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Fish muscle quality assessment

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OECD

CO-OPERATIVE RESEARCH PROJECT ON
BIOLOGICAL RESOURCE MANAGEMENT

FISH MUSCLE QUALITY ASSESSMENT

REPORT ON CURRENT RESEARCH PROGRAMS
OF DIFFERENT INSTITUTIONS IN NORTHERN EUROPE
October 8 to 27, 1990

Benoit FAUCONNEAU

GENERAL CONTEXT

Countries of Northern Europe are producers of salmonid fish: Atlantic salmon and rainbow trout (table 1). Some of them have also large marine fishery activities and related industries (Scotland, Norway and Denmark) and freshwater fisheries (Finland) (Table 2). These countries are similar to France with respect to production but less dependent upon importation.

The aim of my mission in these different countries was to have an overview of the organization of research on quality control and assessment of farmed fish and to learn about the main research projects currently in progress. In some countries (Scotland, Sweden, Netherlands), I have visited laboratories involved in more fundamental research on characteristics of muscle, the main constituent of flesh.

Research on **marine fish quality** (applied research for control or legal specifications and basic research on fish technology) are generally developed under the authority of the Ministry of Fisheries (Norway: Quality Control Laboratory, Institute of Fish Technology; Denmark: Technical University and North Sea Center) or the Ministry of Agriculture and Fisheries (Scotland: Torry Research Station). In Finland, the research on fish technology within a Technological Research Institute (VTT) is under the authority of the Science and Technology Council. In Norway, the main producers of fish meal and fish oil used for feeding domestic animals, a specific institute (Norwegian Fish Meal and Fish Oil Industry Research: SSF) has been created for the analysis of quality of fish meal.

It is important to mention that there are regular **exchanges** (annual meeting, standardization of method and procedure) between these different institutes through the WEFTA (Western European Fish Technology Association) and recently through the FAR project of the EEC (Upgrading of Fish Product)

QUALITY OF FARMED FISH

The research on the quality of **farmed fish** (salmonids and marine fishes) has been developed in the same institutes that work on the quality of fish from fishing. The hygienic quality of farmed fish is generally very much better than that of caught fish or could be improve very easily. The market value of these fish is also very high. Thus, the traditional research on freshness of fish or up-grading of low value fish are not very much developed on farmed animals. However, in each country, some research has been implemented in order to give specifications for control of farmed fish quality (different grading of fish depending on its preprocessing, visual aspects and *freshness*).

The concept of assessment of quality of farmed fish seems to be either very simple: quality as close as possible to that of wild fish or so complex (relationship between physical or chemical characteristics and sensory evaluation of the fish flesh) that nobody has tried to work on it and it seems effectively that there are not specific long term programs on quality of farmed fish.

In the different Technical Research Institute that I have visited, the driving force for research on farmed fish quality came both from the industry and from the government. For instance fish *processing* (freezing, smoking, cooking) is thoroughly studied although these researches are considered as near-market research in the United Kingdom. Some applied research has also been carried out on farmed fish as confidential consultancy for producers, but they are not really coordinated.

Governmental research is more focussed on *safety* aspects. In farmed fish this concerns mainly the presence of residues of drugs used during rearing of fish (antibiotics) or of chemical compounds present in the environment and accumulated in farmed fish (pesticides, hydrocarbons, industrial waste products).

An important aspect of fish is its *nutritional quality*. The institute working on fish nutrition (Aquaculture Research Institute in Norway) has paid some attention to quality of farmed fish. The fish food manufacturers have also developed research on the relationship between feed composition and fish quality. As the main market for fish meal and fish oil is now fish feed, the norwegian institute SSF has also developed research on quality of farmed fish. Some research is also concentrated on the effect of fish lipid characteristics on human nutrition (Torry Research Station in Scotland, University of Stirling in Scotland, Norwegian Fish Meal Industry Research (SSF) in Norway). It is however important for farmed fish to have specifications about the fatty acid composition. Some research has tried to analyze the different means of controlling this composition but now the problem is more in the hand of consumers than in that of producers.

