 | | 6.45 | 4.2 | 43 | 19 |
| **Iron** mg/kg | 237 | 150-725 | 138 | 105-255 | 491 | 250-670 | 362 | 235-450 | 70 - 80 | | 241 | 208 | 93.0 | 208 |
| **Manganese** mg/kg | 9.73 | 4.3-21.1 | 3.07 | 2.0-4.25 | 36.3 | 21.1-65 | 8.53 | 7.10-15.0 | 15 - 20 | | 11.2 | 12 | 38 | 21 |
| **Selenium** mg/kg | 1.38 | 1.18-1.73 | 2.31 | 1.73-3.43 | 2.19 | 1.22-3.98 | 4.47 | 3.40-6.20 | 0.8 – 0.9 | | 1.56 | 2.5 | 0.35 | 0.06 |
| **Strontium** mg/kg | 87.8 | 36.5-161 | 71.0 | 22.8-171 | 63.4 | 37.5-96 | > 200 | | | | | | | |
| **Zinc** mg/kg | 108 | 90-146 | 122 | 105-132 | 147 | 133-169 | 212 | 151-273 | 200 - 250 | | 95 | 108 | 56 | 61 |
| **Iodine** mg/kg | | | | | | | | | 2 - 3 | | | | | |

# Importance of micronutrients – Vitamins

## Vitamin requirements of salmon and growing chickens (IU or mg/kg dry diet)

| Vitamin | Salmon/trout | Chickens |
|---|---|---|
| Vitamin A | 2500 | 1500 |
| Vitamin D | 2400 | 200 |
| Vitamin E | 50 | 16 |
| Vitamin K | unknown | 0.5 |
| Thiamin | 1 | 1.3 |
| Riboflavin | 7 | 3.6 |
| Pyridoxine | 6 | 3.0 |
| Pantothenic acid | 20 | 10 |
| Niacin | 10 | 11 |
| Biotin | 0.15 | 0.10 |
| Folic acid | 2 | 0.25 |
| Vitamin $B_{12}$ | 0.01 | 0.003 |
| Ascorbic acid | 50 | not required |
| Choline | 800 | 500 |
| myo-Inositol | 300 | not required |

*values in yellow are lower for chickens

Extract from: Ronald W. Hardy, University of Idaho, Fish Nutrition Research Differences and similarities with livestock nutrition and what the future holds. Part I.: http://www.pitt.edu/~super4/33011-34001/33021.ppt

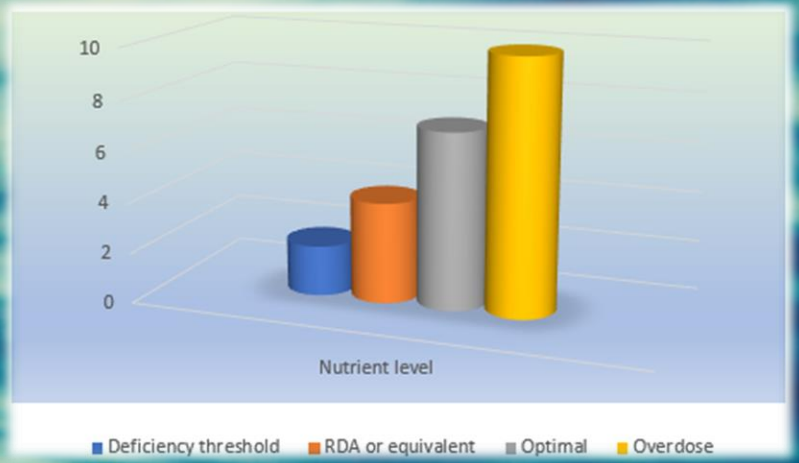
**Table 4:** The vitamin contents of feed meals

