# Production of fish protein and fish oil for human consumption

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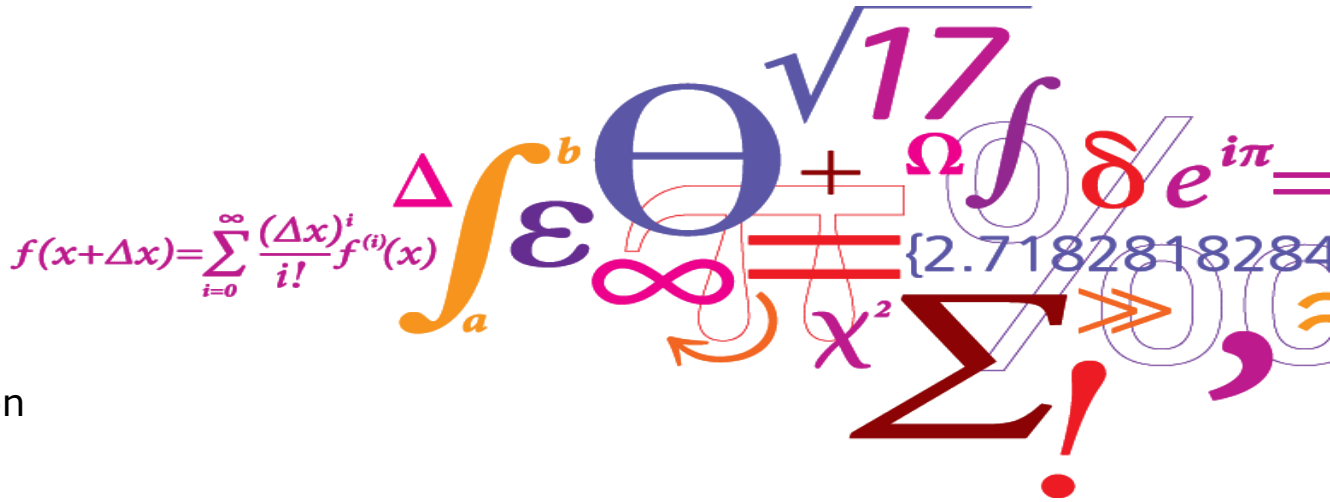


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# Agenda

- Fish oil
  - Refining process
  - Quality criteria
  - Regulations
- Fish protein concentrate
  - Processing
  - Historical background
  - Current use
- Challenges and research needs

# Fish oil

- Fish oil quality and properties will depend on the quality of the raw material and the processing.
- Refining to remove:
  - contaminants (e.g. dioxins and PCBs)
  - residual proteins
  - water
  - pigments
  - free fatty acids
  - phospholipids
  - lipid oxidation products.

- At the same time the desirable properties including the nutritional value of the oil must be kept.
- The properties of the obtained refined fish oil will determine both its application and price.

