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Developments in fish handling and processing: an engineering perspective

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The engineer faces new challenges brought about by demands for improved fishery products and the need to make maximum use of available resources. In recent years, after a period of great expansion, important advances have been made in the handling and processing of fish. The wider application of modern techniques will enhance the position of fish as food.

1 INDUSTRIAL TRENDS

Fishing and the manufacture of fishery products are traditional activities, fundamental to the well being and prosperity of the human race. There have been, however, remarkable changes in recent times. Current developments in fish handling and processing can be viewed in the light of several trends that have exerted a strong influence. Such an approach might help towards anticipation of future needs and developments.

High demand for fish as food and as animal feed has resulted in great expansion of the fisheries. This, by itself, has prompted change. Fishermen now have access to vessels of advanced design, with sophisticated fish-finding instruments and fishing gear, for the production of more fish for less effort. By the same token, a lot of methods, equipment and plant have been developed for efficient processing of large supplies of fish.

Apart from high demand from a hungry world, there are several factors that have had and are having an effect on the fisheries. Notable are the need for conservation of stocks of some of the more widely exploited species and the extension of fishery limits which have had a profound effect on fishing arrangements, trade and the policing of fishing zones. One of the outstanding changes promoted by the extension of limits has been the development of the Alaskan fishery, for pollock, cod, crab, shrimp and other species, by the fish industry of the United States of America. Much European and Japanese technology has been introduced to complement local practices and innovation.

The need to prevent pollution of the oceans is being given greater attention today, with a view to continued high productivity from the fisheries. Another factor of significance is the increased production and self-sufficiency in the lesser developed countries. According to FAO Fishery Statistics from the Food and Agriculture Organization of the United Nations, landings in developing countries reached 48 million tonnes in 1986 and have increased at a greater rate than landings in developed countries (Table 1).

In recent times there has been a strong trend towards 'convenience' foods. The introduction of the fish stick (fish finger) more than thirty years ago was a major contribution in this direction and promoted a large trade in frozen fish blocks from which sticks and portions are made. Fish processors have participated in this development by manufacturing a range of fish and fish-based products that incorporate up-to-date features, advanced packaging and ease of preparation for consumption.

Table 1 World fish production and disposition (millions of metric tonnes)

Items	1960	1970	1980	1986
Fresh	16.9	19.5	15.7	18.2
Frozen	3.5	9.7	15.9	21.4
Cured	7.5	8.1	11.1	13.5
Canned	3.7	6.2	10.3	11.4
Other	8.6	26.5	18.4	26.9
Catch	40.2	70.0	72.0	91.5

Source: FAO Fishery Statistics.

Another aspect of the present-day market that is having an effect on the fish industry is the emphasis on food wholesomeness and the health-giving attributes of particular foods. More and more, fish is being viewed by nutritionists as a most desirable food. Fish oils have received much attention recently, especially marine omega-3 fatty acids, because of claims that they prevent heart disease and other diseases (**1**).

Altogether, therefore, there appears to be ample opportunity for the fish industry to maintain and possibly enhance the position of fish and fishery products as a valuable part of the whole supply of food. These factors, mentioned above, amount to new opportunities and a new challenge for the engineer, who has played a leading role in the expansion and development of the fish industry. In the years ahead there will be increased emphasis on improved products that can compete with other foods, on higher productivity, on maximum use of fish resources for all and on environmental considerations.

2 EXPANSION OF THE FISHERIES 1950–70

The period of 1950–70 was one of intense activity in the fish industry. The world annual catch increased threefold to 60 million tonnes and there were numerous developments that made catching easier and more productive, enabled the handling and processing of increased amounts of fish and promoted the manufacture of superior fish products. Eddie (**2**) has described

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two important mechanical innovations: the power block introduced by Puretic of the United States of America and freezing at sea, on which much of the expansion was based. The power block, consisting of a powered sheave, gave the ability to handle large nets and capture large shoals of pelagic fish. Productivity in the more highly mechanized fishing fleets reached high levels, particularly when fishing for supplies for fish meal and oil manufacture. Thus, Peru, as an outstanding example, attained a harvest of more than 10 million tonnes of anchovy per year.

The large-scale adoption of freezing at sea was prompted by a need to fish in waters distant from home without restrictions on the duration of voyage imposed by the perishability of fish stowed in melting ice. This was a European development of the period, as described by Waterman (3), and was based largely on technological work at Torry Research Station in the United Kingdom. By 1970 there were about a thousand freezing-at-sea trawlers, mother ships and refrigerated transport vessels of over 1000 tonnes, some of them over 10000 tonnes.