Finally, very few research program are related to basic research on assessment of *organoleptic quality* of farmed animals. From many studied carried out on fresh and processed fish, it seems that fat content is a very important component in sensory evaluation of fish. The use of large amounts of fat in fish feeding in order to reduce the soluble pollution of fish farms is a factor which has increased the sensitivity of producers, fish industrialists and consumers to that problem. Thus, the idea of grading fish depending on their fat content is growing and some research is now in progress to understand more about the control of fat content (both at the producer level and for inspection). For the other components of organoleptic quality the research is more fundamental and related either to the contribution of the protein fraction to fish texture (through gelation of fish during cooking) or to an assessment of the overall flavor of fish.

The institute visited are open to *collaboration*. The constraints are related to the fact that some research is developed under private contract (consultancy), that some groups do not need collaboration for funding or that fundamental research on fish quality assessment is not the first priority for their institute. The opportunity of regular exchange in the field of farmed fish quality assessment (as an extension of the WEFTA) is still open.

RESEARCH ON FISH MUSCLE

For more fundamental research on *muscle characteristics*, this research is carried out mainly in Universities (St Andrews, Stirling, Aberdeen for Scotland, Stockholm for Sweden, Copenhagen for Denmark, Wageningen for Netherland). This research is more related to mechanisms of muscle growth and its control than to contribution of muscle to flesh quality. Most of this research demonstrates however that there is a qualitative plasticity of muscle that depend on environmental factors such as temperature, rearing conditions such as exercise and genetic origins (individual potentiality for growth and strains). The plasticity of muscle is expressed at the cellular level (size of cells, metabolic activity) and at the molecular level (structural proteins, regulatory proteins, regulation of expression of genes). The methods used in this research are related to this fundamental approach: light and electron microscopy, muscle cell culture, biochemistry, immunology, molecular biology. The implementation of such methods is important also for development of new technics or new probes for the assessment of flesh characteristics (antibodies against specific regulatory or structural proteins, cDNA probes against corresponding mRNA) or for fish identification.

From a more prospective point of view, this research has tried to find different ways of controlling the development of muscle using early environmental manipulation (temperature), using specific rearing conditions (exercise), using genetics (selection). These ways could be similarly used also for controlling the characteristics of fish flesh.

The possibility of collaboration with the different laboratories visited is important. I.A. JOHSNTON has proposed to build a European network of laboratories involved in fish muscle research.

UNITED KINGDOM

UNITED KINGDOM produces mainly Atlantic salmon (40 to 50 000 t) and rainbow trout (25 000 t) but also turbot. The fish producers belong to active unions: Salmon Growers Association, British Trout Association (and independent associations for the Shetlands and Ireland). The research on fisheries are carried out mainly in two stations of the MAFF (Ministry of Agriculture Food and Fisheries) located at Lowestoft and Aberdeen (Torry Research station). Due to the large activity of fishing in the east coast of Scotland and salmon farming on the west coast of Scotland, basic research on fish physiology and aquaculture is well developed in the universities of Scotland.

GATTY MARINE LABORATORY (St Andrews, Scotland)

The Gatty Marine Laboratory is an old (150 years) pure Research Institute within the small university of St Andrews (4000 students, 400 post-graduates students). These are integrated in a common project IMRI (Inter University Marine Research Institute) with the universities of Dundee and Stirling.

The director of the Gatty Marine Laboratory, Pr I.A. JOHNSTON who is also the present chairman of the Department of Biology of the University of St Andrews is more specifically involved in research on fish muscle.

His own research is related to the biomechanics of fish muscle and its adaptation to environmental temperature. The species studied are Antarctic fishes, temperate fishes (cod, herring, turbot) and tropical species (tilapia).

The **histochemical**, **metabolic** (Phosphorylated compounds), **biochemical** (qualitative analysis of myofibrillar protein and especially troponins I and C), **ultrastructural** (proportion of myofibrils, characteristics of mitochondria), and **mechanical** (Maximum Isometric Tension and Power Output) characteristics of muscle fibres were analyzed in relation to temperature, genetic origin (2 strains of tilapia) and individual variation.

I.A. JOHNSTON has also many contact with G. GOLDSPIK (University of London), S. GEORGES (University of Stirling) and G. CRAMB (University of St Andrews) with a view to obtaining specific homologous cDNA probes against myofibrillar protein mRNA (especially troponins). During my stay, I have learnt of the different techniques they used and we have tried to analyze the differences in myofibrillar protein characteristics between individual fibres in different areas of the trunk musculature.