# Fish oil refining process

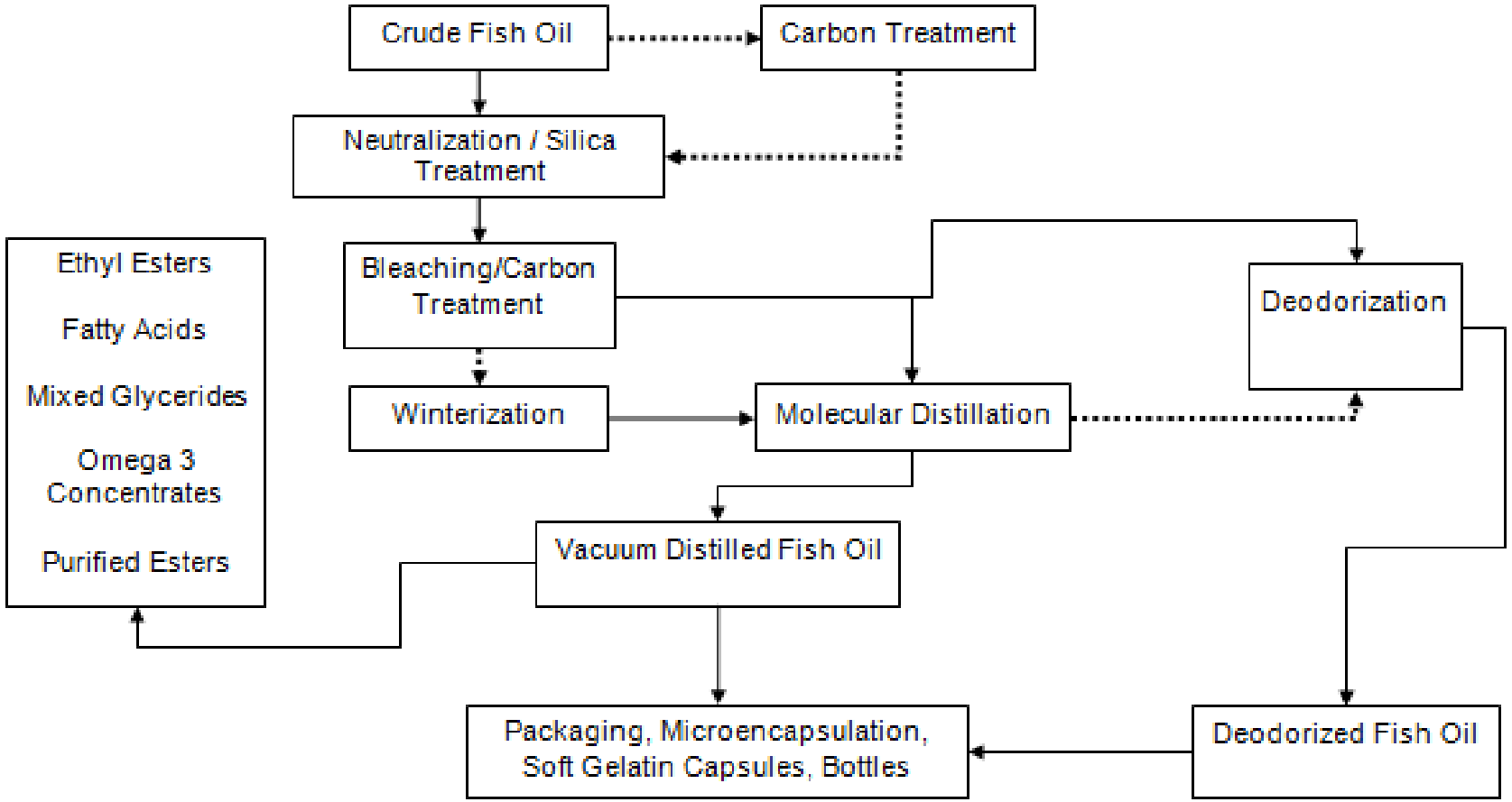



**Figure 1.** Flow diagram for the production of edible and pharmaceutical-grade fish oils and derivatives (Bimbo 2007)



Bimbo, A.P. Processing of marine oils. In: Long Chain Omega-3 Specialty Oils, pp. 77-109 (H. Breivik (ed.) The Oily Press Bridgwater England) (2007).

# Quality criteria

- **Triacylglycerol *vs* methyl or ethyl esters**
- The form of the omega-3 FAs i.e. the natural triacylglycerol form as opposite to the methyl or ethyl esters (via transesterification) has been discussed
- Omega-3 FAs in the form of acylglycerides have been reported to present higher stability against oxidation (Boyd et al., 1992) apart from being more efficiently absorbed by humans compared to those in the form of esters (Lawson and Hughes, 1988).
- Furthermore, stability is also higher when omega-3 FAs are bound to sn-2 position of the glycerol structure than to the sn-1,3 position (Wijesundera et al., 2008).
- In this context, the development of cost-effective technological solutions for the production of acylglycerides concentrates with omega-3 in sn-2 position is highly desirable (Rubio-Rodríguez et al., 2010).
- **Free fatty acids**
- Concentration of free fatty acids must be minimal as hydrolysis and acidity have a major detrimental effect on the quality of omega-3 concentrates.



Boyd et al. (1992) J. Am. Oil Chem. Soc. 69, 4, 325-330; Lawson and Hughes (1988) Biochem. Biophys. Res. Communications, 152, 328-335; Wijesundera et al. (2008) J. Am. Oil Chem. Soc. 85, 6, 543−548; Rubio-Rodríguez et al. (2010) Innov. Food Sci. Emerg. Technol. 11, 1-12.

# Quality criteria

- **Oxidative stability**
- Exposure to factors that accelerate lipid oxidation (i.e. heat, intense light, metal ions and oxygen) must be minimized throughout processing.
- Antioxidants are generally added to fish oil after cooling down following the deodorization step
- **Sensory**
- The presence of impurities and off-flavours in the omega-3 concentrates must be imperceptible to human sensory analysis.

