Rapport nr. 305/26

UTVIKLING AV HALVFABRIKATA TIL INTERNASJONAL PETFOOD-INDUSTRI

RAPPORT-TITTEL

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RAPPORTNUMMER	305/26	PROSJEKTNUMMER	305
UTGIVER	RUBIN	DATO	Januar 1994

UTFØRENDE INSTITUSJONER

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SAMMENDRAG OG KONKLUSJONER

Hensikten med prosjektet har vært å undersøke mulighetene for å finne et bedre betalende marked for fiskebiprodukter enn dagens fôrmarked. Den konkrete idéen gikk på å finne måter å lage et fiskebit-lignende produkt (fiskeanalog), for eksport som halvfabrikata til internasjonal petfood-industri. Det aktuelle råstoffet for en slik produksjon var avskjær fra filétproduksjon av torskefisk.

Undersøkelsen ble gjennomført av PA Consulting Group, som er et internasjonalt konsulentfirma innenfor næringsmiddelteknologi med hovedsete i England. Den norske kontakten var PA Hartmark Iras.

Det er gjennomført en markedsundersøkelse, spesielt mhp. salg av analogproduktet til Pedigree Petfoods, som har en av verdens største kattematfabrikker i England (prod. ca. 500.000 tonn pr. år). Med en pris på på under 4 kr/kg er mulig salg til Pedigree over 50.000 tonn årlig (innblanding i "mainstream"-produkter). Kravene er at fiskebitene minner om fiskemuskel, er forholdsvis hvite, ikke har noen synlige bein, er smakelige og er robuste i forhold til hermetiseringsprosessen og annen håndtering.

I utgangspunktet må fiskeavskjær males opp og gjennomgå en beinseparasjonsprosess. PA antyder et utbytte på 55%, dvs 45% av råstoffet må disponeres på annen måte. Videre har man vurdert 4 aktuelle teknikker for produksjon av fiskeanalog fra den oppmalte fiskemassen; 1. frysing i tynne lag på en ekstrem kald plate 2. geling 3. høytemperatur-ekstrudering og 4. kryostrukturering (frysing). Alle disse er vurdert som mulige, mens ekstrudering som den "sikreste" ut fra erfaringer med lignende produksjoner. Det er utarbeidet kostnadsoverslag for 2 alternative årsproduksjoner; hhv. 6.500 og 13.500 tonn (hhv. 12.000 og 25.000 tonn råstoff pr. år). Netto overskudd er beregnet til hhv. 0,95 og 1,20 kr/kg produkt. Tallene er belagt med stor usikkerhet, bl.a. fordi investeringene ikke er kjent. (Det er anslått 30 mill kr for det minste og 47 mill kr for det største anlegget)

I rapporten er det foreslått en videreføring av prosjektet med produksjon av produktprøver i laboratorie-skal i samarbeid med Fiskeriforskning i Tromsø.

I forhold til RUBIN`s funksjon, funksjonstid og budsjettramme vurderer RUBIN veien fram til en ferdigutviklet/utprøvd teknisk løsning til å være lang og kostbar, og dessuten belagt med mange usikkerheter. Derfor har RUBIN besluttet å selv ikke videreføre prosjektet. Prosjektet kan likevel være interessant for finansiering av mer langsiktige FoU-midler.

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STIFTELSEN RUBIN
Resirkulering og utnyttelse av organiske biprodukter i Norge

FINAL REPORT

VALUE ADDING IN FISH WASTE

PHASE 1A
FEASIBILITY STUDY

OCTOBER 1993

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CONTENTS

EXECUTIVE SUMMARY

This report summarises an investigation into the potential for adding value to fish offal through its use as a raw material for a texturised fish flake analogue for use in canned petfood products.

There is considerable demand for a high quality fish flake analogue. The maximum Pedigree Petfoods would be prepared to pay up to is NOK4,000 per tonne, if an analogue could be produced to their specification.

A number of technology approaches to producing such an analogue have been reviewed and it is proposed that these be evaluated during the next phase of the project via a PA managed programme at Fiskeriforskning at Tromsø (Phase 1 B).

The technologies that might be used to accomplish this are:

- Use of a very cold plate to freeze offal as layers.
- Reforming with gelling agents then layering or shredding to give structure.
- Extrusion cooking of an offal/vegetable protein mixture.
- Adding texture via freezing. (cryostructurisation).

Our preliminary estimate of the potential gross margin from a plant with an annual capacity of 25,000 tonnes is around NOK23M. This figure is based upon information supplied by Stiftelsen Rubin on costs to purchase and transport offal and our own estimates of the likely cost to establish and run a production plant. This figure will be further refined in the light of the findings from Phase 1 B as the process becomes more clearly defined.

1 INTRODUCTION

Fish filleting waste is becoming an increasing problem. It finds use as a basic protein source in petfood, as fish silage for animal feed and for mink feed. The market for mink is in decline and revenue from utilisation as fish silage is minimal. Stiftelsen Rubin are interested in investigating the potential for adding value to fish offal through its use as a raw material for a texturised fish flake analogue.

Fish muscle protein is one of the most functional proteins available. There is a significant and under-utilised resource in fish offal. Fish offal is essentially the head and frame of filleted fish (often including the skin). It is a very cheap raw material and filleting factories will often pay for its disposal.

The petfood industry uses fish in a number of products:

In canned products as a low percentage of the pack for claim purposes (ie 'with Tuna' or 'with Salmon'). It also finds use in top of the range 'gourmet' products (ie pieces of whole, high grade fish) and as a general filler in cheaper products for cats and dogs. Hydrolysed fish protein is also added to petfood biscuits to enhance their palatability.

The petfood industry is interested in using fish that can be seen by the purchaser of top of the range products and which will be enjoyed by the pet.

Since real fish is not very robust to freezing, thawing and retorting, the industry would be interested in a restructured fish analogue (based upon fish offal) which would be:

- white in colour
- mechanically strong
- no obvious bone
- palatable to the animal
- resemble fish muscle
- robust to the canning process

Following discussions between Øistein Baekken of Stiftelsen Rubin and Nick Ashley of PA, it was agreed that PA should conduct the initial Phase 1A of this feasibility study to produce fish flake analogues from fish offal, for use in canned petfood products.

The key objectives of this Phase (1A) of the project were to:

- further explore the market potential for such an analogue through further discussions with Pedigree Petfoods
- to identify technology approaches that could be used to produce analogues

- to develop a laboratory development work programme with the Fisheries Research Institute (Fiskeriforskning) at Tromsø. This will be conducted during Phase 1B of the project under the management of PA.

This report summarises the findings from Phase 1A of the project and our recommendations for further work.

2 PETFOOD MARKET OVERVIEW

2.1 Objectives of the Petfood Industry

The primary objective of the petfood industry is to provide adequate nutrition to the pet animal and to maintain its health at a minimum cost to the owner. This approach is quite different from that of the agricultural feeds industry where maximum feed conversion in minimum time at minimum cost is the prime concern. The petfood industry aims at two customers: there is the owner who buys the product and the pet animal that consumes it. To enable the product to reach the latter, the desires of the former must be satisfied. Experience has shown that a large majority of pet owners extend their preferences or dislikes from the human food area into that of the petfood area. Should the purchaser not like any aspect of the product, it will not be offered to the pet, regardless of its nutritional qualities.

The edible products manufactured for domestic pets cover a wide area ranging from treats such as confectionery, through complementary foods like biscuits and mixers, canned meats or fish products to complete foods containing animal and vegetable materials presented as dry, semi-moist or canned foods. In western Europe the industry annually uses around a million tonnes of meat and fish-based raw materials plus several hundred thousand tonnes of cereals and vegetables at present. The demand continues to rise. It is understood that similar quantities are used in North America and a somewhat smaller amount in Australasia. It is believed that significant quantities are used in Eastern Europe but actual figures are unavailable. The petfood industry is a user of large amounts of human food wastes.

2.2 Wastes Used as Raw Materials in the Petfood Industry

There are many waste materials from the human food industry used as primary raw materials. Examples are: blood, fish and fish by-products (filleting wastes), dairy waste (whey), bone, fat (tallow), poultry mix, egg waste, fish meal, dried yeast (brewery waste), abattoir wastes (offal meats), greaves, whole fish, oilseed waste, bran and millers offals. The meat offals are mainly unwanted organs such as green tripe (stomach), melts (spleen), udders, pig stomachs, lungs. Meat unfit for human consumption is also used. All the above is processed such that it is rendered commercially sterile. This ensures the complete destruction of any pathogenic or potentially pathogenic organisms. There is a complex chain of availability operating within the industry. The petfood industry takes, as raw materials, waste products which the human food industry cannot, or does not want to, use or which are used in small amounts. As new technologies and techniques of food processing develop the human food industry is able to use previously unusable wastes. Thus the petfood industry is increasingly researching into ways of using novel or 'exotic' raw materials as well as yet other human food wastes. Some examples of novel areas investigated or of potential benefit are single cell protein (SCP), mycoprotein and β protein of gluten. In the production of SCP energy requirements are low, yet it is high in protein and may have the correct nutritional balance required. Aspects to overcome when using novel wastes or products are those such as safety, appearance, acceptable forms (will it have the functionality required or the correct texture?).

There are many waste products of the human food industry which can be used together with novel waste or by-products of other industries. The difficulty is in actually using them to produce a product which fulfils all the nutritional, purchaser acceptance and commercial aspects of the final product. Petfood raw materials are very variable, displaying intra- and inter-batch variability. The challenge is to produce a uniform product having all the desired characteristics.

2.3 Properties of Wastes Used as Raw Materials

Many waste materials intended for use as petfood raw materials are susceptible to microbiological spoilage. To prevent or reduce such spoilage it is transported chilled (0-4°C) or deep frozen (≤ 10°C). A proportion of fresh material is used which is not chilled. Rapid transportation and in-plant handling is required. With regard to cereals and flours, the low water activity of these materials is usually sufficient to render them microbiologically stable, providing they are not mishandled.

Since many of the materials used are classified by their producers as waste, it is not uncommon for such material to be contaminated with other quite undesirable matter which has to be removed. To avoid this an active vendor assurance scheme is necessary. Deep frozen meat blocks may have polythene wrappers trapped within folds. For example, when lungs are wrapped and then evacuated, the polythene is trapped by masses of collapsed alveolar tissue. Such wrapping material presents problems when blocks are stripped and broken prior to use. Filleting waste, derived from dock-side operations, may contain metallic foreign bodies such as fish hooks. The fish skips, however, often have the appearance of a receptacle to dump anything unwanted such as wood, paper, etc. Fortunately, programmes of education aimed at the producer with respect to minimising unwanted pollution of such waste products has been most effective, as have alterations in the way meats are packed. Increased sophistication in sensor technology has allowed a very high level of detection and elimination of metallic and non-metallic foreign bodies. The most desirable way of foreign body elimination and the one that is pursued with vigour is elimination at the supplier's or manufacturer's end.

Written raw materials specifications are produced giving precise details of the qualities of raw materials that will be acceptable and the limits of variability that are acceptable. Thus for certain meats there will be specifications for the percentage of bone, fat, smooth muscle protein; these descriptions vary depending on the role of the raw material in the final product. Vendor assurance schemes operate with the suppliers who carry out their own strict quality control procedures. For example, specific properties May be required of a particular raw material such as hydration characteristics, shear tolerance, break strength, etc. Manufacturers using specified tests, sell to these targets and the product is assessed by the industry to check whether it conforms; so the supplier's performance is audited. Many of the raw materials used, especially abattoir wastes and other proteinaceous wastes, may be contaminated with bacteria, usually originating from the gut of the animals, skins and hide and from abattoir equipment. Incoming raw materials such as these are subject to sensory organoleptic evaluation by skilled operators and may be subject to automated bacteriological techniques. In this way they are assessed as to their overall biological quality. Evaluation by these methods greatly reduces the risk of preprocess spoilage of product. Thus considerations of hygiene are of very great importance. Raw materials arrive as non-sterile batches and are converted into a usable state (unwrapped, broken up, thawed, etc.).

At present fish offal is used in some petfoods, as a background fish meat filler. It supplies protein and the claim for 'fish'. In certain varieties, specific species may be claimed ie salmon and salmon waste is used at least 5% of the pack, or simply 'white fish' may be claimed.

2.4 Sub Division of Petfoods into Categories

There are a number of types of petfood. There are super, premium or ultra gourmet petfoods. These products consist almost entirely of meat, fish, specific fish ie tuna, salmon or pilchard, plus necessary vitamins and minerals. These are usually retorted products, found in cans or laminated trays.

There are gourmet products, usually presented similarly to the above, but the product consists of chunks of meat or fish in a background meat/fish mixture. The meat and fish of both products will be of high quality. The fish will cost from £600 to £900 per tonne (NOK6,000 to NOK9,000 per tonne). It would be entirely possible to use a texturised meat artifact in place of an actual fish piece in such products provided that the visual appearance and palatability were of acceptable quality (see later).

Minced fish offal itself is used as background filler material. This is effectively structureless and serves only as a protein source and perhaps for claim purposes for varieties. These types of products are generally of lower quality and palatability then the super premium or gourmet style products.

Dry products, particularly varieties aimed at the cat market, also utilise fish material. This is usually in the form of hydrolysed fish (using enzymes) and stabilised by the addition of phosphoric acid and antimycotic agents (potassium sorbate). This hydrolysate may or may not have been boiled with glucose to provoke the formation of Maillard reaction flavours. Production of such products may also be a market opportunity, but probably a small one since only smaller producers are likely to be interested in the provision of such a product.

2.5 The Petfood Market

The international market for pet products can be characterised by the following key trends. There is real growth in the world's major markets resulting from a rising pet population. In addition there is a greater proportion of spending on industrially prepared products in markets where there was traditionally not the case. Cat food sales are generally experiencing higher growth rates than sales of dog food and there is a trend towards premium varieties for cats and dogs.

There is also greater product segmentation and emphasis on varieties plus an internationalisation of brands. Western Europe offers one of the brightest projects for growth in the short term, although Japan is currently one of the fastest growing markets.

Comparative Size of Markets

	Million NOK
USA	55,573
UK	15,435
France	12,339
Germany	11,107
Italy	6,169

Source: PFMA* 1991

Retail Sales of Pet Products by Sector

% value	***France***	***Italy***	***UK***	***USA***	***Germany***
Dog	71.8	20.8	42	45.4	42.7
Cat	26.5	39.2	38.3	29.6	43.6
Other Foods	1.7	16.9	1.9	-	13.7
Accessories	-	23.1	17.8	25	-
Total	100	100	100	100	100

Source: PFMA 1991

* PFMA = Petfood Manufacturers Association

Growth Sectors in Pet Products (1986-1990)

% Value Change	***CAT***	***DOG***
France	+66.5	+59.5
Italy	+29.3	+28.9
UK	+34.9	+22.3
USA	+22.7	+17.3
Germany	+22.5	+13.2

Source: PFMA

The fact that cat products are increasing in the market place at a significant rate means that the opportunity for a fish analogue is high. Petfood companies currently buy white fish and trimmings at NOK6000 to NOK9000 per tonne. The companies would be very interested in an analogue that sold for <NOK4000 per tonne.

3 THE POTENTIAL FOR USE OF FISH OFFAL ANALOGUES BY PEDIGREE PETFOODS

Initial discussions were held with Pedigree Petfoods to establish a specification for a texturised fish analogue.

Specification: Analogue chunk
Fish or flesh-like

Criteria for acceptance:

- white, as light as possible
- non-granular
- no obvious bone
- does not need to be bone free
- no otoliths
- palatability should be high

Form:

- frozen free flow product.

A further meeting with Pedigree Petfoods was held at the Melton Mowbray site. The objective of the meeting was to discover the commercial considerations of using a restructured fish analogue in place of white fish.