One of the programs of the IMRI concerns different aspects of larval development: osmoregulation (P. TYTLER, University of Stirling), growth (I.A. JOHNSTON, University of St Andrews), Lipid and Membranes (J. SARGENT and G. BELL University of Stirling) and Toxicology (S. GEORGES University of Stirling). I have had the opportunity to discuss with each of the partners of the program. The research on larval muscle development were based on a descriptive work in herring, turbot and antarctic fish, on the study of the influence of temperature and on the relationship between muscle maturation and swimming behaviour of these larvae.

Within the department of Biology, there is also one other interesting research project on osmoregulation in eel: expression of Na⁺/K⁺ATPase in gill, kidney and gut of that species (G. CRAMB, N HAZON).

UNIVERSITY OF STIRLING

The program developed by J.SARGENT (N.E.R.C) within the Department of Molecular and Biological Science in the University of Stirling is mainly concerned with the characteristics of lipids in fish. They have characterized the different classes of lipid in different tissues of fish (especially the composition and chemical forms of phospholipid such as phosphoethanolamine). They now work on the modelisation of membrane in relation to its phospholipid and protein composition (plasticity, elasticity). The role of one important fatty acid 22:6 n-3 has been investigated on the cardiovascular system in man and salmon and on the immune system in fish.

UNIVERSITY OF ABERDEEN, DEPARTMENT OF ZOOLOGY, ABERDEEN

I have had some collaboration with D.F. HOULIHAN on protein synthesis assessment in fish muscle (myofibrillar, myosin and actin synthesis).

His different studies on muscle characteristics (oxygen metabolism, RNA/Protein ratio, protein synthesis) have shown that there are variations due to environmental factors and the activity of fish but also a large individual variation that he has tried to analyse.

There is also a concurrent project to that of the IMRI on the biochemical correlates of growth and metabolism on fish larvae. He has collaborated in that field with W. WIESER (Department of Zoology, University of Innsbruck) and B. PETERSEN (Department of Zoology, University of Copenhagen). The method developed were enzymatic analysis, RNA/DNA measurement, protein synthesis and now molecular biology of larvae. Other projects with which D.F.HOULIHAN is involved, are the interaction between nutrition and the immune response of fish or the prevention of disease (pancreas disease in salmon). The immunocompetence of fish is also tested as a measure of the biological effects of pollution.

MARINE LABORATORY, ABERDEEN

The marine laboratory is dependent on the Department of Agriculture and Fisheries of Scotland (DAFS). M. WARDLE is involved in research on swimming behaviour of fish for the improvement of fishing technics. Its work on the limits of aerobic and anaerobic capacity of fish muscle were realised on different species but mainly in mackerel and salmon. According to M. WARDLE the more the fish swim the more they grow in length and the more the muscle grows.

TORRY RESEARCH STATION, ABERDEEN

The Torry research station is also an old institute (1930-1940) dependent on the Ministry of Agriculture, Food and Fisheries (MAFF). It is in charge of all the fisheries research (engineering, processing, quality assessment and control, valorization of end-products and low-value fish).

Recently the Torry research station has been attached to the Food Safety Group. Some research has been stopped (engineering, valorization of low value fish) and the near-market studies have to be stopped (this includes processing of fish and obviously studies on organoleptic quality assessment). Thus in the future, the station has to move from applied research to more basic research in food safety and nutrition such as:

- * Spoiling of fish and methods of evaluation;
- * Freezing of fish (effect of mucins, effect of stress);
- * Toxins in fish flesh (histamine, diuretic and paralytic compounds);
- * Residues in fish meal and in other feed ingredients: antibiotics (oxytetracyclin, auxillinic acid), leukotrien-like products, polycyclins and other polyoxidized compounds, pesticides (dichloros, PCB), aromatic and aliphatic hydrocarbons);
- * Lipid oxidation in fish flesh and consequence on fish processing (heating of oxidized fatty acid);
- * Nutrition (use of fish products as milk replacers, Polyunsaturated Fatty acid in human nutrition, Use of fish oil concentrate).
- * Acceptability by the consumers of fish and fish products.