- In Norway: Sensory standard for fish oil is being developed (QOMEGA project)

# Regulations and guidelines

**Table 1.** Some quality guidelines for refined fish oils (Hamm 2009).

| Parameter | Quality guidelines |
|---|---|
| Colour | <3.0 Red, 30 Yellow |
| Odour and taste | Bland |
| Matter volatile at 105 ºC | <0.2 % |
| Insoluble impurities | <0.05 % |
| Soap content | <0.005 % |
| Iron | <0.12 mg/kg |
| Free fatty acids | <0.10 % (as oleic acid) |
| Copper | <0.05 mg/kg |
| Peroxide value | <0.1 meq O2/kg |
| Nickel | <0.20 mg/kg |

Source: EFSA 2010

GOED: TOTOX = 2 x PV + AV < 26

- Other proposed guidelines have referred a peroxide value of 5-10 meq $O_2$/kg, but such values would result in some smell that would make the oil unacceptable for inclusion in food products.
- On the other hand, if the oil is incorporated into oil capsules sold as dietary supplements then such peroxide values could actually be acceptable.

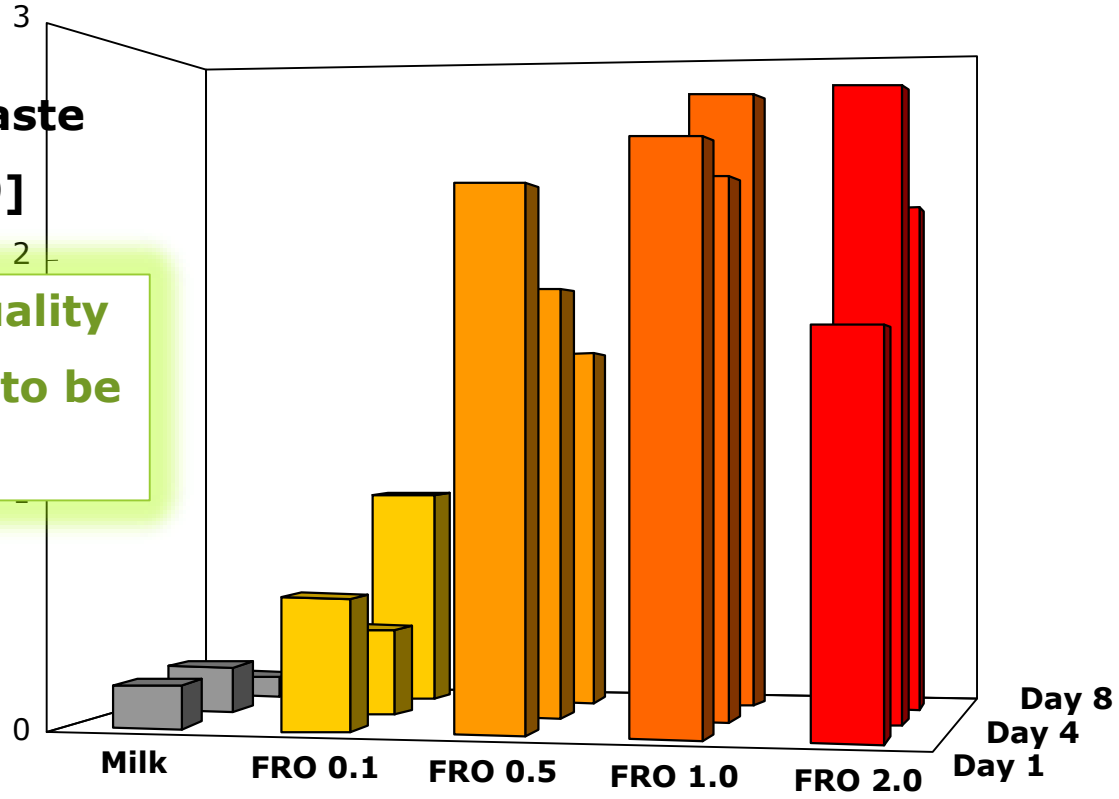


Hamm W, 2009. Processing of fish oil. In: Fish oils (ed. B. Rossell), pp. 81-98. Wiley-Blackwell, UK.