Present at the meeting were Geoff Grantham (Environmental and Legal), Di Orsan (Commercial Division) and Nick Ashley (PA).

3.1 Introduction

Pedigree Petfoods is very interested in buying in a prepared fish analogue chunk, which adheres to the specification already given. Transport of such a chunk from Norway is perceived as expensive. Thus Pedigree would prefer large blocks of material that could be size reduced at the canning site. This is seen as inherently environmentally more acceptable because of the lower use of fuel for transport. Transport of small chunks would also involve transport of air and would be less efficient and more expensive.

3.2 What do Pedigree Petfoods Use Currently?

For the inclusion of pieces of fish into premium products, Pedigree Petfoods use the belly flap through to complete, deboned whole fillets. Pedigree say that prices they can purchase this material for are £400-£500 per tonne delivered. This range is due to seasonal price variations, and good quality fish can be obtained at around £400 per tonne at certain times of the year. Indeed, £400 per tonne would be considered expensive as a 'distressed cargo'.

When costs up to £600 per tonne are approached then Pedigree find local contractors are able to accommodate the company with 'the real thing' i.e. whole fillets.

In addition to the high quality fish bought, Pedigree also buys fish offal; basically this consists of heads and frames, and acts as background 'filler' material, competing with poultry waste. Other fish used such as Salmon, Tuna, Sardine etc. are used from a marketing claim perspective to differentiate sub divisions of brands.

Within Europet (Mars Petfood companies unified European branding), what is required is white fish, as visible pieces, with skin attached if possible. This is seen as giving a 'reality factor' to the product. The continental Europeans are "less squeamish" about identifying the source of the material than the British.

It was asked if we could put the skin back onto our chunks? However, this must not darken the product with migration of melanin pigments during storage or processing.

3.3 Product Costs of the Analogue

"If the analogue chunk can be produced for <£400 per tonne then this would be very attractive". There has to be an "interest hook" to attract Pedigree Petfoods and Europet.

3.4 Considerations of Use

The real thing, such as fish fillets, can sometimes have a colour problem. For instance, Coley is unacceptable because of its 'dirty' colour. In addition, colour stabilisation in processing is an important consideration. Thus, the analogue should remain white during the canning process.
In addition, there should not be any cook-out from the chunk which could cloud the gel, nor should the chunk absorb a disproportionate amount of liquid, ingredients etc. Also, there should be no negative interaction with other product components.

Based on use in a super premium product, Europet would use only 300-400 tonnes per year. The lower the price, the more chance of selling a higher tonnage. A minimal amount of actual white fish is used in Ocean Fish Sheba, while white fish offal is used in Chappie. Some fish is used in Whiskas.

A fish analogue will compete with analogues from, for example, poultry byproducts. There is an opportunity to use fish analogues in Mainstream products, particularly if they have no strong 'fishy' odour etc. **"The fish analogue could go a long way in main stream products. It does not necessarily have to be niche".**

A dry fish analogue that was rehydratable would be interesting; however, fish is very difficult to re-hydrate for human consumption and such material tends to be rubbery. Could this rubberiness or resilience be used as a positive characteristic in the analogue itself to render it more robust?

3.5 Supply Considerations

Pedigree Petfoods would be concerned to have a sole supplier of the material. However, if the technology was licensed to other parties, then other Petfood companies could become customers. This works both ways.

Shelf life considerations are very important for the analogue. A buffer stock is required. Considerations are: where is the analogue source, what product lines are running, when are they scheduled? etc. Pedigree naturally wants to keep the minimum assets on site. The more products it could be used in, the better. However, it is noticeable that commodity products (e.g. offal) have shorter shelf lives, in general, than speciality products.

It is also interesting to consider a single fish species, if appropriate and if catches allow it, to produce a species specific analogue.

The obvious one for Norway is salmon. However, a white fish would be of great interest.

3.6 Summary

In principle, Pedigree Petfoods is interested in buying-in a pre-prepared fish analogue chunk.

If the chunk could be produced to their specification and for <£400 per tonne then there is an excellent chance of its being used in a wide range of mainstream products, not just premium niche ones.

4 CONCEPT GENERATION

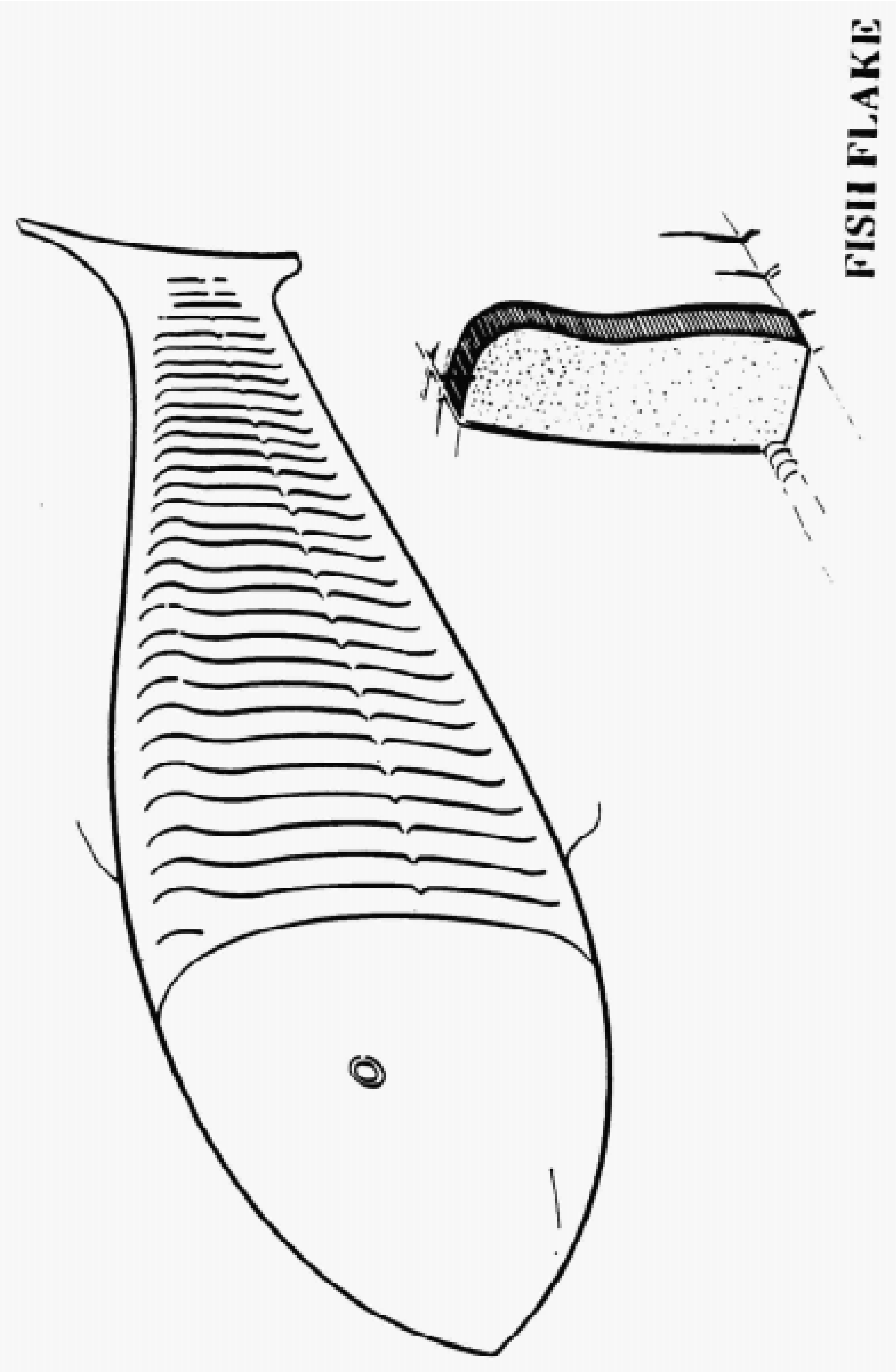
The objective of this section of the work programme was to identify suitable technology approaches that could add value to fish offal. This was by means of current industrial process knowledge coupled with the generation of other ideas and concepts for creating a fish flake/fish chunk analogue for use in canned petfood. The underlying objective was to identify suitable methodologies that would provide a degree of 'technical insulation' (make the process hard to reverse engineer from the product).

What are we attempting to produce? We are attempting to produce a 'fish flake' using a texturisation technology. The fish flake is technically a myotome, or block of fish muscle (see diagram Fish Flake).

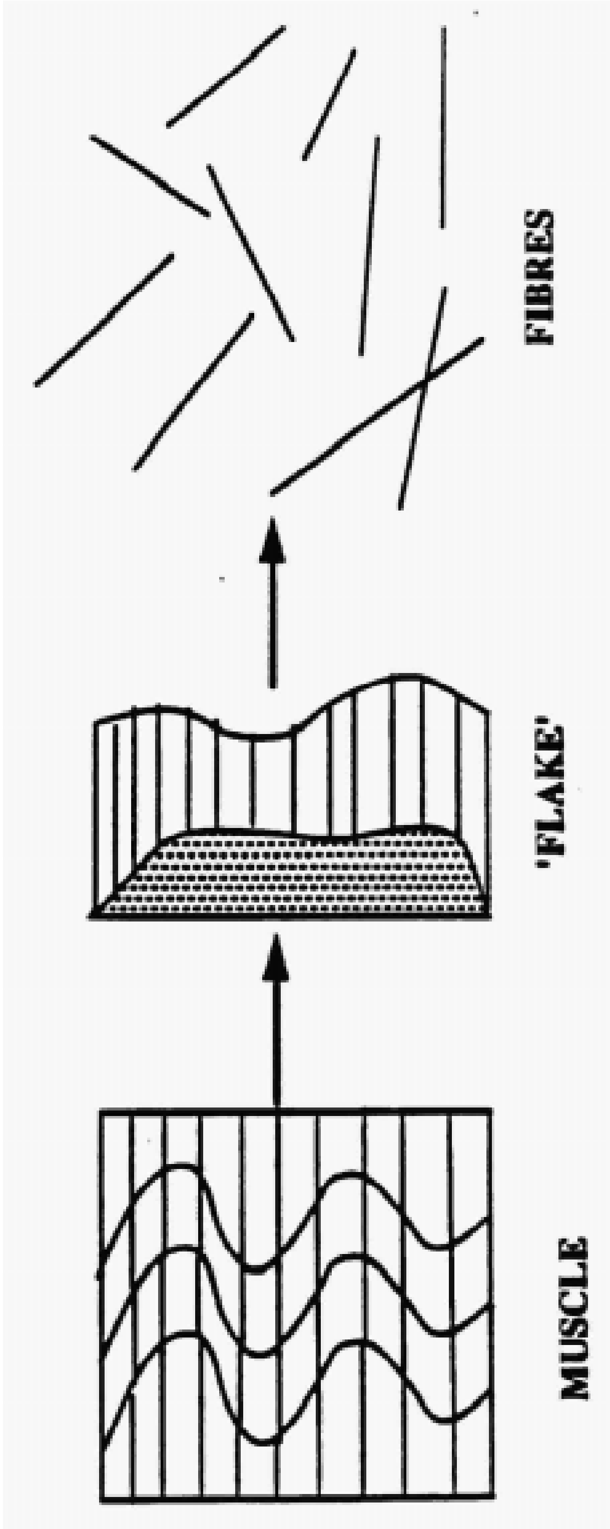
Fish muscle is made up of a number of myotomes or fish flakes. These fish flakes in turn are made up of muscle fibres (see diagram Muscle Flake Fibres).

The fish offal would be partially deboned and all macro structure obliterated by fine mincing. This offal mince will be the raw material for the texturisation process.

FISH FLAKE



MUSCLE FLAKE FIBRES



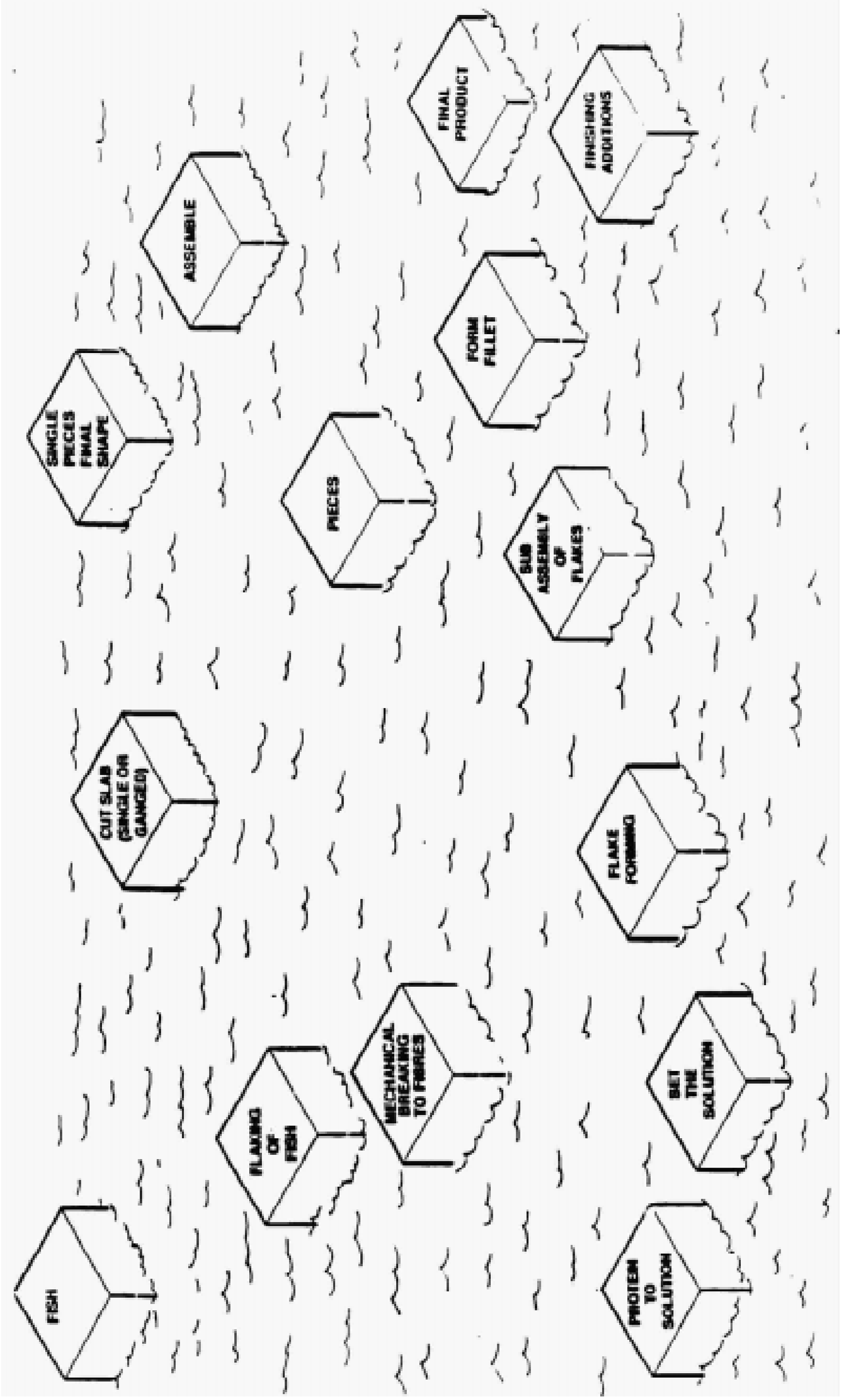
4.1 Texturisation

Texturisation is the process of adding texture. In this context, texture refers to the mechanical properties of the fish analogue chunk, such as elasticity, friability, break strength, Young's modulus etc.

Structurisation is a term referring to the production of a structure within the product. Thus lamination or the generation of fibrosity is structurisation.