Of course there were other important developments during the period 1950–70, many of them concerned directly with the fishing vessel. Advances were made in fish finding and navigation. Trawl gear was made more efficient and the large midwater trawl was developed. The early freezing-at-sea vessels incorporated important innovations, notably the provision of a shelter deck for handling and processing of the catch, arrangements for handling the trawl over a stern ramp instead of over the side and the vertical-plate contact freezer developed for the freezing of whole fish on board. While there had been earlier ventures into freezing at sea in certain specialized fisheries, success in the 1960s was based on improved equipment and methods. These improvements included machines from Germany for automatic filleting of fish, electronic fish finding and navigation equipment, modern propulsion and refrigeration machinery and plastic (thermal) insulation materials. Knowledge of good freezing and cold storage practices, especially the establishment by Reay and his colleagues (4) of −30°C as the recommended temperature of storage, was a vital element.

Another major development for preservation of the catch on board was the introduction of refrigerated sea water systems. Roach *et al.* (5) pioneered this, in Canada's Pacific salmon fishery. They devised a unique heat-exchanger for the cooling of sea water and established criteria for detailed design and operation including refrigeration capacities, water circulation rates, fish stowage rates and procedures for the cleaning of tanks, pipes etc.

The expansion and prosperity of the fisheries has been dependent on supplies of ice for fish preservation, both at sea and on shore. The manufacture of ice at acceptable cost was made possible by earlier developments in mechanical refrigeration. Machines for the production of 'small' ice—flake ice, tube ice, plate ice etc.—were introduced widely during the period and dependence on crushed block ice was reduced.

In light of the limited shelf life of fish in melting ice (at 0°C) and the labour associated with icing generally, various attempts were made to improve the method. Chemical additives to ice, irradiation and superchilling (partial freezing to, say, −2°C) were proposed but regular icing remained the rule. Also, few aids were introduced to reduce the labour involved; even today much of the work is done with a shovel.

Cutting (4), in a review of research into refrigeration of fish and meat, traced the course of development of techniques for chilling and freezing of fish, with emphasis on the pioneering work done from about 1930.

Many of the more important changes during the period 1950–70 had to do with mechanization of processing operations. Machines for filleting, nobbing (removal of heads and guts), heading, splitting, gutting, skinning, sorting according to size etc. were introduced widely. In the main, the objectives were to reduce labour and increase productivity. In some instances the machine was needed to cope with large landings of small fish while in other cases the machine was justified on grounds of increased yield.

There were major changes in the production of cured fish products. Mechanical dryers displaced traditional methods of drying out of doors for the production of dried salt fish in Scandinavian countries, Atlantic Canada and other countries. These enabled the industry to increase production and reduce losses due to poor weather conditions, insect infestation etc. Mechanical smoking kilns were introduced widely in Europe and elsewhere; they found favour as a means of increasing production and reducing losses. The change to mechanical kilns was accompanied by a shift towards mild cures—products of relatively low salt content and with less drying and smoking—dependent on refrigeration for preservation. Weight loss on the smoking of herring (kippers) in the United Kingdom was typically 25 per cent forty or fifty years ago but by 1970 values had declined to about 10 per cent.

3 NEW DEVELOPMENTS

3.1 Some aspects of production

Since 1970 expansion has slowed; the world catch in 1986 reached 91.5 million tonnes and there is wide agreement that the sustainable limit cannot be much greater than 100 million tonnes. Some stocks have been depleted through overfishing.

There have been marked changes in world production and disposition of fish since 1970. Values for the years 1960, 1970, and 1986 are given in Table 1, in five categories; fresh, frozen, cured, canned and 'other' (mostly fish meal for animal feed). They show that, while the amount of fresh fish has remained more or less constant, there have been large increases in the other categories.

The values in Table 1 show the (final) disposition but do not give a direct indication of the major role of refrigeration as a means of preservation. 'Fresh' fish is essential to good results in all categories and some supplies of frozen fish are used in the manufacture of canned and cured products. Also, cured products are sometimes frozen and cold stored (as well as canned).

The present paper is concerned mainly with fish handling and processing and not with catching and the production of supplies of fish. Nevertheless, mention of aquaculture and the holding of live fish are warranted. Indeed, by exercising control over the condition of the live fish, to some extent the operator can control ultimate quality of the fish as food. Aquaculture is making a significant contribution and is expanding. In China, India and some other countries it has accounted for a large part of the total production. Salmon, shrimp, mussels, tilapia, carp, catfish and other kinds of fish are farmed on an ever-increasing scale. They are, in many cases, among the more valuable, prized species, fairly costly to rear but able to fetch high prices.