# Fish oil enriched milk

**Oil quality affects the food quality**

**→ seems that PV needs to be ≤ 0.1 meq/kg fish oil**




**Milk with a fish oil and rapeseed oil mixture**

*Let et al., 2005. Int. Dairy J. 15:173-182*

# Regulations and guidelines

**Table 2.** Some quality guidelines for omega-3 concentrates (FDA GRAS Notification 2002; 2006).

| Parameter | Quality guidelines |
|---|---|
| Appearance | Light yellow to yellow at room temperature |
| Triglycerides | >50 % |
| Odour and taste | At worst, a slightly fishy odour and taste |
| Acid value | <1.0 % |
| Peroxide value | <2.5 meq $O_2$/kg |
| p-Anisidine value | <20 |
| Totox value | <25 |
| Density | 0.85-1.00 g/ml |
| Tocopherols | >2.0 mg/g |
| Moisture | <0.1 % |
| Unsaponifiables | <2.35 % |

Source: EFSA 2010

- In the USA, the FDA has established a set of quality guidelines for omega-3 concentrates with food-grade specification, which must be fulfilled in order to receive a generally recognized as safe (GRAS) status.

# Regulations and guidelines

- **Dioxins and dioxin-like PCBs**
- The levels of dioxins and dioxin-like PCBs must be below the threshold values set by EU.

**Table 3.** Combined maximum dioxin and dioxin-like PCB levels and action limits in seafood for human consumption.

| Maximum levels[1] | Sum | Dioxins & Furans | Dioxin-like PCBs |
|---|---|---|---|
| Fish | 8 pg/g | 4 pg/g | 4 pg/g |
| Marine oil, incl. fish body oil and liver oil | 10 pg/g | 2 pg/g | 8 pg/g |
| **Action limits[2]** | | | |
| Fish and fish products | 6 pg/g | 3 pg/g | 3 pg/g |
| Marine oil incl. fish oil | 7.5 pg/g | 1.5 pg/g | 6 pg/g |

[1] EC Regulation 199/2006; [2] EC Recommendation 2006/88/EC

# Fish protein concentrate

- According to the FAO there are three major types of fish protein concentrates (FPC):
  - Type A: a virtually odourless and tasteless powder having a maximum total fat content of 0.75%.
  - Type B: a powder having no specific limits as to odour or flavour, but definitely having a fishy flavour and a maximum fat content of 3%.
  - Type C: normal fish meal produced under satisfactorily hygienic conditions.
- The fat content is specified when defining types of FPC because fat when oxidised can produce a strong, often rancid, taste in the product.
- The protein content of FPC depends on the raw material used and the extent to which water has been removed, but the products normally contain at least 65 percent protein and, in type A, up to 80 per cent (FAO 2001).
- Other types of fish protein concentrates such as fish protein hydrolysates are not included in the above definition.



FAO 2001 http://www.fao.org/wairdocs/tan/x5917e/x5917e00.htm#Contents

# FPC processing

- Several approaches for preparing FPC have been investigated including chemical, biological, and physical methods (Dubrow and Stillings, 1971).
- The most widely investigated methods are based on the use of chemical solvents to remove the water, fat and fishy-tasting components from whole fish (Dubrow and Stillings 1971; FAO 2001).
- Although, technically PFC can also be prepared from fish meal (FAO 2001).



Dubrow and Stillings (1971) FISHERY BULLETIN, VOL. 69, NO. 1; FAO 2001 http://www.fao.org/wairdocs/tan/x5917e/x5917e00.htm#Contents