| | Anchovy | Herring | Menhaden | Tuna | Salmon | Jack Mackerel | White fish | Sandeel | Soya | Canola/ Rapeseed |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Mean | Mean | Mean | | | Mean | Mean | Mean | Mean |
| **Biotin** mg/kg | 0.25 | 0.46 | 0.18 | 0.20 | | | 0.08 | | 0.25 | 0.97 |
| **Choline** mg/kg | 4404 | 4833 | 3112 | 2994 | | | 3750 | | 2804 | 2764 |
| **Folic acid** mg/kg | 0.18 | 0.4 | 0.12 | | | | 0.43 | | 3.6 | 1.4 |
| **Niacin (nicotinic acid, Vitamin $B_3$)**mg/kg | 97.5 | 106 | 55 | 144 | | | 54.5 | | 27 | 41 |
| **Panthothenic acid (vitamin $B_5$)** mg/kg | 12.2 | 24.0 | 8.6 | 7.7 | | | 12.5 | | 14.5 | 13.7 |
| **Pyridoxine (Vitamin $B_6$)** mg/kg | 4.07 | 4.24 | 4.66 | | | | 4.61 | 3.0 | 8 | 7.0 |
| **Riboflavin (vitamin $B_2$)** mg/kg | 6.85 | 8.50 | 4.8 | 6.79 | | | 7.8 | 7.0 | 3.55 | 3.3 |
| **Thiamin (vitamin $B_1$)** mg/kg | 0.10 | 0.40 | 0.6 | | | | 1.7 | 1.0 | | 6.6 |
| **Vitamin $B_{12}$** mg/kg | 0.27 | 0.34 | 123 | 0.31 | | | 0.08 | 0.28 | | |
| **Vitamin E (tocopherol)** mg/kg | 5.00 | 22.1 | 12.0 | 5.6 | | | 8.9 | 8.0 | | 16 |
| **Vitamin K** mg/kg | | 2.2 | | | | | | | | |

# Fish nutrition studies are based on identification of levels that avoid deficiency

***"Unfortunately, limited research effort has been directed to characterize the pathological changes associated with disorders linked to nutrient deficiencies in fish"***

Lall, S. and Lewis-McCrea, L.M. (2007) Role of nutrients in skeletal metabolism and pathology in fish – An overview. Aquaculture 267, 3-19 doi:10.1016/j.aquaculture.2007.02.053




**What about optimisation?**

**How do requirements change with species?**

**With farming system?**

**With life cycle stage?**

**With specific pathogen challenge?**

**Scope for customised diets….**

# Reducing FMFO in aquafeeds has repercussions…..

SCIENTIFIC OPINION

EFSA Journal

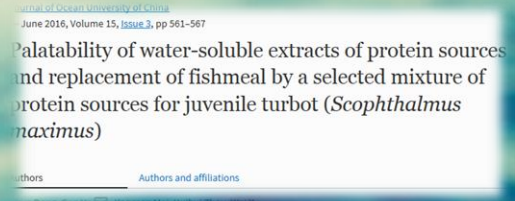
ADOPTED: 25 January 2017

doi: 10.2903/j.efsa.2017.4713

**Safety of vitamin $D_3$ addition to feedingstuffs for fish**

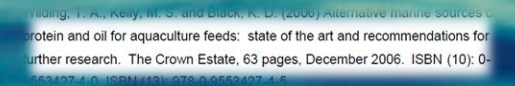
EFSA Panel on Additives and Products or Substances used in Animal Feed (FEEDAP),
Guido Rychen, Gabriele Aquilina, Giovanna Azimonti, Vasileios Bampidis,
Maria de Lourdes Bastos, Georges Bories, Andrew Chesson, Pier Sandro Cocconcelli,
Gerhard Flachowsky, Jürgen Gropp, Boris Kolar, Maryline Kouba, Marta López-Alonso,
Secundino López Puente, Alberto Mantovani, Baltasar Mayo, Fernando Ramos, Maria Saarela,
Roberto Edoardo Villa, Pieter Wester, Lucio Guido Costa, Noël Dierick, Paola Manini,
Jordi Tarrés-Call and Robert John Wallace

# Marine Ingredients & Aquafeed Palatability


June 2016, Volume 15, Issue 3, pp 561–567

Palatability of water-soluble extracts of protein sources and replacement of fishmeal by a selected mixture of protein sources for juvenile turbot (*Scophthalmus maximus*)

Authors and affiliations


protein and oil for aquaculture feeds: state of the art and recommendations for further research. The Crown Estate, 63 pages, December 2006. ISBN (10): 0-


Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

An evaluation of the complete replacement of both fishmeal and fish oil in diets for juvenile Asian seabass, *Lates calcarifer*

Brett Glencross [a,*], David Blyth [b], Simon Irvin [b], Nicholas Bourne [a], Marcel Campet [c,1], Pascal Boisot [d], Nicholas M. Wade [a]