The term reforming is a general term and refers to the creation of a textured and structured product.
The various stages of adding texture are shown on the diagram 'Texturisation Overview'.

TEXTURISATION OVERVIEW



4.2 Approach

A series of creative 'brainstorming' sessions were held. These sessions involve gathering teams of people from a variety of backgrounds in an attempt to:

a) use the wide knowledge base that a multidisciplinary team possesses and

b) to determine whether an everyday technology from one area could become the novel technology in another.

A large number of ideas and concepts were generated. Some generated by different teams were very similar or variants on a main theme. Most team members had some knowledge of food processing technology or equipment, but some had none. The Basic Long List of Concepts is shown in Appendix 1.

The concept generation process and content is summarised in the following diagram.

Assemble Teams with Multi disciplinary Backgrounds
- Food scientists/Technologists
- Biotechnologists
- Chemists
- Materials Scientists
- Engineers

↓

DescribeProject Brief and Creative Input Required

↓

Key Areas for Brainstorming
eg . Extraction
- Texturisation
- Bleaching

↓

Generate a **Very Long List of Ideas**
- No negatives
- No selection at this point

↓

Grouping of Ideas
- Further description
- Shortlisting
- Rejection of untenable ideas

↓

Ranking of Ideas

The concepts were taken and grouped into subject areas. These concepts were then assessed against a number of criteria. These criteria were:

Feasibility

- ability to be put into effect

Suitability

- will it work with fish offal?

Novelty

- is it totally new or a development of interesting ideas.

Complexity

- technically easy or difficult.

Cost

- the likelihood of a production process being of reasonable cost or being expensive to develop.

Timescale

- short term, medium term or long term development.

Market Potential

- is there a market pull for the product?

Product?

- status of market - non-existent, niche, immature, mature.

4.3 Concept Criteria Weighting

To enable the concepts to be ranked, a weighting system was employed.

The weighting was:

10	low risk, proven, known technology/product
5	medium risk, unproven in this area, technology needs adaptation
2	high risk, unproven, some technical information
0	very high risk, unproved, unknown technology.

The concepts were grouped into three basic areas:

Extraction
Usage.
Texturisation

There may be some overlap between some of these areas. Also, many of the ideas were generated at several of the concept sessions. These were combined. The basic ideas were ranked against the evaluation criteria and then the top concepts were evaluated in more detail. The results of this ranking are illustrated in a table in Appendix 1.

4.4 Evaluated Concepts

The concepts were ranked against the weighted criteria and given a percentage score against the 'ideal' score. The top scoring concepts from each group were taken and evaluated further.

5 'USE A VERY COLD PLATE AND FREEZE OFFAL AS LAYERS, THEN HEAT SET THE STRUCTURE'

This is essentially a cryogenic layering technique. It would rely on a very cold plate, and the accurate deposition of a fish offal slurry, probably a highly ground slurry. As a thin layer this would freeze very quickly. This now cold surface would be used to create a new frozen layer as a further layer of slurry was added. This would be continued to give a multilayered frozen offal block to the maximum energy efficiency of the plate. The block would then be separated from the plate, cut into chunks, and the larger structure set by flash heating (probably IR and μ wave).

The layer of slurry would be just a few millimetres thick. It may have a collagen layer interleaved between the minced offal layers to act as a binding layer for thermal processing. This would simulate the natural connective tissue layer found between actual blocks of fish muscle.

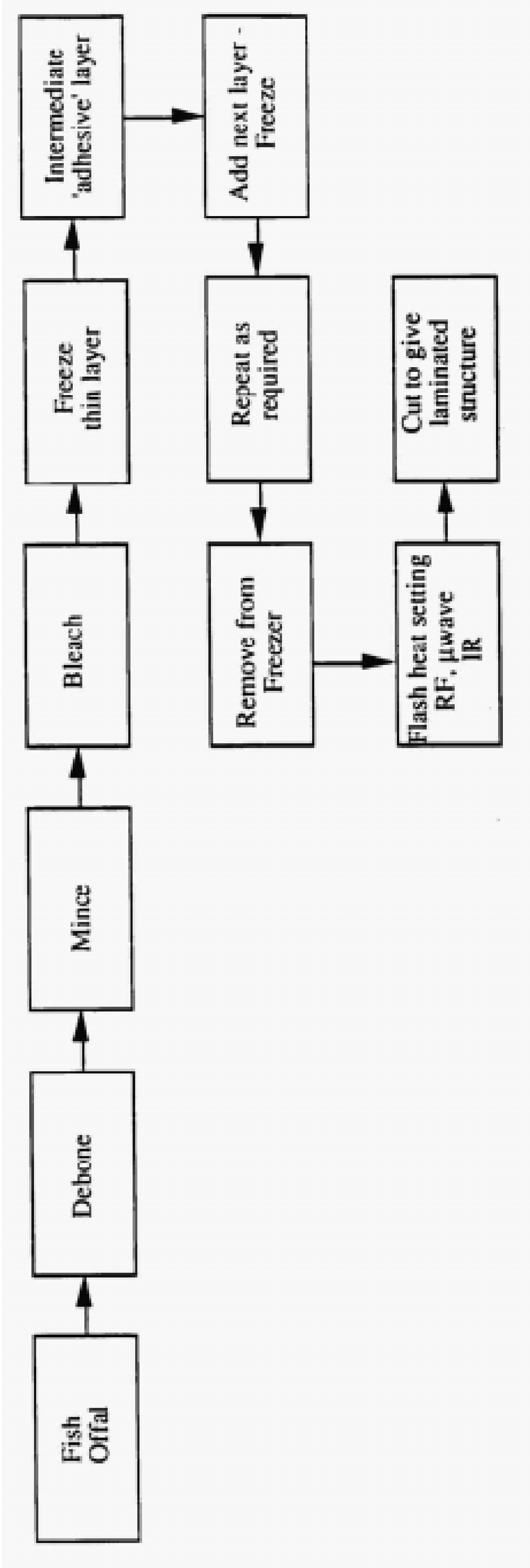
The extrusion of the slurry through a die slot may give a certain degree of fibre orientation, but this would probably be only at a low level.

The cold plate would be cooled with normal refrigerant, liquid CO_2 or liquid air depending on the thickness of the final laminated structure. The plate should have the facility for being warmed too, to free the laminated block.

The angle of the cut could be adjusted to give a similar banded or laminar structure to that of fish muscle.

This process would be a novel procedure in the forming area. It could be modified using protein additives or cryoprotectants to control the freezing process.

Use a very cold plate and freeze offal as layers



6 REFORMING WITH STRUCTURISING AGENTS

6.1 'Reforming with Alginates, Shredding the Gel and Aligning the Fibres Via Rolling'

6.2 Lamination Flaky Pastry,with Alginates, Shredding the Gel and Aligning the Fibres Via Rolling'

6.3 Lasagne, Layering,with Alginates, Shredding the Gel and Aligning the Fibres Via Rolling'

It is worth considering these concepts together since they have the common theme of gel reforming technology. This area too has been described in Appendix 1 and should be considered in light of that Appendix.

Although it is well known technology, it has not been applied to fish offal per se.

Also, alginate may not be the ideal gelling agent, it just serves as an illustrative example. Thus fish offal would be mixed with a suitable gelling agent (sodium alginate, carrageenan/carob/xanthan mixture, tragacanth (very expensive), pectin, gluten, albumin (very expensive)). A gel would be formed, via a chemical or physical treatment depending on the type of gelling agent used.

The potential chunk would not simply be produced as a blob-like entity. The gelling fish offal would, once a surface skin was formed (this is where alginate can be so useful), be layered so as to give a laminated structure. Gelation would continue and the structure toughen. The layers could be coated as they formed to encourage them to stick together. The whole mass, when cut correctly, would have the laminated, gross structure of a fish fillet.

The other method described, whereby the gel is shredded is an alternative to the lamination approach. Here, the gel would be cut and pulled to produce random, long 'fibres' or shreds of gelled fish offal. To produce a fish artefact, the fibres of gelled fish offal need to be aligned.

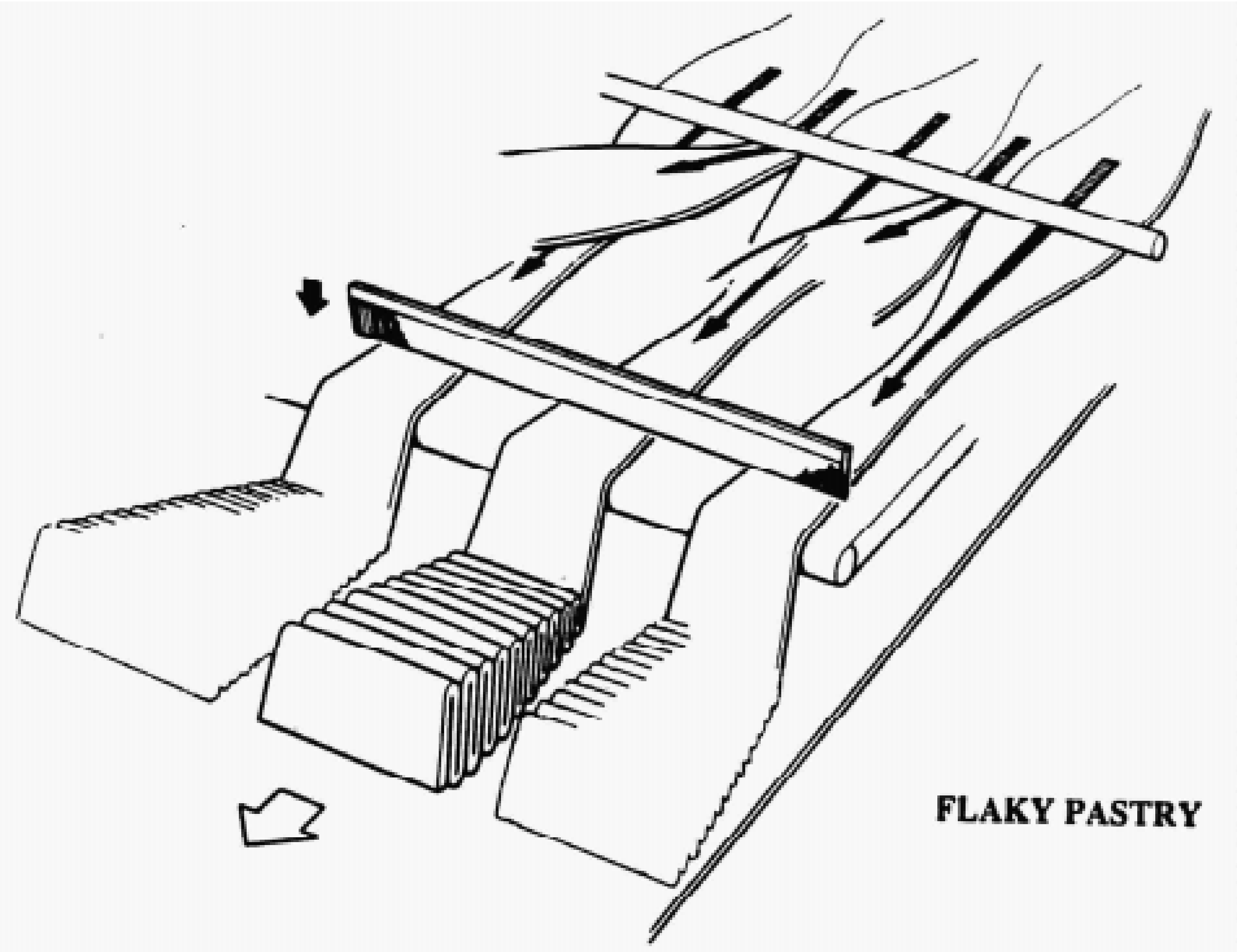
A rolling process is envisaged with multiple offset rollers, the spacing of which can be adjusted during the rolling process. PA Consulting Group has considerable experience of aligning mycoprotein fibres (the RHM "Quorn' product) and thus knows from experience that such fibres or shreds can be aligned. Once this has been achieved the aligned and compacted fibres would be cut; then the cut slices would be pressed together with a little binder. This would produce pseudo fish flesh flakes, in a mass, resembling fish muscle.

Fibrosity is created by using a texturising agent such as a gelling agent. The gelled fish offal mince sheet would then be shredded, and the shreds compacted into a structurised sheet. This would then be folded to create the laminations. Upon cutting, the laminate structure should present the appearance of muscle flakes. If the flakes are teased apart, they should exhibit fibres reminiscent of actual fish muscle.

The layering concepts of 'Flaky Pastry' and ‘Swiss Roll’ are shown in the following diagrams.