# FPC processing

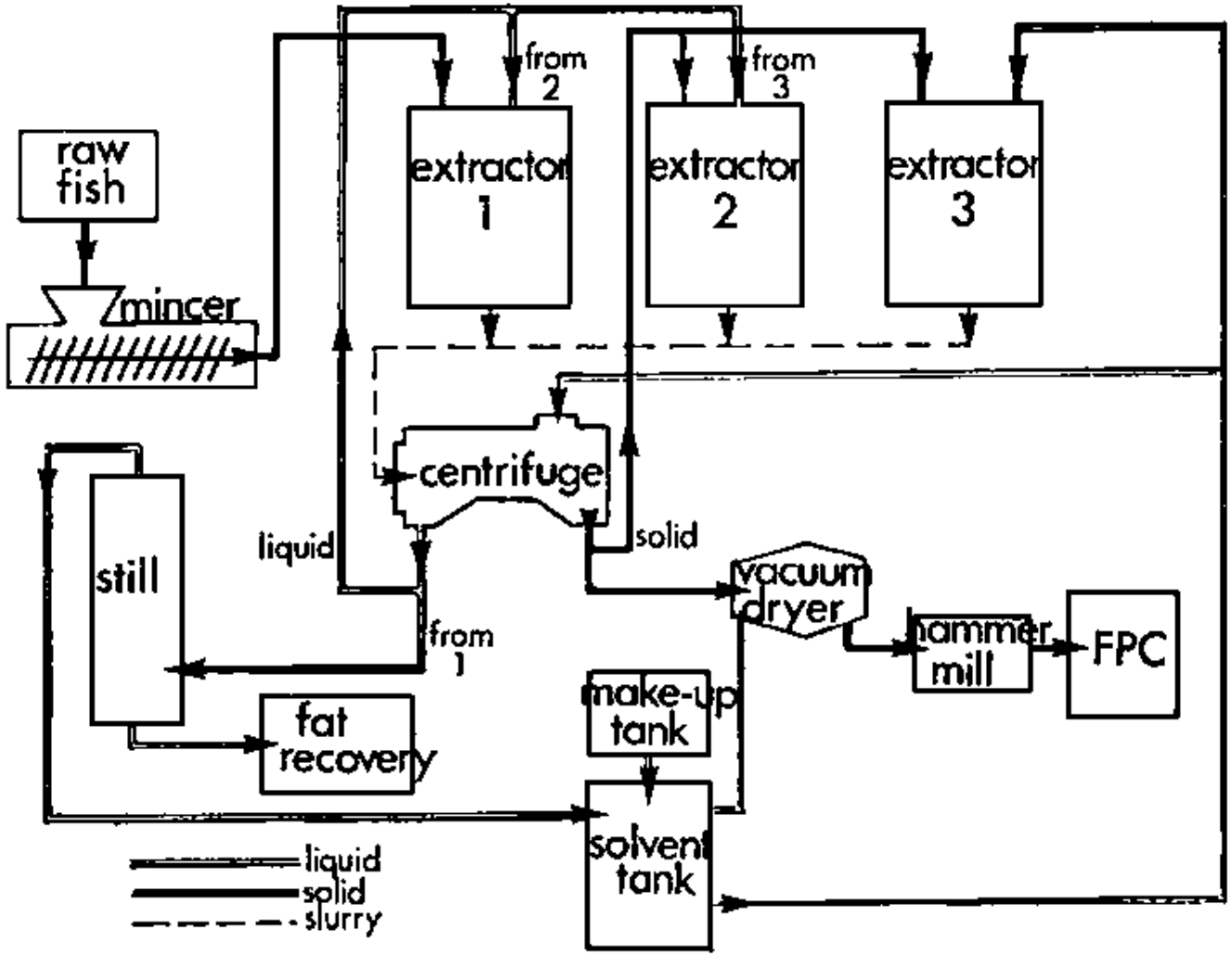



**Figure 2.** Flow diagram for the production of FPC (solvent extraction).

 Source: FAO 2001

# FPC composition and value

**Table 4.** Proximate analysis of fish protein concentrates.

| Raw material | Percentage protein (dry basis) | Moisture (%) | Ash (%) | Fiber (%) | Fat (%) (ether extract) | Fat (%) (chloroform–methanol extraction) |
|---|---|---|---|---|---|---|
| Cod fillets | 92.9 | 4.64 | 1.89 | 0.50 | 0.02 | 0.033 |
| Whole cod | 84.7 | 7.62 | 14.6 | 0.88 | 0.02 | 0.056 |
| Headed eviscerated cod | 90.26 | 5.25 | 8.37 | 0.81 | 0.02 | 0.02 |
| Cod trimmings | 87.2 | 3.54 | 11.42 | 0.34 | 0.039 | 0.04 |
| Cod trimming[a] press cake | 76.6 | 4.19 | 26.68 | 0.63 | 0.03 | 0.035 |
| Cod trimming[b] press cake | 70.7 | 5.66 | 23.78 | 0.60 | 0.01 | 0.032 |
| Whole herring | 89.7 | 8.24 | 7.13 | 0.94 | 0.09 | 0.18 |

[a]Cod trimmings cooked with indirect heat and pressed to 60% moisture.
[b]Cod trimmings cooked with live steam and pressed to 60% moisture.