The Torry Research station (Director, M. HOBBS) is composed of different departments:

- * Biochemistry of fish flesh (I.A. MACKIE);
- * Analytical chemistry (A. MAC GILL);
- * Physics (M. KENT);
- * Quality (J. LAVETY);
- * Microbiology (D. GIBSON);
- * Marketing (A. HUME);
- * One department is more focussed on shellfish (J.C. EARLY).

The interesting research in that institute is focussed mainly on methods:

- * of assessment of fish freshness using analysis of:
 - * different chemical compounds related to freshness of fish (amine);
 - * changes in chemical composition with fish storage;
 - * physical characteristics of fish flesh (texture and dielectric properties of fish: Torrymeter);
 - * microbiological characteristics (factors which affect bacterial growth and toxin production, modelisation for the implementation of a Time/Temperature Integrator);
 - * sensory characteristics of fish;
 - * the integration of various characteristics in a multiparameter components system.

- * of control fish processing (freezing/thawing, cooking) using the same kind of multiparameter analysis but also a physical modelisation of the evolution of flesh during heating;
- * of species identification including differences between farmed and wild fish;
- * of the effect of different methods of killing in farmed fish;

The aim of some of this research is to propose standard methods of analysis (for amine analysis, color assesment) or of control (torrymeter, species identification).

The department of physics works on a system of evaluation of chemical composition of fish (water, lipid: fattymeter based on a microwave set-up) and on a system of fish identification and measurement (size) based on an image analysis system) which could be used on board.

Finally, there is no research program on texture, but the relation between histological structure of fish flesh (C. MAREY), physical measurement of texture and sensory evaluation of texture (R. HASTINGS) is studied.

This expertise in the different field of control of fish handling, storage and processing is transfered to industry using training course, an Information Club and direct consultancy for specific problem.

Farmed fish quality is more sepcifically studied through:

- * specification for handling and processing farmed salmon and trout and effect of these different steps on aspect of fish (fillet gaping, blood spots in the flesh, color stability, abnormal color in the flesh) and on texture ;
- * fitness to microbiological standard (standard of Food for British) and role of different steps (icing, mucus and visceral tissues removal, salting, smoking) in fish contamination.
- * studies of factors affecting flavor (short term tainting of fish with plancton bloom, hydrocarbons, farm effluents).
- * Consumers acceptability (fat content and composition, evolution in consumers habits: moderate salting and smoking)

FINLAND

Fish production in Finland is based on rainbow trout farming (20 000 t, commercial size: 1 Kg), marine fishing (Baltic Herring: 80 000 t) and freshwater fishing (whitefish).

TECHNICAL RESEARCH CENTER OF FINLAND

The institute is in charge of all the physical, chemical and biological technical research. Within the division of process technology there is the Laboratory of Food Research located at ESPOO in the Helsinki University of Technology campus. The research on fish technology is carried out in the Quality section supervised by M. KIESVAARA. That section is supposed to work on all food products quality control, but fish represent a large part of its activity. Both industry and government use the laboratory for official consultancy. It tend now to developed more basic research.

The research programs are focussed on

* the shelf life of fish:

- * assessment of freshness using chemical (amine, nucleotides), physical (Torrymeter) and sensory (panels) parameters;
- * the effect of additive on visual aspect and shelflife of fish (ascorbic acid).
- * the standardization of fish handling and processing. Results are transferred to fisheries through official specifications and through training courses for fishermen;

* on the effects of pollution: off-flavor of fish due to pulp mill industry, radioactivity (Tchernobyl);

* on the texture of fish (K. AUTIO): microstructure of fish fillet and fish products (histology, rheology), heat gelation capacity of fish muscle (role of myofibrills and isolated protein, effect of additives). K AUTIO has many collaborative works with Sweden (Electron microscopy of fish myofibrills), Norway (immunofluorescent visualization of myosin and actin) and Japan (texture of fish gel).