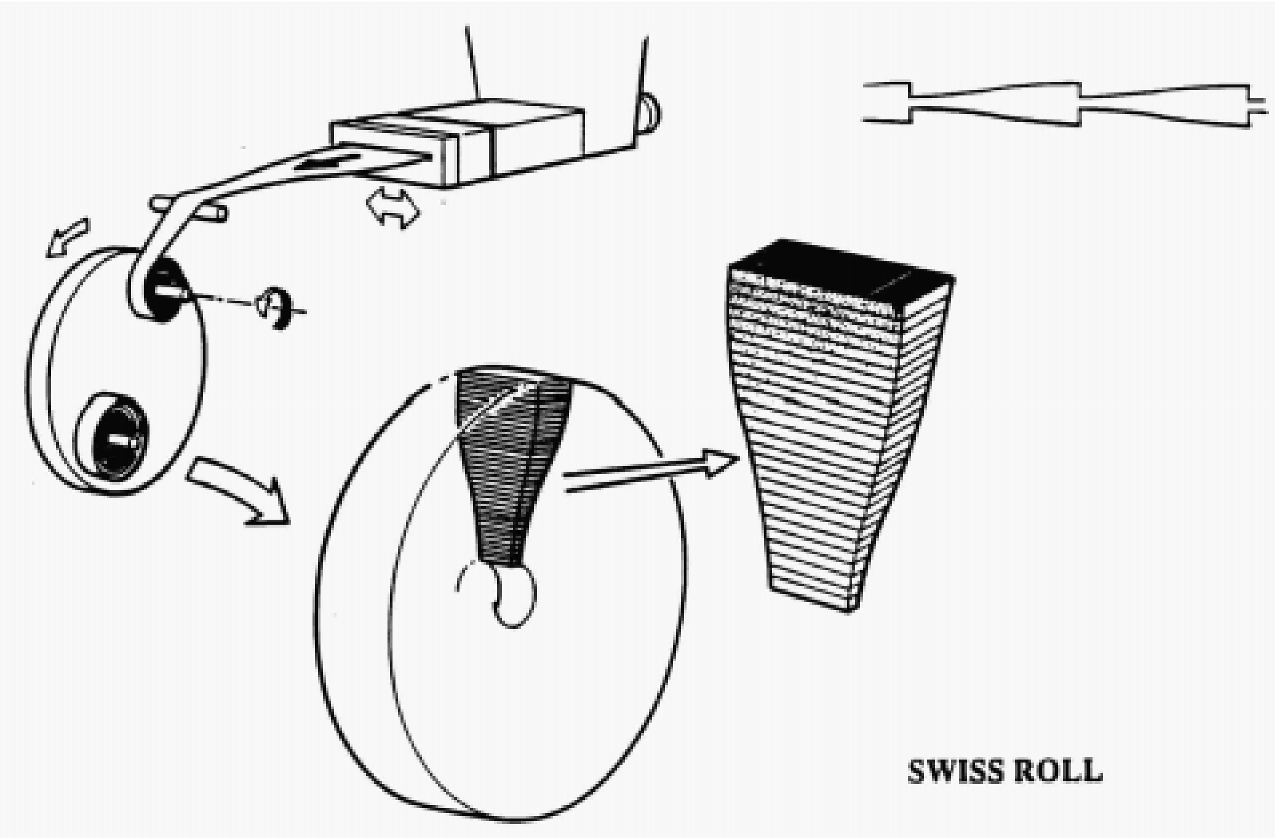
FLAKEY PASTRY

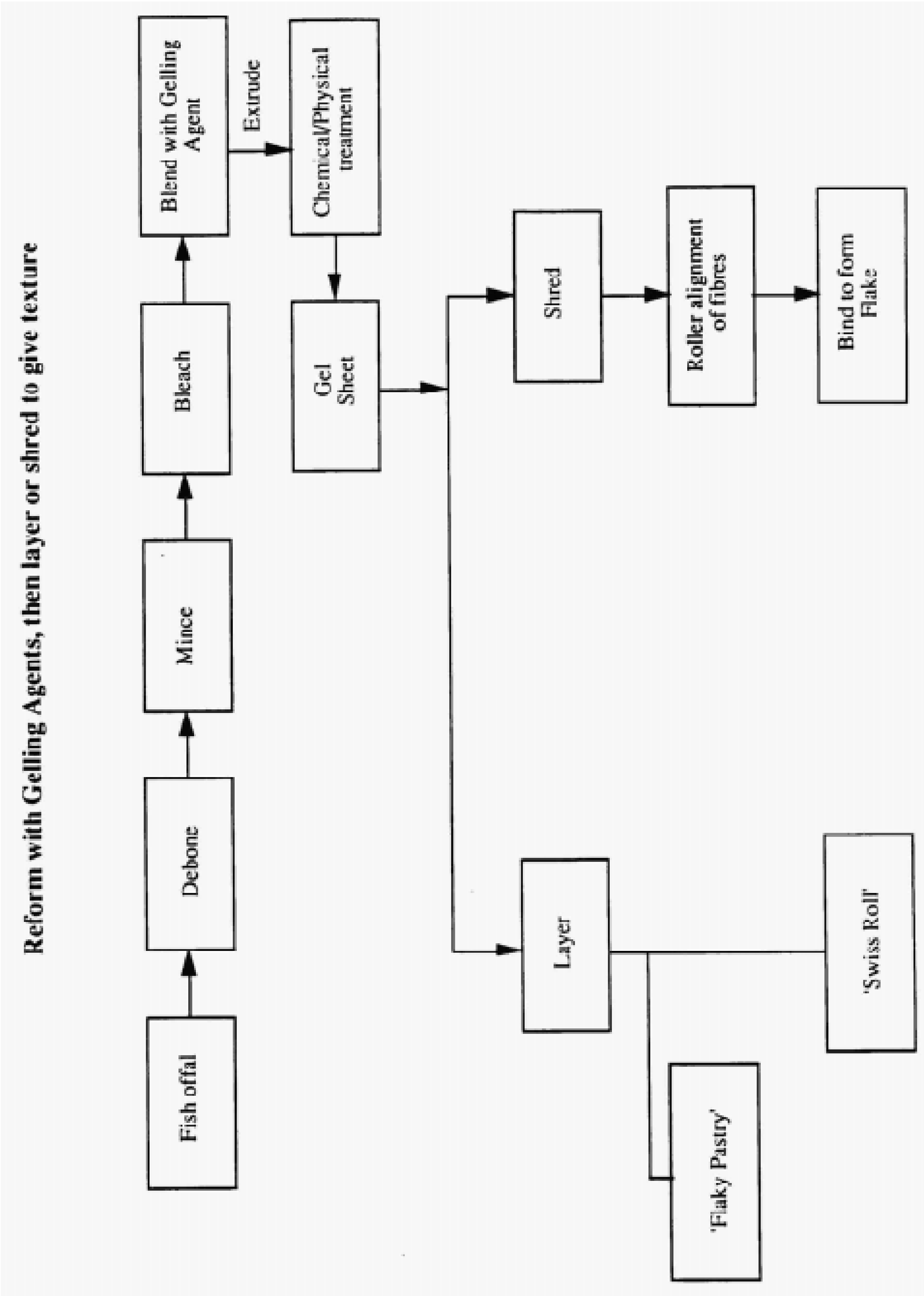
Here a continuous sheet of primordial fish flake is folded backwards and forwards to form a layered structure. This would be a continuous, high yield process. It should give excellent flake alignment and a full three dimensional form.



SWISS ROLL

A sheet would be extruded from a variable-width die. The sheet would be wrapped around a mandrel before dividing the roll radially. This is a discontinuous process. All the machine technologies are known in other industries and it should give excellent flake alignment and consistency.




Reform with Gelling Agents, then layer or shred to give texture
Fish offal
Debone
Mince
Bleach
Blend with Gelling Agent
Extrude
Chemical/Physical treatment
Gel Sheet
Shred
Roller alignment of fibres
Bind to form Flake
Layer
'Swiss Roll'
'Flaky Pastry'

7 'USE GLUTEN THEN EXTRUDE'

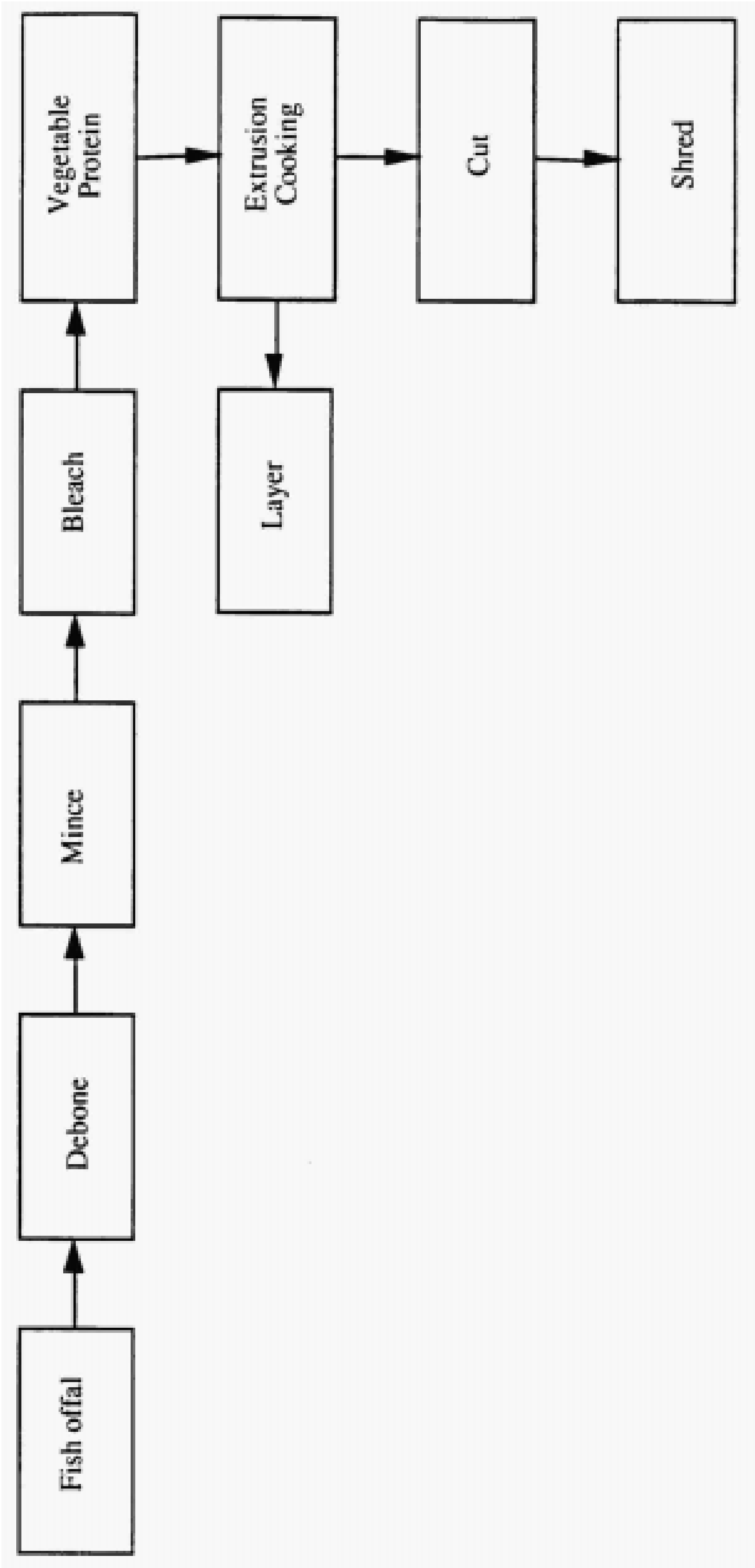
The potential application of extrusion cooking technology to the production of meat analogues has been discussed previously in Appendix 1, section 1.2.

Most texturised vegetable proteins are based on defatted soya proteins, although some work has been carried out on the extrusion of blends of abattoir offal and soya grits. It was found that defatted alkali extracted offal protein could be incorporated at high levels to produce an expanded texturised product. Provided the fat content of the mixture is kept below 1% there is no reason to believe that fish offal could not be utilised in the same way. A number of protein sources could be used in place of soya, these include cotton seed, peanut, corn, wheat (gluten), sesame and yeast. It is further known that blood protein/offal and gluten have been extruded to yield meat analogues with good stability to canning.

The following flow diagram illustrates a possible approach to the use of extrusion cooking to produce texturised offal. The deboned, bleached slurry would be pumped into the extruder. Here it would be mixed with a suitable vegetable protein such as gluten. The moisture content of the resultant 'dough' would be controlled by the ratio of the two components.

With high levels of gluten (low dough moisture content) it is envisaged that high shear condition would produce an expanded product which could be cut to form slices or chunks at the die plate of the extruder. The alternative to this is to add lower levels of gluten to produce a wetter dough in the extruder which could be removed from the die via a take off belt. If a slit die were used then a continuous sheet could be produced. This could be subjected to layering or shredding as described earlier. The layered structure could then be cut to produce layered chunks or flakes.

Extrusion cooking of an offal/vegetable protein mixture



8 'ADD TEXTURE VIA FREEZING'

This was basically a brief description of cryostructurisation. A full account of this technology was given in Appendix 1, section 1.6 which is devoted to the production of texture and structure in structureless protein mixes with the emphasis on fish.

Essentially this technology is driven by the controlled freezing of protein slurries.

The fish offal would be rendered structureless via a comminution/grinding process to thoroughly homogenise the flesh and a predetermined amount of bone. This would then be mixed with structure enhancing agents, such as soya flour, gluten, or albumin.

The mixture would be slowly frozen under anisotropic freezing conditions. This promotes slow, large ice crystal formation and not ice nucleation events within the mixture. The growing unidirectional crystals push the protein from their path and cause localised high protein concentrations to occur. The crystals and their branches promote the formation of a protein network, which forms a 'negative' image of the ice lattice.

This convoluted, layered protein matrix is then heat-set or made permanent using chemicals (acid, salts etc). Thus the layered structure is maintained.

An examination of the literature has shown some excellent textured samples and this process has been used to produce, purely experimentally, fish fillet like structures from minced fish.

It is a novel technology and it is possible for Rubin 'to get in on the ground floor' here and exploit this novel approach. It is certainly worth performing some experimental work using this approach.

This is potentially the most expensive technology, based on energy expenditure. Also, dedicated equipment would be required for commercial production using this process.

9 AN OUTLINE OF THE MARKET AND POTENTIAL PROCESS ECONOMICS

It is important that the evaluated concepts are not judged solely on technical feasibility. The market potential for a texturised analogue is considerable.

9.1 European Petfood Market 1991

Country	Volume (ooo's tonnes)	Market Value (NOK millions)
UK	1,294	15,435
France	725	12,349
Germany	525	11,107
Netherlands	241	6,300
Italy	240	6,169
Belgium	84	1,200
Switzerland	50	860
Denmark	51	800
Spain	50	750

Source: PA

The cat product % in the top five markets averages 45%. Although canned cat products vary as a % of the total market depending on the country, the amount of canned cat product in the UK is around 600,000 tonnes.

The fish analogue would be present as 10%-20% of the pack weight. Averaging 15%, this gives a potential requirement of 90,000 tonnes of the texturised fish analogue for the UK. Of the UK market, Pedigree Petfoods produces around 360,000 tonnes of canned cat products, so then requirement would be approximately 54,000 tonnes per annum. Thus production of 25,000 tonnes of a restructured analogue would only satisfy approximately 50% of the requirement of Pedigree Petfoods, and only 28% of the total UK canned cat food market, if it was generally available. This would suggest that the market opportunity, from a production volume perspective is a realistic one.

The potential process economics of the two fish offal production capacities suggested by Rubin are outlined in tables 1 and 2 (12,000 and 25,000 tonnes respectively). These estimates are based upon a number of assumptions:

- The cost of purchasing offal is NOK300/tonne for unfrozen and NOK450/tonne for frozen.

- Offal is fully utilised (ie the material purchased is used as is, with no further fractionation).

- Transportation costs are:
  within Vesterdlen frozen (NOK100/tonne), unfrozen (NOK150/tonne)
  From Tromsø and W-Finnmark NOK160/tonne

- Frozen offal is stored at Vesterålen for an average of 1 week at a cost of NOK30/tonne/week.

- Process equipment requirements will be more clearly defined during the next phase. They could include mincers, tanks, extruders, shredders, compactors, ovens, freezers. These could cost up to NOK30M for a 12,000 tonne capacity plant (and NOK47M for a 25,000 capacity plant). These would be amortised over 5 years.

- Other ingredients will be required to bind and gel the analogue. Our estimates are based upon addition of 1% of an ingredient costing NOK30,000/tonne.

- Labour and utilities are estimated at NOK350/tonne and NOK150/ tonne.

- Frozen storage of the analogue could be for up to 1 month (at NOK120/tonne). Removal of extracted bone waste, NOK200/tonne.

- Shipment to the UK port will cost NOK450/tonne.

As the process becomes more clearly defined during subsequent phases of the projects then a more detailed analysis of the economics of producing an analogue will be necessary.

It should be noted that a considerable proportion of the overall cost of producing the analogue is in storage and transportation of the materials. This will be a key factor in the selection of an appropriate production location.