Source: Power 1964

**Table 5.** Percentage of essential amino acids of tested fish FPC against their requirements for human and growing rats

| Essential amino acids | FPC "Pollack" | | FPC "Sardine" | |
|---|---|---|---|---|
| | Human*1 | Growing rat*2 | Human*1 | Growing rat*2 |
| His | —— | 96 | —— | 104 |
| Arg | —— | 114 | —— | 126 |
| Ile | 138 | 120 | 135 | 117 |
| Leu | 134 | 152 | 119 | 134 |
| Lys | 158 | 116 | 160 | 117 |
| Met+Cys | 109 | 76 | 106 | 73 |
| Phe+Tyr | 110 | 99 | 110 | 99 |
| Thr | 93 | 88 | 95 | 90 |
| Trp | 120 | 92 | 140 | 108 |
| Val | 112 | 112 | 122 | 122 |
| Amino acid score | 93 (Thr*3) | | 95 (Thr*3) | |
| Chemical score | | 76 (Met*3 / Cys) | | 74 (Met*3 / Cys) |

*1 Scored against the FAO/WHO pattern (1973)
*2 Scored against the NRC requirement pattern (1972)
*3 Denote the first limiting amino acid

Source: Iwaya and Yamaguchi 1979

- Excellent quality FPC can be prepared from a variety of raw materials (incl. whole fish and trimmings).
- FPC are a source of high-quality proteins, with a balanced amino acid profile and high digestibility (Iwaya and Yamaguchi 1979).
- Therefore, FPC can potentially be used to supplement diets that contain inadequate amounts of high-quality protein and/or fortify food for those with special requirements (e.g. sports nutrition).



Power (1964) J. Fish. Res. Bd. Canada, 21(6) doi.org/10.1139/f64-125; Iwaya and Yamaguchi (1979) Japan. J. Nutr., 37 (5): 247-254

# FPC Historical Background

- Early 60’s rapid and widespread growth of interest in FPC for human food, the possibilities of upgrading fish meal were naturally a prominent item in the deliberations of various working parties.
- Different organization including the UN Protein Advisory Group have gradually hardened their position that in order to be suitable for consumption by the protein-starved people of the world a food must also be acceptable by the standards of the well-fed; and in this regard, any suggestion of an upgraded animal feed supplement should be avoided.
- Despite subsidies from national or international agencies, all attempts made in the following decade to introduce FPC into staple cereal foods have failed to get beyond the trial stage, e.g. in South Africa, Morocco and Chile (Lovern 1969).


Lovern (1969) doi.org/10.1079/PNS19690016

# FPC Challenges

- In a review on the **problems in the development of FPC** during the 60's Lovern (1969) highlights some of the challenges:
  - Even the FPC type A (virtually fat-free, odorless, tasteless product) acquired a slight fish meal-like taste and odour after storage (reversion flavours).
  - Solvent-extracted FPC has a gritty texture that is detectable in the mouth even after very fine grinding, when it feels chalky.
  - Addition of FPC in cereal products at inclusion levels of 5% and above has a detrimental effect on the product colour, taste, volume and structure.
  - Substantial increase in production cost for FPC in the degree of sophistication envisaged to overcome this technological challenges.

# LIPROMAR case study/exemple

- German company member of EUfishmeal
- currently produces oil and fish protein concentrates for human consumption.
- The raw material used by LIPROMAR is e.g. trimmings from aquaculture salmon from Norway.
- The raw material quality does not vary significantly over the year because it is cooled down from the supplier to LIPROMAR.
- LIPROMAR http://www.lipromar.de/en/lip/food/

# Research needs

- **Fish oil:**
- According to EFSA (2010) some of the knowledge gaps and research needs concerning the production and use of fish oils for human consumption include:
  - Investigate the threshold level of oxidation of refined fish oil (as measured by peroxide and anisidine values) that may have detrimental effect on health (e.g. oxidative stress).
  - Thorough evaluation of the impact of individual oxidation products originating from refined fish oil on human health.
  - Establishment of quantitative relationship between peroxide and anisidine values and the specific volatile oxidation products.
  - Establish a clear relationship between crude oil PV and the PV in the final oil.
- **Fish Protein Concentrates:**
- Develop alternative extraction methodologies. Especially to increase flavor stability (avoid reversion flavors) and avoid “gritty texture” and “chalky mouthfeel”.
- Develop/test new/alternative food systems where FPC can be incorporated at meaningful levels without impairing the properties of the product.

# Thank you for your attention!

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