NORWAY

NORWAY is the main producer of salmonids (Atlantic salmon: 150 000 t, rainbow trout 3 000 t) and the main fishing country (1.9 million t) of Europe. More than 60 % of the total catch is processed by the Norwegian Herring Meal Industry (fish meal and fish oil). A large part of basic and applied research on fish quality is focussed on fish meal and fish oil characteristics. Furthermore, there is a specific organisation, the **Norwegian Herring meal and fish oil industry research Institute (SSF)**. The Ministry of Fisheries has also its own research institutes: the Directorate of Fisheries for quality control of both caught and farmed fish and the Institute of Fishery Technology Research for fisheries research. The Norwegian Agricultural Research Council has also the **Institute of Aquaculture (Aquvaforsk)** for research on farmed fish. Finally, there is also research on fish technology and physiology in the Technical University of Trondheim, the Biological University of Bergen and the Agricultural University of Oslo.

THE NORWEGIAN HERRING MEAL AND FISH OIL INDUSTRY RESEARCH INSTITUTE.

This non-profit cooperative institute receive funding both from the government (20 %) for control of fish products and from industry: fishermen, fish meal industry, food manufacturers and fish producers. Traditionnaly, fish meal used to be incorporated in food for terrestrial farmed animals. Large experimental facilities has been built in the institute for the analysis of the digestible and metabolic values of fish meal in poultry, pigs and in mink as a model animal for standard test. Thus, the research was more focussed on nutrition of mammals. At the present, fish meal is mainly used in fish feeding and the research has moved more and more on fish nutrition. The institute has their own experimental facilities for trout and salmon.

The main part of the institute activity is devoted to quality control of fish meal and fish oil. Fish meal is classified in three main qualities: standard quality, North Sea Mink and Low Temperature fish meal (LT 94). The control is mainly focussed on chemical composition, evaluation of freshness (amine) and analysis of oxidation products.

Fish itself is also controlled before processing (freshness) in order to improve its preservation.

The research and development activities are related to

- fish meal quality assessment:
 - * standard test for digestibility and metabolizable energy are carried out respectively on mink and poultry.
 - * the nutritional effect of lipid from fish meal and fish oil (rich in w3 fatty acid) is assessed on pigs (effect on fatty acid composition of brain phospholipids, effects on cholesterol, lipoproteins and blood pressure) as a model for man.
- oil processing,
- feed processing (effect of extrusion process on nutritive value of fish meal included in the feed),

- and fish nutrition:

- * the digestibility of fish meal by salmonids (rainbow trout and Atlantic salmon) is compared to the standard mink digestibility.
- * the use of fish hydrolysates for early feeding of fish and the use of water soluble compounds extracted from fish hydrolysates for food attractants is evaluated.
- * the use of low hydrogenated fat in fish feeding is also tested.

DIRECTORATE OF FISHERIES (BERGEN) FISH QUALITY CONTROL DEPARTMENT

There are no basic research in that institution (150 staff members) that is composed of the Central Laboratory located at BERGEN (20 staff members supervised by B. BOE), of three districts laboratory and of field inspectors.

The control of fish and fish products is related to:

- * freshness of fish using chemical, microbiological and sensory analysis;
- * fish identification using a multiparameters method;
- * chemical composition, fatty acid composition, cholesterol, vitamins, pigments of fish and fish products used for human consumption;
- * presence of residues of antibiotics in farmed fish and of pollutants (pesticides and heavy metals) in wild and farmed fish;

Applied research have been implemented on farmed animals (shelf life of salmon, effect of sexual maturation) to give specification for quality grading of fish. There are 3 general grading for all the fish (super class, ordinary and fish for production based on sensory evaluation in the field) which are applied also to farmed salmon. The higher quality standard is related to fresh fish killed by bleeding in cold water then eviscerated before icing. Commercialisation during sexual maturation is prohibited.

Other applied research is also related to the study of the relationship between sensory evaluation and chemical analysis (chemometric analysis using GLC profile on raw extract) of fish. Differences between fresh fish and fish stored on ice during one week has been detected by these means.

The philosophy for quality standard offarmed animal is very simple: the aspect, the fat content, the color of cultured fish cannot be too different from wild fish. It is possible to draw further specifications but only by agreement between producers and sellers.

INSTITUTE OF AQUACULTURE RESEARCH (As-NLH) AQUAVAFORSK

That institute developed research on nutrition and breeding for growth and sickness. Part of these research are related to salmon, trout and halibut quality: genetic control of lipid content (B. GJERDE) and nutritional control of fish quality (M. THOMASSEN for lipid, T. STORREBAKEN for color).