12000 Tonnes Per Annum Plant

	RUBIN FISH ANALOGUE PRODUCTION PLANT		
ASSUMPTIONS			
Plant 12000 tonne raw material per year Plant capacity 6600 tonne product per year Capital cost NOK 30 million Yield of product on raw materials equals 6600/12000 equals 0.55 Fresh and frozen raw materials used in proportion 5 to 7 Plant depreciated over 5 years			
	Usage	Cost	Unit Cost
Materials	te/te product	NOK/te raw mat	NOK/te Prod
Fresh offal	0.76	300.00	227.27
Frozen offal	1.06	580.00	615.15
Ingredients	0.01	30000.00	300.00
Total raw Materials			1142.42
Deboning			200.00
Transport			450.00
TOTAL VARIABLE COSTS			1792.42
Depreciation			909.00
Labour			350.00
TOTAL FIXED COSTS			1259.00
TOTAL MANUFACTURING COSTS			3051.42
Sale price			4000.00
GROSS MARGIN			948.58
Gross margin on 6600 tonnes of product NOK 6,25M			

25000 Tonnes Per Annum Plant

	RUBIN FISH ANALOGUE PRODUCTION PLANT		
ASSUMPTIONS			
Plant 25000 tonne raw material per year Plant capacity 13500 tonne product per year Capital cost NOK 46.5 million Yield of product on raw materials equals 135000/25000 equals 0.55 Fresh and frozen raw materials used in proportion 5 to 7 Plant depreciated over 5 years			
	Usage	Cost	Unit Cost
Materials	te/te product	NOK/te raw mat	NOK/te Prod
Fresh offal	0.76	300.00	227.27
Frozen offal	1.06	580.00	615.15
Ingredients	0.01	30000.00	300.00
Total raw Materials			1142.42
Deboning			200.00
Transport			450.00
TOTAL VARIABLE COSTS			1792.42
Depreciation			676.00
Labour			350.00
TOTAL FIXED COSTS			1026.00
TOTAL MANUFACTURING COSTS			2818.42
Sale price			4000.00
GROSS MARGIN			1181.58
Gross margin on 25000 tonnes of product NOK 16M			

Price and Costs Sensitivity

	PRICE AND VARIABLE COST SENSITIVITY				
		12000 TONNE PLANT			
Price NOK / Tonne	3000	3500	4000	4500	5000
Gross Margin NOK Millions	-0.3	2.96	6.25	9.5	12.85
Variable costs (% change)	-20%	-10%	10%	20%	
Gross Margin NOK Millions	3.89	5.07	7.4	8.6	
Break even on Yield	25.00%				
Break even on offal tonnage	5485 t				
	PRICE AND VARIABLE COST SENSITIVITY				
		25000 TONNE PLANT			
Price NOK / Tonne	3000	3500	4000	4500	5000
Gross Margin NOK Millions	2.45	9.19	16	22.7	29.4
Variable Costs (% change)	-20%	-10%	10%	20%	
Gross Margin NOK Millions	11.1	13.52	18.3	20.8	

9.2 Benefits of a Re textured Fish Analogue

	Fish Analogue	**Fish Fillet**
Quality	Low variability in quality	Can be very variable in quality
Price	Price stable	Can vary in price and can be expensive
Composition	Seasonal variation minimal	Seasonal variation can be marked
Physical stability	Robust to canning process	Not robust to canning process
Microbial load	Microbiologically controlled	Microbiologically variable
Fish odour/texture	Organoleptically uniform	Organoleptically variable
supply	Potentially supply stable	Supply can fluctuate
Nature	A product of technological processing	A wild animal product

9.3 Analysis and Summary

This economic overview assumes only a partial use of fish bone in the product and that the product would be used exclusively for pet food. This may not always be the case. There may be an opportunity to develop a fish product for human consumption if the analogue attains the petfood criteria. It would be just like 'real' white fish. There is a European and Japanese interest in a product for people made via this approach.

The break even production level of analogue product is approximately 3025 tonnes. This represents only 3.4% of the total available UK market, and only around 5.5% of the potential market (54000 tonnes) within Pedigree Petfoods. The 12000 tonne plant will produce around 6600 tonnes of product per year and generate a gross margin of NOK 6.25 million. This represents 12% of the requirement of Pedigree Petfoods. The 25000 tonne plant will produce around 13500 tonnes of product per year and give a gross margin of NOK16 million. This will supply only 25% of the Pedigree Petfoods requirement. Thus there is considerable opportunity to develop this business to supply the entire potential demand. If the entire demand were met, then this would generate a gross margin of approximately NOK90 million and require an input of 98000 tonnes of offal. The business could only be developed if all criteria were met during the development and production programmes, with respect to the quality and organoleptic behaviour of the analogue.

The economic analysis is only an outline and provides essentially just a crude overview of the potential operational characteristics of the production of the retextured fish analogue. At present the production process has not been decided upon. The process will have a major bearing on the capital equipment and building costs required to produce the analogue. once this area has been defined, the economics of production can be developed with greater rigour and accuracy.

Fish offal is a waste material. It is low grade and of low value. It's use in fish meal is limited by the market for fish meal. The fur feed market is also in decline. Offal will build up and will constitute an environmental pollution risk. Thus although the current economic overview suggests only a marginal case, we can ask the question; "Can you afford not to use and upgrade fish offal into a saleable product rather than allow it to become a pollution hazard?"

In addition, there is an opportunity to scale up utilisation of offal to the point where the revenue does become significant. If this could be coupled to the development of a product for human consumption as well then this would have a positive influence on the revenue stream.

The waste bone could also be upgraded, into a horticultural - type product for example, which could be sold for commercial or private use. This would add a further revenue stream.

In addition, there is the positive environmental benefit that will accrue from using large volumes of this potentially polluting waste material.

10 CONCLUSIONS

Texturised fish offal represents a real opportunity in the petfood industry. This industry is used to using fish offal as a background filler in dog and cat food products.

The petfood market is buoyant and expanding in Europe, particularly the cat segment. The petfood manufacturers will tolerate a proportion of bone in the upgraded fish offal product. The manufacturers are very interested in the development of a fish flesh-like artefact, based on fish offal, which could be cheaper for them than currently bought in real fish pieces for their top range products.

The production of a fish-like product from fish offal, while a challenge technically, could be accomplished using a number of techniques. These are:

- use of a very cold plate and freezing offal as layers
- reforming with gelling agents, then layering or shredding to give structure
- extrusion cooking of an offal/vegetable protein mixture
- adding texture via freezing (cryostructurisation)

These should be used to develop prototype fish analogue texturised chunks.

Pedigree Petfoods would be prepared to pay up to NOK4,000/tonne for an analogue that meets their specification. Our initial estimate of the potential cost to produce and transport a frozen fish analogue is around NOK3000/tonne. Given an annual plant capacity of 25,000 tonnes of offal intake this would generate a gross margin of around NOK16M revenue per year.
The opportunity is to develop a business based on the upgrading of large volumes of fish offal and diversification into other markets via active product development.

There would also be a positive environmental benefit in using the waste material as an industrial resource.

The next steps in the process for the development of the project would be via the activation of the next phase, phase 1B. This is the laboratory development phase. Here we propose that we explore the techniques selected during phase 1A in the laboratory to generate 'prototype' analogue chunks. The qualities of the chunks would be fed back into the processes and the final products compared. This will enable the optimal process to be identified. The petfood company would aid in this product assessment. The laboratory programme is fully described in the appendix.

11 RECOMMENDATIONS

We believe that the project should continue. There are three areas that should be addressed.

We recommend that the market position should be investigated in more detail, and in a wider context than just a single company and a single geographical location.

We recommend that the economics of the process and the environmental considerations of developing the analogue business be analysed in further detail.

This more in-depth economic analysis should be progressed in parallel with the laboratory development of Phase 1B. We believe that this would ensure that process and technology considerations are able to be more accurately addressed and factored into the economic analysis and that there would be as little time lost as possible in progressing the development aspects of the project.

1 Production of an Added Value Texturised Product from Fish Offal

1.1 Introduction

Texturisation is a process whereby amorphous biomolecules are in some way given a structure which renders them functional. That is they acquire a physical or mechanical property that was lacking in the starting material. An example from the fish processing industry is that of surimi manufacture. Here, minced fish is washed to remove water soluble proteins, followed by extraction of the actinomyosin from the muscle using brine. A surimi gel results. In other parts of the food industry sodium alginate is mixed with ground meat and injected into a calcium chloride bath. The resulting pieces or chunks of 'meat' are used for pie fillings and for types of lower quality canned products.

Texturisation can be achieved by a number of means, although most are via a combination of physical processing and chemical changes (induced by the processing).

There are a number of published methods of creating texture in proteins which could be applied to fish offal. These are:

Extrusion
Gelling agent/functional ingredient
Fibre spinning
Freeze texturisation.

1.2 Extrusion processing

Of the techniques currently employed to texturise proteins, extrusion processing is the most popular as, in comparison with spinning, it requires less equipment and less sophisticated technology. This process, which was initially applied about 50 years ago to the production of shaped pasta products and ready-to-eat breakfast cereals was subsequently used to texturise vegetable proteins. It is now a widely practised technology, accounting for a significant fraction of fabricated proteinaceous foods.

In extrusion processing the proteinaceous material (usually defatted soy flour) is placed in a conditioning chamber where it is moistened with steam or water to a moisture content of 15-40%. Additives such as salt, polysaccharides, colorants and flavours may also be added at this stage. The mixed homogeneous ingredients are fed through a feeder/hopper into the hollow barrel of the extruder where a tapered screw with whorled ridges forces the material towards the exit orifice of the barrel. The temperature of the barrel may be controlled. The heights of the ridges on the screw decrease towards the exit and this, together with the decreasing clearance between the flights and the inner barrel surface, causes high shearing as the material is moved along. As the clearance diminishes, the temperature and internal pressure also rise (to 120-175°C and 2.8-4.4 MPa respectively) converting the ingredients into a plastic viscous state in the metering section of the extruder. Under these conditions starchy components gelatinise, proteins denature and the tractable components are restructured and/or aligned. The shearing action of the rotating flights tends to align the denaturing proteins into parallel sheaths. The usual residence time in the extruder is 30-60 s after which time the molten mass is further aligned within the die prior to being squirted out into the atmosphere. With the instantaneous release of the high pressure, the superheated water within the structured protein 'flashes' off leaving an expanded porous structure. This evaporation causes rapid cooling and consequent thermo setting of the product to yield a puffed, fibrous structure which may be cut into strips or chunks or broken down into powder or granules. The moisture content is about 2% initially but it is usually reduced to about 8% prior to packaging.

Although textured protein products have been primarily made from soya; other sources such as cotton-seed, peanut, corn, wheat, sesame and yeast proteins have also been successfully employed. A mixture of soya grits with several defatted, extracted offal proteins have been successfully extruded as also has defatted, dehydrated pork rind. Due to slipping (increased lubrication), textured thermoplastically extruded products can normally only be manufactured from protein sources containing 1% or less of fat.

The texture, density, chewiness, rehydratability, fat absorption and colour of extruded products can be influenced not only by the nature of the ingredients but also by moisture content, temperature profile within the extruder, pressure generated, shear rates (screw speed), residence time in the extruder, the type and configuration of the extruder, shape and size of the die, post die cooling and post-extrusion treatments. Many of these factors are interrelated and the precise effect of different variables in determining the texture of thermoplastically extruded products will also depend on the idiosyncrasies of the individual machine.

The texture of thermoplastic extruded products depends on a combination of starch gelatinisation and cross-linking of denatured proteins. The successful application of the process to abattoir offal, therefore, was found to depend on the presence of a carrier such as soya grits. In addition, the lipid content of the offal needed to be decreased. Thus, protein extracted by sodium dodecyl sulphate (SDS), a procedure which involves acetone treatment, from lung or small intestine had little residual fat and could be extruded directly but untreated offal, or protein isolated therefrom by alkali, required to be extracted by acetone as there still remained about 4% lipid in untreated small intestine and in protein isolated from the latter by alkali.

It Was found (Mittal, 1981) that defatted, alkali-extracted offal protein could be incorporated in mixes with soya grits up to 65% and still produce a highly expanded, texturised product. At incorporation levels above 35%, however, products containing porcine or bovine lung protein, whilst having a good external appearance, contained internal channels. Products containing SDS-extracted proteins possessed little or no texture, the extrusion process seeming only to shape the mix and not to introduce fibrous structure.

In respect of water-absorbing ability, products containing alkali-extracted protein were also superior, the maximum benefit again being when the extrusion temperature was 170°C. the water-absorption ability of products containing SDS-extracted proteins was very poor at all extrusion temperatures.

Products containing alkali-extracted proteins required least force to shear, were least hard and had the lowest values for chewiness whereas those containing SDS-extracted proteins had the highest values for these parameters. Moreover, although products containing either SDS-extracted proteins or untreated offal showed maxima for these parameters with an extrusion temperature of 170-180°C, those containing alkali-extracted proteins exhibited a continuous decrease in hardness and chewiness as the extrusion temperature rose from 150-190°C.

The increase in shear strength with increasing processing temperature observed by Mittal in mixtures of soya grits with untreated offal protein and soya grits with SDS-extracted protein, agrees with previously reported work (Cummings, Stanley and de Man, 1972; de Man, 1976; Maurice, Burgess and Stanley, 1976) on soya grits alone. However the tensile strength of the fibres from soya grits alone was maximal after processing at 150-170°C. If the hardness and chewiness parameters measured by Mittal (1981) are related to the tensile properties, then the behaviour of both the soya/untreated offal and soya/SDS extracted offal mixtures fits in with this pattern. These results suggest that, with increasing temperature from 150-190°C, increased orientation and fibre formation occurs leading to increased structural integrity (shear force) but that at the higher temperatures (>170°C), excess fissuring takes place leading to loss of tensile strength (and hardness and chewiness). For reasons that are not obvious, the alkali-extracted proteins drastically modify this behaviour, so that maximum structural integrity is developed at a barrel/die temperature of 160-170°C.

Although studies similar to those outlined above have been described for several protein sources little is known of the physical and chemical changes taking place in these concentrated systems at high temperatures and pressures. There is no reason why fish offal could not be used here.

With respect to the chemical changes taking place during extrusion processing, most workers have concentrated on those involving the proteins and have attributed the characteristics of the extruded fibres to the breaking of existing protein-protein linkages and the formation of new interprotein bonds. The resultant fibre is believed to consist of a protein matrix within which the carbohydrate and other non-protein material is embedded (Harper, 1981). Thermal denaturation of the proteins is obviously of paramount importance in the texturisation process as this results in extensive unfolding of the native structure, allowing the protein to align in the shear field until reactive sites come into juxtaposition to form stable intermolecular bonds. The number of type of such bonds, at least to some extent, govern the physical characteristics of the fibre. This explanation of the texturisation process will obviously explain why admixtures of proteins, eg soya and offal, extrude differently to soya alone. It is not unexpected that proteins from the same source, which have been extracted under differing denaturing conditions (SDS and alkali), should exert differing effects on the extrusion behaviour of the mix.

Under the conditions of extrusion, it is likely that hydrogen, ionic and disulphide bonds will break, as also may a few of the more labile (non-disulphide) covalent bonds. Subsequently, at the elevated temperatures, hydrophobic interactions may become significant and a few specific covalent linkages form. On cooling, further additional linkages may form.

In extrusion processing the chemistry is further complicated because the protein usually represents only about 50% of the ingredients used (the rest being carbohydrate, fibre and ash) the role of the polysaccharides is not passive.

Recent work has shown that alginates of high mannuronic/glucuronic acid ratios are most effective in modifying the extrusion behaviour of soya grits Smith, Mitchell and Ledward (1982) have outlined mechanisms by which the alginate may modify the normal extrusion behaviour of the soya. Whatever the mechanism by which the alginate acts, the observations that only low levels cause marked differences and that these differences are dependent on the composition of the polysaccharide, may explain the reported variations in extrusion behaviour of apparently similar batches of soya grits, ie. the differences may be due to differences in the carbohydrate component rather than the protein.

An advantage of extrusion processing is that, in many instances, the steam distillation occurring at the discharge of the extruder is an effective deodoriser, thus naturally occurring off-flavours are eliminated. For example, Mittal (1981) found that, following extrusion, highly odorous soya/offal protein mixtures were invariably bland in flavour and free of any objectionable odour.

This could be advantageous where fish offal is concerned particularly if aged offal was present.

1.3 Texturisation and gel formation

Under appropriate conditions concentrated solutions of several proteins will form gels of suitable textures for use as foodstuffs. A well established, and commercially successful, application of this principle is in the preparation of several meat products whereby mechanical andior chemical treatment of meat pieces causes the muscle proteins to exude to the meat surfaces where, following heat processing, they effectively set and bind the chunks together into an appropriately shaped product. Myosin is the principal protein involved in binding. If large pieces of meat (~250g) are involved, vigorous mechanical working will cause sufficient exudation to cement the meat pieces together and, although the binding at this stage is relatively weak, subsequent heat processing or cooking yields a high quality product which maintains its integrity. This type of process has also been used for fish products. Thus Sugino (1979) described a system for moulding and mashing seasoned crab meat pieces whilst heating to yield a gelled product which could be subsequently shredded to resemble crab meat.