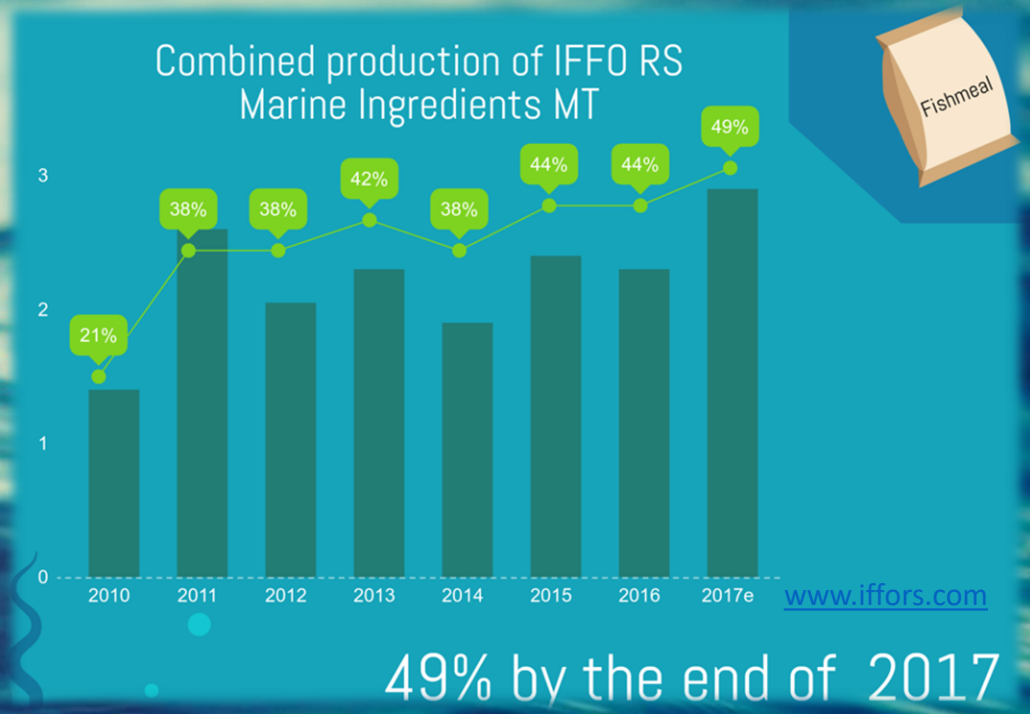
***"Poor palatability is a limiting factor for replacing fishmeal with other protein sources in aquaculture"***

***"The feed-palatability issue may be overcome, perhaps through the inclusion of krill meal"***

***"…it has also been determined that a critical threshold of 15% fishmeal was pertinent to barramundi, based on a diet balanced for digestible protein, energy and amino acids using a plant protein concentrate as the alternative (Glencross et al., 2011)…"***

# Sustainability: Management of forage fish stocks


# Sustainability: Certification




- IFFO Responsible Supply
  - 132 certified sites
  - 17 countries
  - 18 fisheries
  - 129 byproducts
- Proportion of global annual production certified is significant

- **Marine ingredients are the foundation of modern fed aquaculture;**
- **Marine ingredients have nutritional benefits beyond protein & energy supply;**
- **Those benefits have +ve impacts on survival, growth and feed efficiency;**
- **All ingredients are complementary and support the growth of the aquaculture industry – volume is required.**

*"Fishmeal and fish oil are still considered the most nutritious and digestible ingredients for farmed fish feeds"*

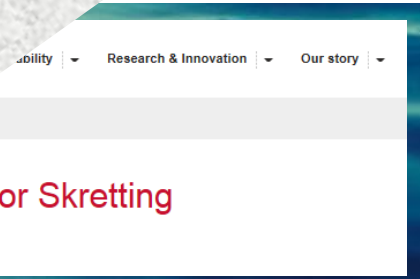
(FAO, 2016)

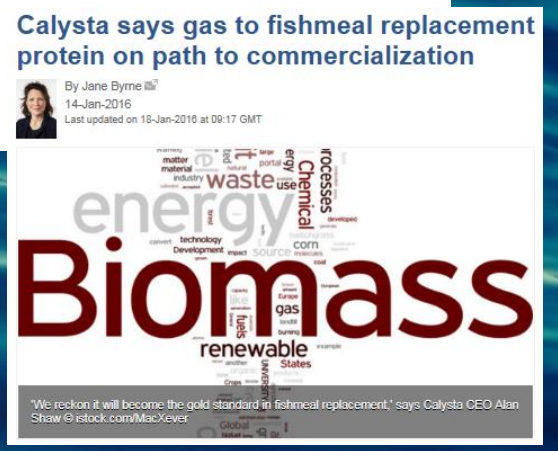
# Complementary ingredients (i.e. not substitutes)









# Questions?

Email: nauchterlonie@iffo.net

Web: www.iffo.net