A large variability in the fat content of salmonids is observed mainly as a consequence of differences in fat content of fish food which now could contain up to 30 % of fat (for decrease in ammonia pollution but also for growth). Thus, lipid is considered as an important determinant of fish quality and the idea of a *specific label for salmon depending of their fat content or fat composition* is growing. The current research tried to analysed:

-the factors controlling the lipid content of salmon:

*the long term changes in lipid content due to various factors: quantity of feed, seasonal variation, size of fish, growth rate, individual variation, effect of exercise, effect of triploidy. It seems that the lipid content in the flesh is correlated to the lipid content in the food (from 10 to 22 % of fat).

* the short term changes: due to starvation, and time course of changes between two levels of fat in the diet (minimal time required to change the fat content in the flesh).

- factors controlling the composition of fat (stability of polyunsaturated fatty acids: PUFA).

* effect of lipid composition (source of lipid, amount of PUFA)

* Time course of changes between two fatty acid composition in winter and in summer;

* the effect of storage at low temperature;

- the sensory evaluation of fish containing different amounts of fat fits well with chemical analysis in fish of the same size (sensory evaluation of fish of different size is confusing and there is probably some interaction between fat and other components in the flesh). But few differences in fish taste has been observed due to changes in lipid composition.

- the possibility of controlling fat content and composition is also tested (chemical correlates: perivisceral fat, biopsy of flesh, physical measurement: tomography which allowed also to analysed the repartition of fat).

NORWEGIAN ASSOCIATION FOR AQUACULTURE RESEARCH.

During my stay at Bergen, a meeting of this association was held (see annex 2). The research currently in progress is related to vitamin and mineral nutrition, to lipid and carbohydrate metabolism and nutrition, to fish disease (interaction stress/immunity) and to new development in fish rearing. The existence of this association gives the possibility of contact for further exchange.

DENMARK

Denmark is one of the main fishproducers in Europe (after Norway). Few years ago, trout culture has been developed and now the production is close to that of United Kingdom and a little bit lower than that of France. The status of control and research of fish quality in Denmark would thus be very interesting to compare with that of France. The **Fisheries Laboratory** within the Technical University of Denmark at Copenhagen (supervised by T. BORESEN) is in charge of all the research on fisheries. But recently Denmark has built up a new center (North Sea Center, Hirstals) which is supposed to developed the same kind of research including also control of fish quality. The relation between these two research center seems not to be very strong.

TECHNICAL LABORATORY (LYNGBY near Copenhagen)

This laboratory is an old institution (60 years) and develop the same kind of research as those of the Torry Research Station in Scotland (handling and processing of fish on board, freshness of fish) but with less constraints about near-market research (fish engineering, valorization of low market value fish). The research division (chemistry, biochemistry, bacteriology, sensory evaluation) are also similar.

Due to the large fishing production in Denmark, research related to processing and quality control of fish meal and fish oil is also developed as it is the case in the SSF research institute in Norway.

The current interesting research is the following:

- * methods of control of fish quality: multiparameters system using pocket computer for field control (EEC support), control of fish characteristics on the processing line on board are tested;

- * Development of fish hydrolysates for facilitating bone removal from fish meal and thus reduce the phosphorous pollution of fish farms. The different hydrolysates tested (with high and low degrees of hydrolysis) are well used by salmonids (rainbow trout) but in fact the same low phosphorous content in the faeces has been detected.

- * Development of fish oil products for the valorization of fish oil coming from fish meal danish factory. The use of fish oils for fish feed is one of the aim. But the main purpose is to use fish oil for human foods. Some margarine products containing 20 % of fish with satisfying shelflife has been developed. New products such as enriched omega 3 oils (up to 60 %) are also studied.

- * Effect of ice and frozen storage on gel forming ability of fish. The interaction between protein involved in gelling process and degradation product of lipid (due to natural hydrolysis or oxidation) is specifically studied.

AQUAFEED COMPANY

The Danish fish food manufacturer implemented applied research on farm fish quality in collaboration with the Technical University of Denmark and with private farms. These company is also open to collaboration with french scientist. They have developed high fat diet (up to 30 % fat with 40 % protein based diet) both for reduction of fish farms pollution and better growth of fish (N. ALSTED).