For smaller meat pieces it is necessary to tumble them in salt/phosphate solutions to extract sufficient salt soluble myosin to form, after pressing, a cohesive mass which, following cooking, is very similar in appearance, texture and sliceability to a single large piece of meat of the type from which the pieces were derived. To avoid the use of salt/phosphate solutions several workers have suggested that selected proteinaceous substances may be used as binders. Crude myosin, extracted from low grade meats, is a very effective binding (gelling) agent and may be very useful in reforming high quality meat products. Other proteins capable of forming gels on heat treatment may also be of use in reforming small meat pieces into large, integrated cuts and wheat gluten certainly appears to be capable of performing such a function. Siegel, Church and Schmidt (1979) showed that, of a whole range of non-meat proteins in the presence of 8% salt plus 2% phosphate, only wheat gluten, and to some extent egg white, gave improved binding to that observed with salt and phosphate alone. In the absence of salt and phosphate only wheat gluten, blood plasma, and to some extent isolated soya protein, gave any measurable binding.

As well as being used solely as a meat binder, several patents have been taken out, which utilise the gelling ability of gluten to create meat or fish-like analogues. For example, the Nippon Seifun Co. (1980) have a patent for the production of a meat-like product from gluten. In this process a paste of gluten and inactive yeast is mixed with seasoning, fats, emulsifiers and such like, and the mixture heated to create a textured product.

As well as wheat gluten, other non-meat proteins have been used to bind protein fibres to yield meat-like textures. Nisshin Mills, KK (1981) have patented a method involving the impregnation of the fibres with a binding solution of heat denatured soya bean protein and gelatin. Heat treatment of the impregnated fibres gives rise to binding in such a manner that the final product has the chewiness of meat.

Although several systems have been described involving the addition of functional protein to waste or low grade protein to yield textured products, most success appears to have been achieved utilising the functionality of the recovered or waste protein itself.

One potentially successful product is a textured fish protein concentrate (Marinbeef) which has been developed in Japan (Suzuki, 1981). In a typical process the washed meat of the fish is mixed with 1-2% salt and the pH adjusted to 7.4-7.8 by the addition of sodium bicarbonate. At this salt concentration not all the muscle proteins are solubilised and thus those that are extracted serve to bind the remaining fibres together into a viscous paste. The paste is extruded as long, spaghetti-like strands into cooled ethanol (5-10°C). After the ethanol has again been removed by centrifugation the residue is dried to less than 10% moisture by hot air at 30-45°C. The texture of the product (Marinbeef) can be adjusted by varying the salt concentration, the number of ethanol treatments and the length and temperature of such treatments.

The product formed by the above process has a good meat-like texture, good rehydration properties and excellent nutritional quality. Sensory evaluation showed that, when used as a partial meat replacement in hamburgers, meat loaves, meat balls and sauces, it was quite acceptable and was preferred to products containing meat flavoured soya bean extenders (Suzuki, 1981).

The possible disadvantages of Marinbeef production are that about 2100 kJ of energy are necessary to produce lkg of product and large amounts of ethanol are required. (Most of the ethanol can be recovered by appropriate distillation procedures). Also the process produces meat-like textures rather than fish-like textures.

1.4 Fibre-spinning

In what is now regarded as standard technique, Boyer (1954) extracted proteins from defatted plant matrices (such as soya) using food grade alkali at pH 10-11, concentrated them to about 15% and held them at 40-50°C until the viscosity had reached predetermined values, as the proteins unfolded from globular configurations into randomly coiled polypeptides. The dope was then forced through a metal spinneret (consisting of thousands of apertures of approximately 0.2 mm diameter) into a coagulating bath (containing salt and acid at pH 3-4.5), when the protein precipitated as long, thin filaments. In a continuous operation, the latter were gathered together longitudinally, over godet wheels, as a 'tow' of fibres. Since the wheels rotated as a faster rate than the filaments emerged from the spinneret, the latter were stretched and the polypeptide chains aligned. If desired, fibres could then be passed through further baths in which they were bound together by added fat, egg albumen or polysaccharides such as carrageenan and associated with flavour and colour.

The texture and appearance of fibres produced by the Boyer process can be altered by controlling the viscosity of the dope, the rate of flow of dope, the rate of removal of the precipitated fibres from the bath, the tension applied to the fibres and by the temperature, pH, concentration and nature of the bath constituents (Horan, 1974). Typically, the fibres contain 50-70% moisture and, on a dry weight basis, 60% protein, 20% fat, 17% carbohydrate and 3% ash (Smith and Circle, 1972).

When subjected to agents capable of disrupting the ionic, disulphide, hydrogen and hydrophobic bonds which determine their native secondary and tertiary structure, the ability of proteins to unfold varies considerably, as does the speed with which they reaggregate thereafter. It is evident that differences in the overall amino acid composition, and in the sequence of amino acids along the polypeptide, affect their behaviour. Thus, those polypeptides which have relatively high contents of free hydroxyl and amino groups will tend to form hydrogen bonds readily and the latter determine the secondary and tertiary configurations the proteins will assume (Nagano, 1974).

For effective fibre spinning it has been suggested that molecules should be at least 100 nm in length and have a molecular weight (MW) of 10000-50000. They should have no bulky side chains but have abundant polar groups and cystine residues. The fibres which form are weak and above 50000 difficulties due to high viscosity occur. The degree of alignment determines intermolecular binding and thus fibre strength. During spinning shear forces disentangle the polypeptides, and flow through the spinneret enhances parallel alignment, thus favouring association into crystalline regions.

The Boyer process has been applied to the proteins extracted from many plant sources-soya, casein, cotton-seed, safflower, sesame, field beans, and wheat gluten (Horan, 1974); but it has also been used in efforts to upgrade protein recovered from unaesthetic animal sources, such as offal, when it has become evident that the source determines the procedural details which must be followed (Young and Lawrie, 1974b, 1975a). Thus, with blood plasma (partially freeze-dried to a protein concentration of 11%), the dope tends to gel and must be stabilised at a viscosity suitable for spinning (~250 poise, P) by first adding NaOH until the ratio of NaOH/protein is 1:10, allowing the mix to stand for 15 minutes and then reducing the pH to 11 by adding acetic acid (Young and Lawrie, 1974a,b). The dope can then be pumped (at a pressure of 150-200 kPa) into a bath containing 20% NaCI in 1M acetic acid. Alternatively, if handling circumstance permit, the dope can be spun before it has had time to gel (Swingler and Lawrie), 1977). The protein fibres thus formed contain about 17% protein and 73% moisture. Their high ash content can be reduced to acceptable levels by water-washing (Swingler and Lawrie, 1977).

On the other hand, the behaviour of proteins extracted by alkali from lung and intestinal tissues differs insofar as the exponential rise in viscosity (and gelation) does not develop (Young and Lawrie, 1975a). Fibres spun from the proteins isolated from lung, stomach and rumen also differ from those of blood plasma in being less elastic and more brittle. They all contain collagen, the amount of which depends on the pH, duration and temperature of extraction (Swingler and Lawrie, 1979). Boyer (1954) reported that, unless fibres were stretched during their formation, they were weak and lacked desirable organoleptic properties. Fibres of higher shear strength (lower take-away speed) showed a clearly defined structure in cross-section, whereas weak fibres revealed a much more random orientation of proteins.

In spun fibres from all sources a considerable quantity of a protein component of MW around 130000 was detected by gel electrophoresis. Evidently it was formed in the spinning process since it was absent from the corresponding protein isolates (Young and Lawrie, 1975b). Because the electrophoretic conditions employed incorporated sodium dodecyl sulphate and β-mercaptoethanol, and thus any protein-protein associations involving electrostatic, hydrogen, hydrophobic or disulphide bonds should have been broken, some type of covalent linkage must arise in the spinning process. Certainly when alkaline conditions are extreme, racemization of amino acids, and both hydrolysis and synthesis of cross-links between polypeptide chains, take place (DeGrott and Slump, 1967).

The formation of unusual derivatives of proteins by alkali has been widely reported (Bohak, 1964; Asquith, Booth and Skinner, 1969). Thus, it is evident that when the temperature of alkaline extraction is relatively high (~60°C) and the time is prolonged (~8 h), appreciable quantities of lysinoalanine are formed from lysine and cysteine (Swingler and Lawrie, 1979).

1.5 Polysaccharide incorporation

It has been demonstrated that admixture of charged polysaccharides in the spinning dope, enhances fibre-spinning ability (Giddey, 1960; Imeson, Ledward and Mitchell, 1979). For coagulation to pH range of 1-3 is required when the polysaccharide is carrageenan (which has strongly acidic sulphate groups) but a bath of calcium chloride solution is required for alginates and pectates. The composition and rheological properties of such fibres can be varied by adjustment of any one of several parameters including the spinning dope composition, the pH and ionic strength of the coagulating bath, and the chemical composition of the polysaccharide.

Imeson, Ledward and Mitchell (1979) found that, when a solution of blood plasma (6%) and sodium alginate (2%) was extruded into unbuffered coagulating baths of calcium chloride (pH~8), there was a rapid increase in the shear strength of the fibre bundles with increasing salt concentration up to 3% calcium chloride. Above this level the strength of the fibres was independent of the calcium concentration. When dopes were extruded into 5% calcium chloride, fibre strength was independent of pH in the range 4-8. Below pH 4, however, the fibre bundles rapidly decreased in strength exhibiting a minimum value at pH 3.5. Decreasing the pH still further increased fibre strength once more. In all cases the fibres contained about 5-6% alginate and, above pH 3, 5-6% protein. Below pH 3 the protein content increased significantly being about 15% at pH 2. The rheological properties of the spun alginate-blood plasma fibres were found to vary in a complex manner with the glucuronic acid block content and the molecular weight (viscosity) of the alginate (Imeson, Mitchell and Ledward, 1980).

It has been suggested that, at neutral pH values, the protein is merely trapped within the calcium alginate filaments since it can be easily washed out from the fibre (Imeson, Ledward and Mitchell, 1979). At lower pH values, however, the carboxylate groups of the alginate will tend to exist in the undissociated form (since the pK values of these groups are ~4; Haug, 1961). Consequently, extrusion into a bath of about this pH would be expected to involve the formation of fibres containing a high proportion of alginic acid filaments, which are of lower strength. As the pH is reduced still further, however, the precipitating conditions become similar to those employed in conventional protein fibre production and thus the acid denatured proteins will precipitate irrespective of the presence of the alginate. The protein fibres could then coexist with the calcium alginate and alginic acid filaments to give bundles of increased strength. Thus, at pH 2, there is almost complete recovery of both the alginate and protein.

As well as allowing an extensive range of textures to be generated, the incorporation of charged polysaccharides (especially alginate), into the spinning dope does have some further advantages. The dope is stable and of a suitable viscosity for spinning without the need to adjust the pH to extreme values, the fibres so produced are of low (~1%) ash content and, in addition, the protein used does not necessarily need to possess good functional properties and thus it may be a possible means of texturising protein of low functionality (including those of hydrolysates). A possible disadvantage of using the alginate spinning system is that the dope must be of a reasonably low calcium content, otherwise gelling may take place prior to spinning. Thus, whey ultrafiltrates may be spun into fibres using the alginate system but the protein must first be extensively dialysed to decrease the calcium content to a suitable level.

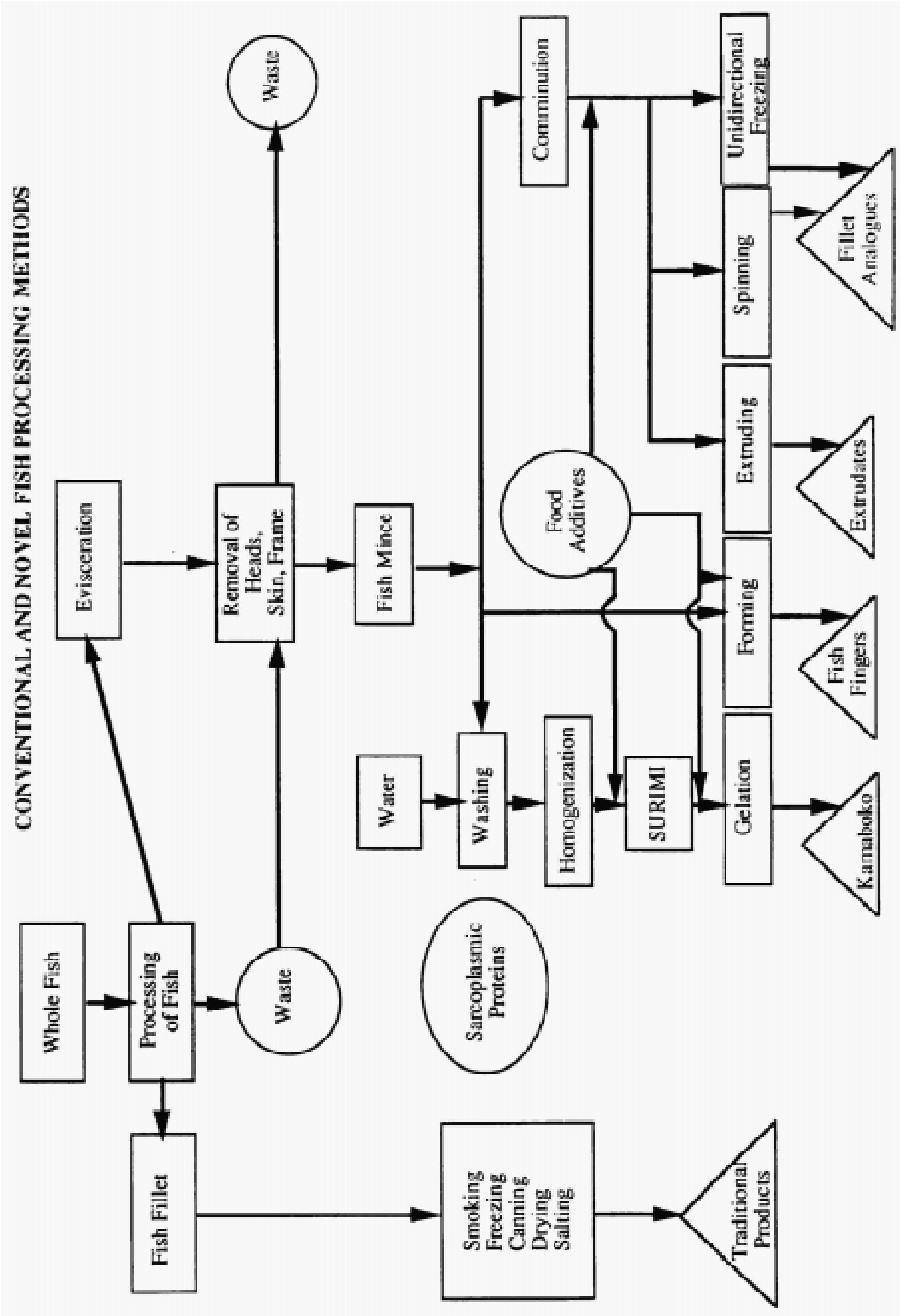
As Millar showed in 1989, fibres can be produced from a protein dope by dry-spinning. Dry-spinning a casein dope into hot air improves the heat stability of the fibres formed in comparison with other spinning procedures (Burgess, 1980). An alternative dry spinning process (Visser et al., 1980) involves preparing an aqueous mixture (pH 5.0-6.6) of casein and a heat-setable protein (such as soy protein) containing, per g of casein, 0.1mMol calcium ions and 0.04mMol orthophosphate. The mixture is spun at temperature below the gelling temperature (40-70°C), into a gaseous medium and the fibres dried.

Let us now consider the user of conventional and unconventional processing approaches that can be used with fish and the types of products that are produced. Freeze texturisation is clearly an unconventional or novel processing technique.