It seems that above 15 % of fat in the diet, the protein sparing effect of lipid is low. The effect of high fat diet as compared to that of medium fat content (15-20 % fat) on fat content in the flesh itself are also low (2 to 3 percent of lipid) and not detectable by a consumers panel. But the fat content in the viscera increase dramatically with the amount of fat in the diet.

FISH TECHNOLOGY PROGRAM

Within the University of Copenhagen, the department of zoology (supervised by L. OLESEN) which have some experience on toad physiology is involved in a collaborative program on fish larvae. This program is developed with the Fish Technical Laboratory (T. BORESSEN, Lyngby), the Fish Marine Laboratory (B. PETERSEN) and a Serum Institute. Apart from fish larvae some other aspects such as fish adaptation, fish disease and fish genetics are covered in that program.

The program on fish larvae (herring and turbot) is focussed on:

- * digestion (development of monoclonal antibodies against protein digestive enzyme such as trypsin);
- * osmoregulation and drinking (B. KORSGAARD);
- * growth (protein synthesis in collaboration with E. LIED, Institute of Nutrition, Bergen and D.F. HOULIHAN University of Aberdeen).

NETHERLAND

The fish production of Netherland both by fishing and by production is low, but the experience of that country in term of agricultural research is well-known. Within the Agricultural University of WAGENINGEN, there is the Department of Fish Culture and Fisheries (catfish, tilapia, carp) and the Department of Experimental Morphology and Cell Biology that work mainly on fish as a model.

The Department of Experimental Morphology and cell Biology is composed of three department working on:

- * Embryology of fish: development of germ cells and control of expression of specific genes during embryonic development (TIMMERMANS);
- * Cell Biology (Pr W.B. van MUISWINKEL): Immune system of fish (lymphocytes typing, Major Histo Compatibility system);
- * Experimental morphology: morphological and anatomical adaptation to feeding of fish and fish larvae (programm developed by Pr J.W.M. OSSE) and muscle growth (H.A. AKSTER).

The research carried out on muscle has been focussed on typology of fish muscle (ultrastructure, biochemical characteristics) in relation with its role in different function (locomotion, feeding). Since few years, these research has turned more on fish muscle growth (role of increase in the size of fibre and increase in the number of fibre in the growth of skeletal muscle) using different complementary approach:

- Light microscopy (distribution of size of muscle fibre);
- Immunology (monoclonal antibodies against specific proteins of precursor cell: the satellite cell or of muscle fibre);
- Electron microscopy for quantification of satellite cells);
- Muscle cell culture (satellite cell).

The more important result is the successful development of satellite cell culture that open the possibility to study *in vitro* muscle cell differentiation and to obtain specific markers against these cell for *in vivo* study. From the data obtained by H.A. AKSTER and J.T.M. KOOMANS it seems that there two different populations of satellites cell are present in fish muscle: one of these (cell in proliferative state) contribute to hypertrophic growth of fibre by increase in the number of nuclear per fibre and the other one (cell in non proliferative but differentiating state) contribute to hyperplasic growth of muscle.

H. AKSTER and J.W.M. OSSE have proposed collaboration in the field of muscle growth and especially for using myosin and myosin mRNA of satellite cell as early markers of muscle differentiation. Pr OSSE has also some collaborative project with P. BERGOT on fish larvae.

Table 1 Production of Salmonids in the Northern European Countries in tons
(from estimations of the visited correspondent)

	SALMON	TROUT
UNITED KINGDOM	40 000	25 000
NORWAY	150 000	3 000
FINLAND		20 000
SWEDEN		15 000
DENMARK		25 000
<i>FRANCE</i>		
PRODUCTION		35 000
IMPORTS	40 000	3 000*

Table 2 Fish catch and total fishing of the main producing countries in million tons.

	PRODUCTION	
	FISH	TOTAL
NORWAY	1.6	2.5
DENMARK	1.0	1.9
<i>FRANCE</i>		
PRODUCTION	0.5	0.7
IMPORTS	0.5	

APPENDIX

LIST OF ADRESS OF CORRESPONDANTS AND INSTITUTES VISITED

UNITED KINGDOM:

I.A. JOHSNTON, **Gatty Marine Laboratory**, University of St Andrews, ST ANDREWS KY16 8LB, Scotland, Tel: (0334) 76161, Telex 76213 SAULIB G.

I. MACKIE, **Torry Research Station**, 135 Abbey Road, ABERDEEN, AB9 8DG, Scotland

NORWAY:

A. ASKNES, , **Norwegian Herring Oil and Meal Industry Research Institute**, 5033 FYLLINGSDALLEN, BERGEN

M. THOMASSEN; **The Agricultural research council of Norway, Institute of Aquaculture Research**, N-1432 ÅS-NLH

B. BOE, **Fish Quality Control, Directorate of Fisheries**, BERGEN

SWEDEN:

A. VON DER DECKEN, **The Wenner-Gren Institute, Biologie Building F3**, University of Stockholm, S-10691 STOCKHOLM

FINLAND:

AUTIO K., KIESVARRA M., **Technical Research Center of Finland, Food Research Laboratory**, Biologinkuja 1, 02150 ESPOO

DENMARK:

T. BORRESEN, **Technological Laboratory**, Technical University, Danish Ministry of Fisheries, B 221, DK-2800 LYNGBY (Qualité du muscle de poisson).

NETHERLAND:

AKSTER H.A., J.P.W OSSE, **Department of Experimental Animal Morphology and Cell Biology**, Agricultural University, P.O. Box 338, NL-6700 HA WAGENINGEN.

PROGRAM OF THE ANNUAL MEETING OF NORWEGIAN ASSOCIATION OF
RESEARCH IN AQUACULTURE. (BERGEN, 19-21 October, 1990).

Session 1: Salmon feeding

- K. Sandnes et al.: Vitamin C requirement of salmon
S. Albrektesen et al.: Vitamin B6 requirement of salmon fry
A. Maage: Selenium requirement in young salmon
M. Lorentzen et al.: Selenium uptake by muscle of young salmon

Session 2: Lipid metabolism and sexual maturation in farmed fish.

- B. Ruyter et al.: Comparative studies of key enzymes of fatty acid metabolism in liver of flounders, salmon and trout.
M.S. Thomassen: Use of slaughtering wastes for controlling fat content and fatty acid composition in farmed salmon.
A. Sandvin et al.: Lipid transport in salmon (Salmon salar) during sexual maturation.
A. Veebenge et al.: Effect of diet composition and feeding level on early sexual maturation in salmon.
M. Rye et al.: Effects of sexe and phase of sexual maturation on growth of large salmon.

Session 3: Physiology and behaviour of fish

- M. Jobling: Compensatory growth: myth or reality ?
G.I. Hemre et al.: Effect of dietary carbohydrates on stress resistance in cod ?
E.H. Joergensen: Effect of flow rate on stress reduction in *Salvenilus alpinus*
M. Jobling et al.: Effect of size selection on growth in *Salvenilus alpinus*.

Session 4: Health of farmed fish

- Y.A. Olsen: Physiological and immunological effects of stress in fish.
- S.E. Fevolden: Stress and disease resistance in farmed fish
- A. Lillehaug: Role of water temperature on the effectiveness of vaccination in salmon.
- A.V. Mariussen: Vaccination of turbot fry against vibriosis: immunocompetency and protection durability.
- A.M. Onarheim: Role of digestive tract on improvement of health of fish (?)

Session 5: New species - New activities

- I.J. Miglas: An overview on Antarctic krill project.
- I. Pedersen: Metamorphosis in cod.
- T. Soldberg: Commercial rearing of turbot fry using extensive methode of LMT A/S. What we have learn ?
- T. Helle: Vesteraalen - potentiality for development of this marine area. Present state and development.

Session 6: Marine Rearing

- O.K. Berg: Growth and survival of sea Salvenilus alpinus at Vardneselva, Tromsoe.
- R. Nortvedt: Smoltification of salmon in various kinds of freshwater. Effect on sea water growth using two different methods of sea water transfert.
- M. Holm: Behaviour of smolt. Consequences for sea water rearing.
- S.O. Handeland et al.: Consequences of adaptation to sea water of salmon (*Salmo salar*) with cod (*Gadhus morhua*) on salmon survival.