1.6 Freeze texturisation

Freezing is normally associated with the preservation of food. It has also long been known that the process of ice crystal formation can have detrimental effects on the texture of some foods, particularly fresh foods. However, freezing may also have a beneficial effect on texture and can be utilised as a mechanism to impart texture to structureless slurries of proteins.

This freeze texturisation was discovered long ago in the production of Kori-tofu in Japan. Here tofu is frozen and its texture modified. On thawing it possesses a porous and sponge-like texture and more mechanical strength than the original tofu.


CONVENTIONAL AND NOVEL FISH PROCESSING METHODS
Whole Fish
Processing of Fish
Fish Fillet
Evisceration
Waste
Removal of Heads, Skin, Frame
Waste
Fish Mince
Water
Washing
Homogenization
SURIMI
Sarcoplasmic Proteins
Food Additives
Comminution
Smoking
Freezing
Canning
Drying
Salting
Traditional Products
Unidirectional Freezing
Spinning
Extruding
Forming
Gelation
Fillet Analogues
Extrudates
Fish Fingers
Kamaboko

The freezing of the water within the fish mince is the most important phase change in this process. As the temperature falls, the proportion of unfrozen water decreases rapidly. The size and form of the ice crystals depends to a large extent on the speed and direction of freezing.

Both anisotropic and isotropic gels may be produced by cryogenic structurisation methods. The gel formulation is dependent on the retention time in the frozen state. Permanence of the structurised form after thawing and the existence of a defined shear yield strength are criteria to determine a significant change of state cause by freeze structurisation.

It has been found that freezing of a reactive polymer matrix promotes the foundation of a spatial structure. This is true for proteins and also of polyacrylic amides coupled with cysteine residues. Thus crystallisation of a reactive system, ie transition from a liquid to a solid state, generally results in the production of a three dimensional polymer matrix.

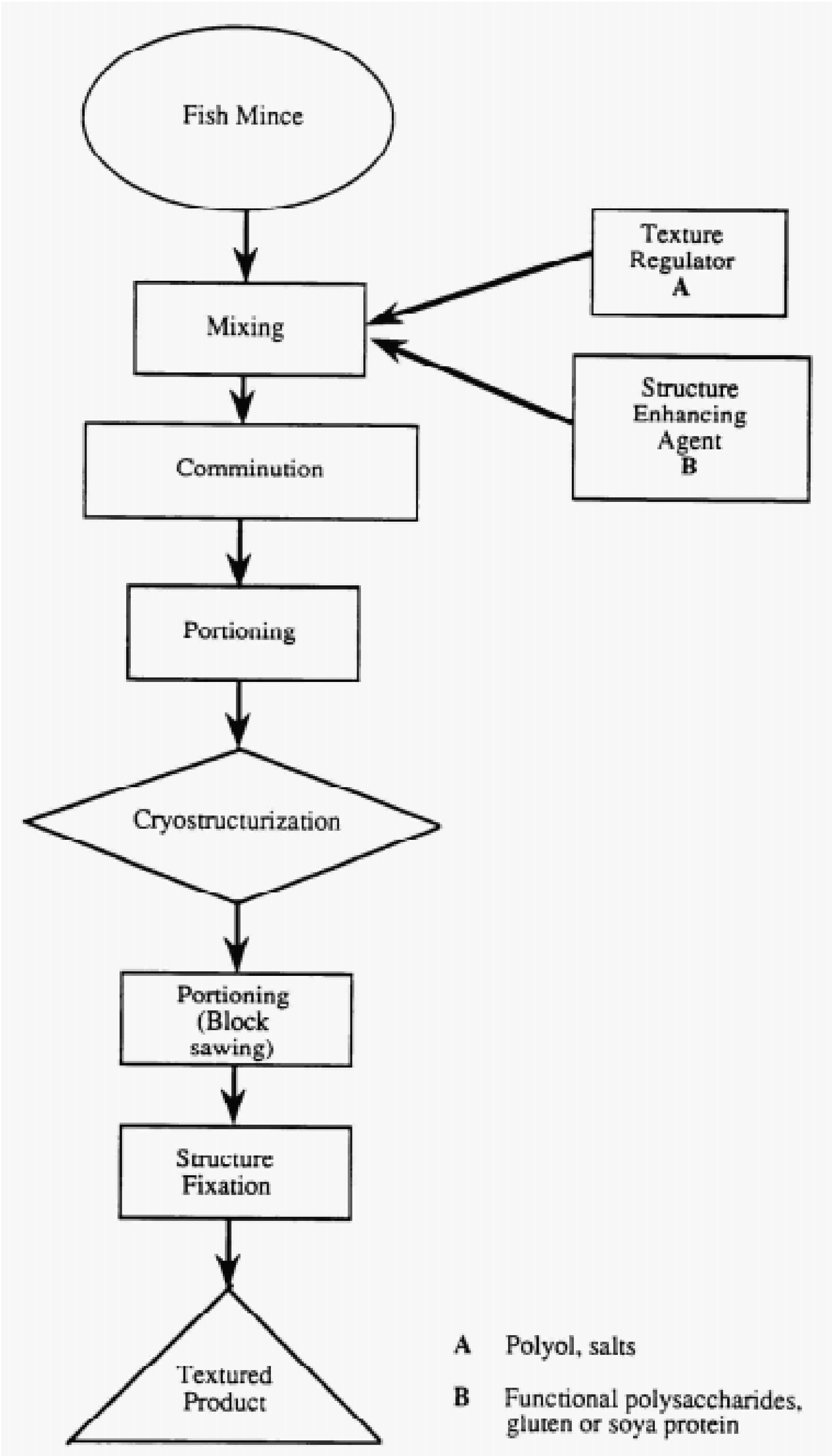
The degree of cryogenic structurisation and the stability of the resulting structure depend on the duration in the frozen state. These same processes occur in fish muscle and minced fish. Other factors that have to be considered when applying this process are the physiological state of the fish, the storage time and temperature history of the fish.

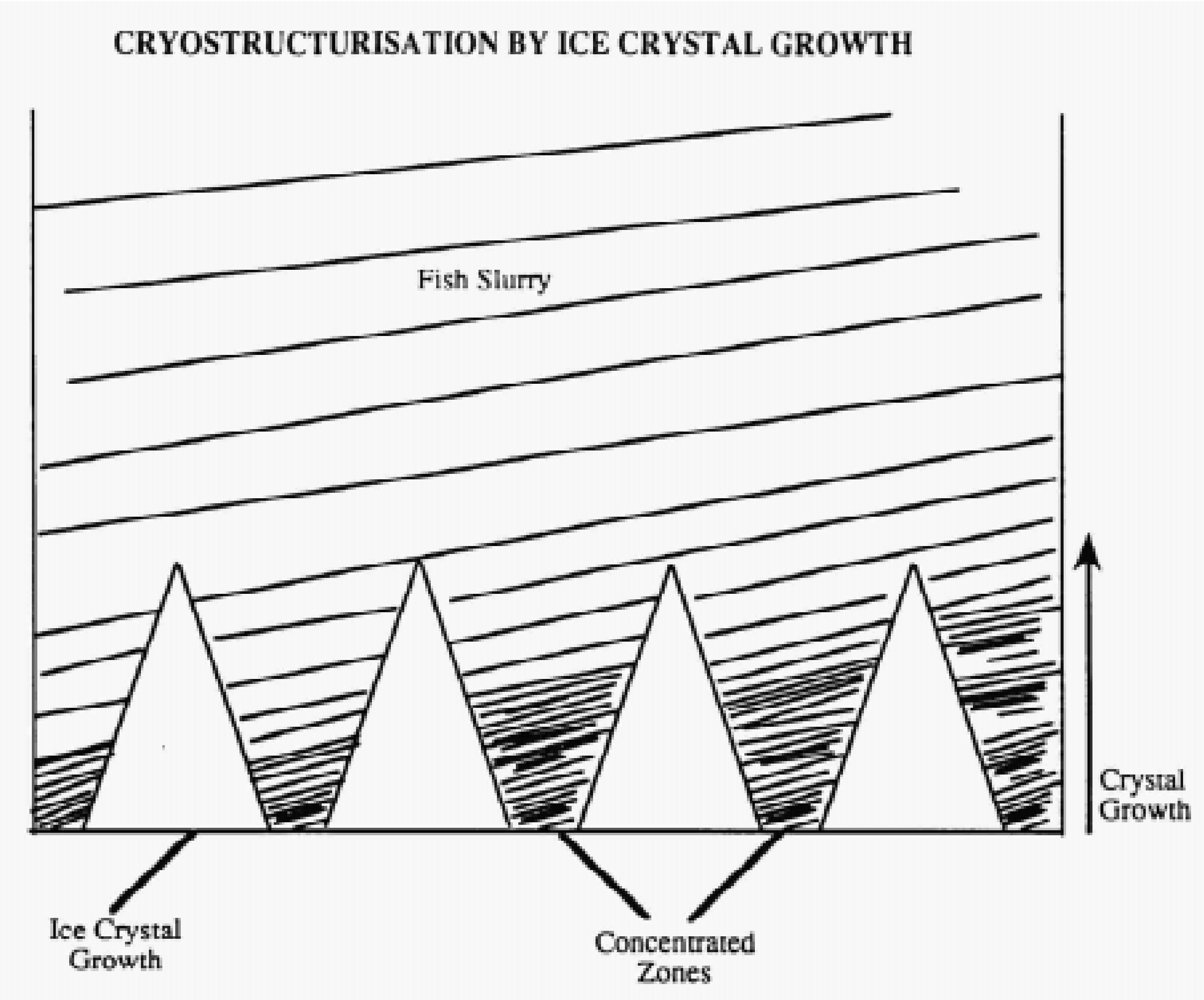
The largest possible ice crystals are required to produce anisotropic, musclelike structurisation. To achieve this, existing structure has to be abolished (via comminution) and the freezing process must be unidirectional and proceed fairly slowly. Crystal growth should not be hindered by gel formation of the comminuted fish. The use of offal with some bone may be advantageous, for the higher mineral content may tend to suppress gelation of actinomyosin in the comminuted fish.

Crystallisation causes the muscle protein to be concentrated in the spaces between the ice crystals. The resulting protein network thus forms a kind of ‘mirror image’ of the ice crystal complex.

The stability of these anisotropic structures during thawing varies and is dependent on the composition of the raw materials, especially the protein content. Thus it is desirable to incorporate a step within process to set the physical structures obtained. This can be done via heat, acid, or high salt, to denature the protein and thus 'harden' the structures produced by cryogenic texturisation. The anisotropic gels produced are generally laminar in structure and are said to resemble fish fillet material.

CRYOGENIC STRUCTURISATION





Texturisation enhancers may be added to help establish the desired texture and, when added as dry powders, to help control the level of water in the total mixture. This use of enhancers, such as functional vegetable proteins, is similar to that described for extrusion and spinning. Thus if the quality of the raw material is poor with respect to gelation, and fish offal is relatively poor, then addition of a texturising agent would be a sound approach to achieving a saleable end product, though which agent would be determined by any further processing that the product would be subjected to and the type of customer for which the product was intended.

Textured products have been produced using this method with fish mince by Schubring *et al* (1990) and for meat analogues by Lawrence *et al* (1986). There are also a number of patents in the area.

This technology should be examined in more detail as to its potential for producing textured fish products from fish offal.

2 Bleaching of Fish Offal

2.1 Fish offal and colour

Fish offal is generally considerably darker than the fish from which it is derived. This is due to the presence of skin, blood from the caudal vein and gill capillaries, kidney remnants attached to the dorsal frame, the stomach membrane and swim bladder remnants, eye pigments and presence of dark flesh.

It is desirable to sell light coloured fish products. This is generally true apart from speciality products (kippers, other smoked fish, salmon products, 'crab' surimi etc.). Indeed, the petfood companies have included whiteness or lightness as one of their quality criteria. In addition, the addition of lightening agents such as titanium dioxide was a negative for these companies.

The overall colour of the offal can be lightened by the addition of a small proportion of white fish flesh, although the net result is probably darkening of the flesh rather than lightening the offal unless an uneconomic amount is added. Other texturising agents such as the addition of soya would lighten the offal. However, the best option to generate a white or light offal would be the use of dilute hydrogen peroxide. The final product could be further lightened with soya so the peroxide treatment need not be extreme.

2.2 Bleaching of fish offal with hydrogen peroxide

A number of workers have evaluated the oxidising ability of hydrogen peroxide to bleach fish. The prime motivation for this work was the observation that consumers preferred whole pieces of white fish and found that the use of coloured minced fish for the use of reformed products was visually unappealing. Reformed white minces however have been found to be visually appealing. Thus there was a market opportunity to convert the perceived lower grade coloured fish mince into a higher grade (and thus added value) white mince.

Other workers have added dyes and smoked the product to produce a smoked fish analogue. While this has found common acceptance the technique is of limited application. It has been known for many years that colours can be removed from foodstuffs with chemical oxidants.

It has been found that at neutral pH, bleaching with hydrogen peroxide required quite strong solutions which may have negative organoleptic effects on the product, particularly promoting oxidative rancidity. However, much milder bleaching conditions can be used at higher pH values. Mackerel fillets have been successfully bleached in hydrogen peroxide solutions (0.75%) in a pH 10.5 buffer for 15 minutes. In addition, Young *et al* have demonstrated that cod fillet waste mince, homogenised and non homogenised (but mixed) with 0.75% hydrogen peroxide at pH 10.5 for 15 minutes were rendered very light, while cod fillet mince was completely bleached. Saithe flesh was also whitened successfully by this technique, as was saithe fillet waste mince, when homogenised with the H_2O_2 at pH 10.5 for 15 minutes.

Epoxide and peroxide in the flesh were measured to try to ascertain the level of lipid oxidation that occurred under these conditions. No significant detrimental effects on this parameter were found. Some changes in amino acid composition were found, particularly the sulphur - containing amino acids. This would be relatively unimportant if this product was used to make a reformed fish fillet chunk analogue because it would be incorporated into a rich meat background and because it would probably be fortified with soya or another functional plant protein.

2.3 Bleaching - conclusions

Bleaching of filleting waste mince has been demonstrated for several species of fish (cod, saithe, mackerel). It could be easily applied to fish offal.

A bleached offal could then be used to produce a restructured fish product by means of one of the methods described earlier.

1 LABORATORY DEVELOPMENT PROGRAMME WITH FISKERIFORSKNING, TROMSØ

A meeting was held between PA Consulting Group and Nils Kristian Sørensen of Fiskeriforskning, Tromsø to discuss the fish offal texturisation/analogue development programme with a view to developing a laboratory work programme to be performed at the Fiskeriforskning facilities during Phase 1B of this project.

The meeting outlined the top line technology approaches, distilled from the creative concept generation and evaluation process described earlier, that we believe could be used to restructure partially deboned offal to recreate a texture imitating that of white fish muscle flake. A pragmatic appraisal of the practical development issues to be addressed for each technology was made in the context of working with a relatively undefined raw material. Suitable key apparatus that could be used to develop each technology process were identified at Fiskeriforskning's laboratories.

1.1 Work Plan

A work plan has been formulated, in combination with Fiskeriforskning, to address the laboratory development of sample fish-flake chunk analogue product using the leading technology approach following an initial evaluation stage to study the characteristics of each of the leading concepts.

The work plan aims to achieve the production of sample fish-flake chunk analogues using the leading technology approach within four months from the start of laboratory evaluation activities.

The work plan will address practical aspects in the following areas:

1.1.1 Fish offal as starting material

At the start of the work programme the deboning, preparation, mincing and bleaching of offal will each be separately evaluated and an initial process developed to enable the batch production of a consistent homogeneous starting material for use in the initial evaluation of each technology approach. A storage method will be devised for this starting material to ensure that its characteristics are similar in each investigation.

1.1.2 Initial evaluation of leading technology approaches.

Using the starting material previously described, a short programme of work for each technology approach will be carried out using the equipment at Fiskeriforskning. The aim of this short programme will be to learn the strengths and weaknesses of each technology approach in the context of the fish offal starting material with the development target of producing samples of texturised fish chunk analogues for a first evaluation.

It is anticipated that the top four approaches to be addressed will be:

(a) use a very cold plate and freeze the offal as layers

(b) reform with gelling agents, then layering or shredding to give structure

(c) extrusion cooking of an offal/vegetable protein mixture

(d) add texture via freezing

The division of responsibilities will be dependant upon the resources and equipment available to both Fiskeriforskning and PA.

Where possible work will be conducted at Fiskeriforskning, particularly approaches (a) and (b) and if appropriate approach (d). The ability to pursue approach (c) will be dependent upon the access to extrusion cooking equipment. Whilst Fiskeriforskning do not have direct access to an extruder they are investigating the possibility of using facilities available within the local area.

It is envisaged that this initial laboratory work will be quite pragmatic, rapidly performing a range of focused experimental trials to achieve a texturised product.

Whilst it is not appropriate to describe the fine detail of these trials the following key unit operations in the flow diagrams will need to be addressed.

1.1.3 First product evaluation

Offal starting material and samples produced using each technology approach will be formally evaluated at the halfway stage of the work plan.

A set of criteria for evaluation will be decided and the samples assessed and ranked on this basis. The criteria are not yet defined but would typically include issues such as colour, texture and retort stability.

It is expected that at this evaluation stage one or more technology approaches will be excluded from further investigation on the grounds of performance. It will be possible from the evaluation results and hands-on experience of the offal in combination with the technology approaches to define the leading techniques for further process development.

1.1.4 Refocus of work plan to refine methodologies for sample production.

At the halfway stage of the laboratory programme it will be prudent to assess the experience gained during the initial development phase in handling a novel raw material and the trial processing techniques. Owing to this experience it will be possible to define more closely the experiments required during the second half of the work programme - refining the offal processing and storage and then addressing texturisation using a focused, iterative approach.

1.1.5 Refining fish offal starting material

Significant experience will be gained from having handled the fish offal at the beginning of this work programme. In the light of this experience it will be possible to refine each stage of offal processing - deboning, separation, mincing, bleaching and storage more closely to obtain a superior starting material for the next section of work. A new batch of starting material will be prepared for further processing at this point.

1.1.6 Refine leading technology approaches

Using the refined starting material a focused phase of work to optimise the production of a texturised fish flake chunk will be carried out. It is expected that this experimental work will be iterative and will build quickly on the experience already gained from working with the material and techniques during the initial technology approach evaluation phase

The leading technology approaches identified at the first evaluation will be developed further with the aim of producing a range of textured fish-flake chunk analogues for the second product evaluation

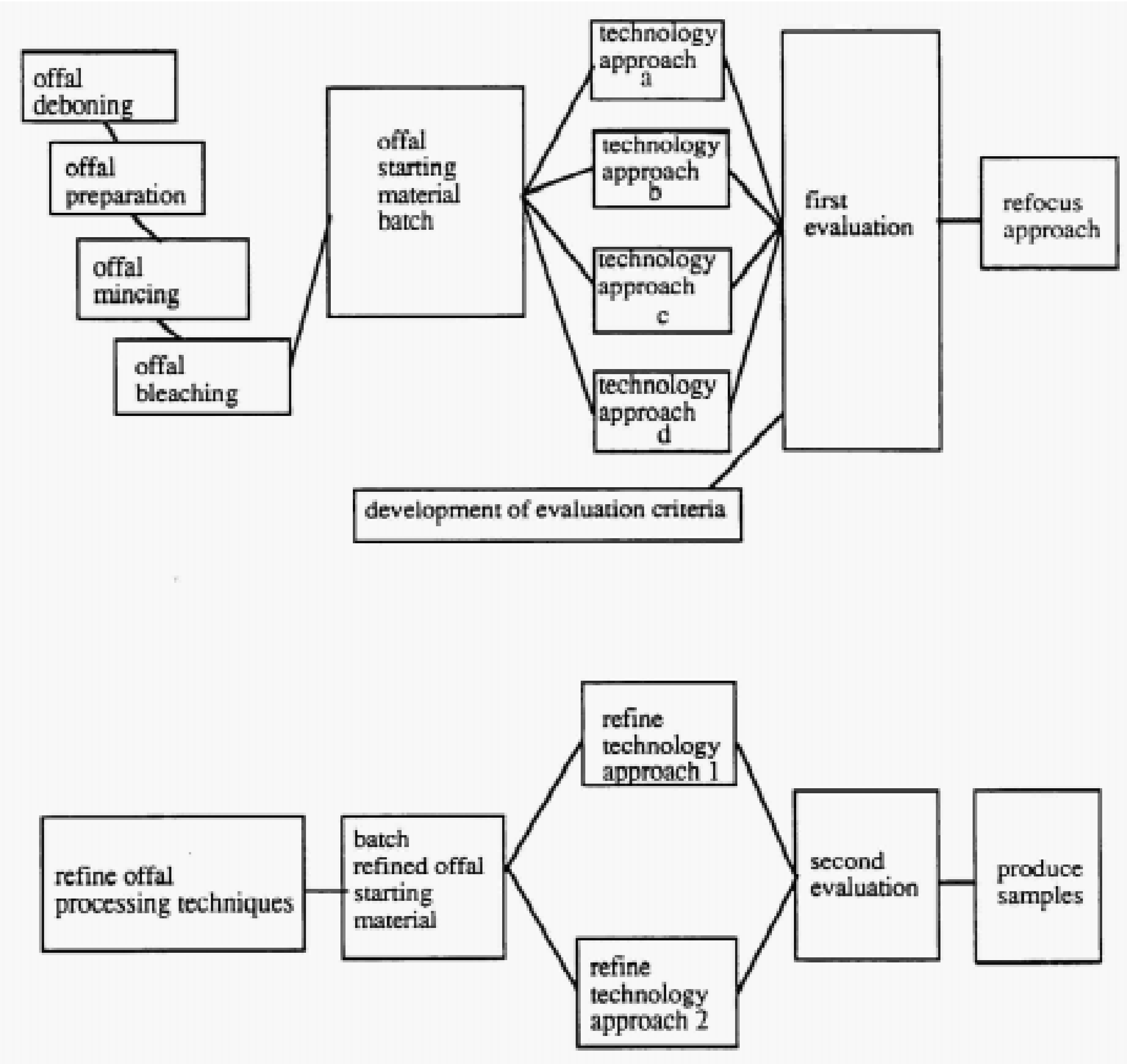
1.1.7 Second product evaluation

The fish chunk analogues produced using refined starting material and the focused development programme agreed following the first evaluation will be assessed using the evaluation criteria defined as before. The purpose of this second evaluation will be to rank the textured fish-flake chunk analogues produced and to select the best for production in a large batch for evaluation by Pedigree Petfoods.

1.1.8 Sample production for Pedigree Petfoods

Having closely defined the conditions for the production of the best texturised fish-flake chunk analogues it will be necessary to produce a large batch for evaluation by Pedigree Petfoods. The final action in the work 'programme will be to produce this large batch at Fiskeriforskning and store this material prior to the evaluation phase.

1.2 Work Programme with Fiskeriforskning



1.3 Project Management and Communication

The work programme will be operated primarily at Fiskeriforskning at their facility in Tromsø, with parallel investigation running at PA Consulting Group's Cambridge Laboratory.

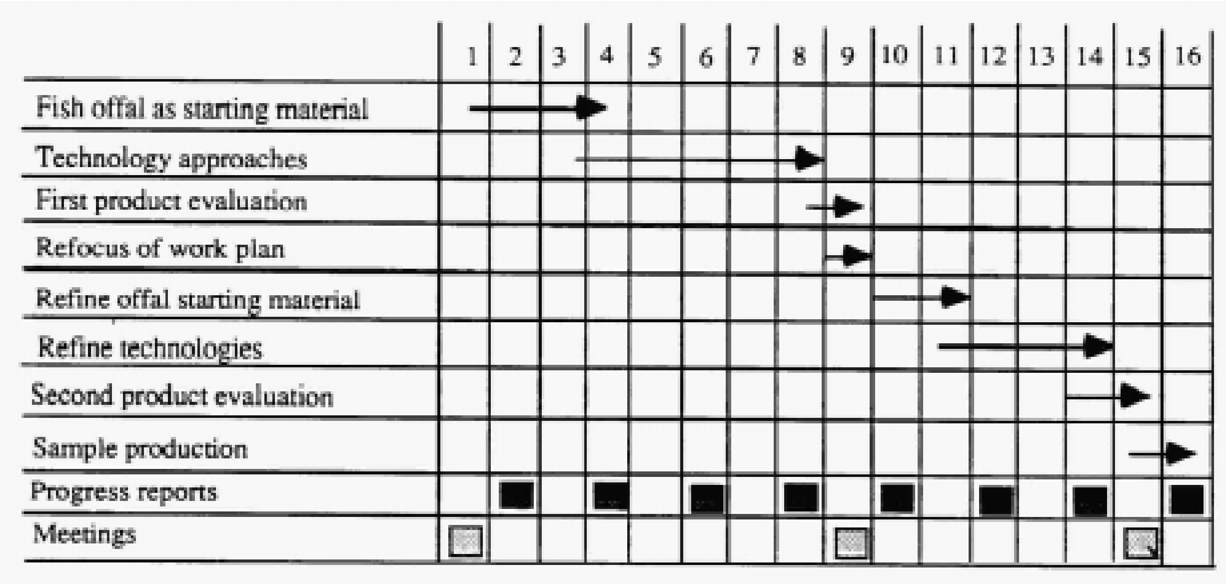
Project management of the work programme will be the responsibility of PA with Fiskeriforskning taking the role of sub-contractor.

Week-on-week project communication between PA and Fiskeriforskning will be in the form of biweekly written reports by fax, and telephone conferences. Meetings will be held at the beginning of the project and at each evaluation review point during the work programme. It is envisaged that some work by PA staff at Fiskeriforskning will be required.

1.4 Cost and Timescales

The complete work programme is predicted to run over four months.

A preliminary estimate of the time required in each work area (-in weeks from start) is illustrated below.



The cost of this work programme at Fiskeriforskning is estimated to be in the range of NOK400-500,000. In addition to this, PA's costs for our management and inputs to the programme will be included in the proposal for Phase 1B

1 USAGE

Cosmetics

- any marketing advantages

Healthcare

- are there any health or environment connotations that can be exploited?

Nutrient source

- can it be used as a nutrient source for fermentation

Hydrolysed Fish Offal

- use in fish stock cube (like an Oxo cube).

Can you make energy from it? Can you burn it?

Make into fish soup
Fish sauce
Marine leather
Cod head a delicacy in Portugal
Fish cheeks a delicacy in Japan

Extract Collagen

- use in petfood
- gelatin - cosmetics/photography

Make bone meal. Sell through garden centres.

Tail section of salmon has the best flavour. Used for soups, ragouts etc.
Salmon tails on sale as product in France. Can we do the same?

Bones

- Calcium. Dietary supplement
    - animal
    - human

2 EXTRACTION

Supercritical fluid extraction

- oil removal
- solids retained
  May take out water
- astaxanthin removal

Remove Otoliths

- use for stone washed jeans manufacture

Extract Bones

- collagen - wound healing
- organic selenium - dietary supplements
- would the bones be used for human surgical techniques?
- toothpicks from bones
- scales - keratin - wound dressings

Extract Specific Fatty Acids

Hydrolysed proteins - human foods
- use in cosmetics

Taurine from fish bile
Insulin from fish pancreas
Oil soluble vitamins

Scales - source of cysteine/cystine for flavour production

Krill - eyes contain high levels of astaxanthin. Are there any colours in the eyes of red fish? Can you extract and feed to salmon?

Extract Enzymes

- Use for industrial purposes or to texturise the fish

3 TEXTURISATION

Reforming

- alginates
- gelling agents
- freezing
- rolling technique as for mvcoprotein

Plastein Production

- make into a hydrolysate. Use proteases in **reverse to** make a protein. Retexture protein.

Liquefy Offal

Extract actinomyosin. Inject into acid bath. Produce fibres. Align fibres. Make a chunk.

Mix with meat protein as a meat extender.

Lamination - make sheets or wafers. Mince and alginate. Extrude sheet.
Layer bet fish texture.

Add alginate to give gel, shred. Get texture via alignment of fibres using extrusion or rolling.

Layer Gelling Agents

- weak, strong, weak, strong, weak, strong etc. Compact. Cut. Will fall apart - 'naturally' after cooking when mechanical pressure applied. Hu -Man food.

Make fish flake using reforming. Press together to make a 'fish fillet'.

Alternate layers of fish offal with layers of meat.

Iced lollipops have a grain. Freeze offal, get a grain or texture.

Evaporation of a slurry, get stratifications.

Spray solubilised protein onto a surface. Denature. Spray more. Build up layers.

Cold cook under very high pressure.

Add an agent that separates out and so produces a layer or layers. Filo pastry. Fat, offal, fat, offal, fat, offal. Cook. Fat melts, leaves layers of offal, looks like fish texture.

Vienetta - confection, ripple texture. Cut.

Lasagne production equivalent.

Compost. Add layers, ferment.

Papier mache.

3 roll/5 roll refiner. Cadbury's flake.

Create fibres or plates using diehead and extrusion.

Cut spaghetti obliquely, smear the fibres, generate a layered structure. Use fibres from offal.

Make a 'Swiss roll' of offal, then chop it.

Use a very cold plate and freeze offal as layers.

Selective hydrolysis. Hydrolyse in layers, leave stratified product.

Layer using a fluidised bed. Very deep. Get layers based on buoyancy/density.

Create layers via resonance.

Differential setting times of different gelling agents in liquid slurry. Set in a layered manner.

Aeration gives layering/structure.

Puff pastry - layering.

Apply vacuum, use microwave drying.

Use gluten and cooker extrude to texturise.

Combine with Quorn mycoprotein.

Make mini sausages (skin dissolves in can).

Use pectins to add texture.

Drum dry to produce flakes.

Wafer biscuit technology.

Foam and microwave set.

Use xanthan to gel.

Conventional slit extrusion, then laminate.

Use egg or lactalbumin.

Grooved heated roller (APV breakfast cereal shredder to produce fibres

Spray slurry through IR beam (to produce a fibre mat).

Extrude into hot oil.

Injection mould molten fish

Apply textile fibre technology.

Offal as matrix, fibrosity applied externally.

Cigarette technology

Layered sheets, about to gel, comb to add texture.

Form layers between sausage skins.

Heated comb.

Use pineapple waste to give fibre.

Non-woven technology. Alginate fibre mats.

Use modified starches.

Use chitin to add fibrosity.

Use corn flour/starch as texturiser.

Use 'silk' from maize cobs for fibre.

Bubble gum.

Salt gradient to induce setting of structure.

Use dextrans to add texture.

Carboxymethyl cellulose.

Cellulose acetate.

Microcrystailine cellulose.

Panning process as in sugared almonds.

Fish finger process.

Use enzymes such as catalase to produce gas to open the structure.

Magnetic alignment.

Blow air across the surface. Set crenellated waves.

Use gelatin from skin or animal source as gel binder.

Vermicelli process, align and bind.

Use coir, coconut fibre

Use latex for texture

Use'Novon' biodegradable plastic from Ferruzzi.

Use ICI Biopol for texture.

Ultrasonic cavitation then set.

Use- surimi process.

Rope spinning technology.

Use animal hair to give Fibre.

Extrude into alcohol.

Induce bone component to give a superstructure.

Clathrate hydrates (fizzy ice technology) to give structure.

Use grass of other plant fibres.

Differential setting times of different gels in a liquid slurry.

1 References

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