The heat pump has found application in aquaculture for energy-efficient warming of water to increase growth rate and production. It has also been used in live fish holding. One recent application, for the holding of lobsters in Atlantic Canada, has been particularly successful and is an example of the value of coupling publicly funded research and development with commercial expertise. An optimum temperature of about 1°C is maintained by heating in winter and cooling in summer, which has allowed the supply of live lobsters of high quality to international markets throughout the year.

The shrimp bycatch also warrants particular attention because it is a substantial part of the total world catch but, for the most part, is discarded at sea. The amount of bycatch varies but, typically, shrimp makes up 20 per cent of a haul and the bycatch 80 per cent. The total annual amount of bycatch has been estimated at 5 to 16 million tonnes by the International Development Research Centre (**6**). Efforts have been made to retain and utilize this material, much of which consists of small fish that tend to spoil quickly. Various schemes have been proposed, often for the production of deboned flesh in the form of mince. Some success has been reached in projects in Guyana, Mexico, Mozambique and other countries but, overall, progress has been slow. The fisherman usually does not have sufficient incentive to retain the bycatch and generally facilities for preservation of the bycatch on board are lacking.

3.2 Transfer of the catch

Many systems for transfer of the catch from fishing net to vessel, from ship to ship and from ship to shore have been employed or proposed in the fish industry. In recent years there have been a few important developments, giving better handling and reduced damage to the fish. Of particular interest are the arrangements for transfer at sea and the ship-to-shore transfer of iced fish and fish held in refrigerated sea water. Centrifugal pumping systems have been improved. Systems that employ compressed air to transfer water and fish have been employed successfully. Containerization of iced fish, notably boxing of the catch at sea, has also brought improvement, since the fish are undisturbed on transfer.

3.3 Fish-processing machinery

Machines are used, especially for small fish, for a wide range of handling and processing operations including grading for size, separation of male from female herring, gutting, nobbing, splitting, filleting, skinning and separation of meat from shellfish. They reflect the international nature of the fish industry, as they have been developed in a number of countries. Many of the machines in use are supplied by West German industry which in the early 1950s produced the first of a series of successful filleting machines (**2**). Although filleting machines are high in price because of their complexity and require a fair amount of service and maintenance, they are justified on grounds of high output, yield and quality of fillet. The United States of America and Denmark have supplied machines for the peeling of shrimp. Various other machines are produced in Scandinavian and other countries.

There have been substantial improvements to fish-processing machinery since 1970, with the availability of modern materials and microprocessors. One long-standing problem that has not been fully resolved, however, is the shucking of molluscs. Manual shucking is difficult and arduous but is the rule in many fisheries. Another problem is posed by the need to remove parasites from some fish. Again, much manual work is involved and better methods are needed. Improvements to systems for the handling and processing of demersal fish at sea are being sought. In separate developments in Canada and the United Kingdom, newly designed gutting and washing systems have been installed on commercial vessels within the past few years (Fig. 1). These changes have been prompted by the need to improve working conditions and productivity. A further consideration is the size of fish which has decreased in some fisheries and made the gutting machine more attractive.

Several gutting machines for round fish such as cod have been developed but never have been wholly successful because their output has not been high enough and generally they do not match the tidiness and completeness of hand gutting.

Since 1970 there has been widespread introduction of deboning machines which separate edible flesh, in the form of a mince, from skin and bones. Deboners have been used to extract flesh from skeletons from the filleting line and for the production of mince from small fish, including those from the shrimp bycatch. Fishery technologists have devoted a lot of attention to studies of the properties of fish mince and of various products such as salt fish and fish cake portions (**7**). The main application is in the production of surimi which is discussed below.

Apart from surimi, fish mince has not found the large markets that might have been anticipated. This has been due largely to the poor storage properties of mince; the rate of bacterial spoilage tends to be much higher than in the intact fish and cold storage changes occur much more rapidly in frozen mince than in, say, frozen fillets. Work in progress covers the use of additives to increase storage life and the evaluation of quality which varies according to the nature of the raw material and the method of separation (**8**). In a major development based on traditional Japanese technology for the processing of fish into kamaboko, production of surimi has expanded in recent years. Surimi, an intermediate material, is mechanically deboned and washed flesh, normally frozen after the addition of cryoprotectants (**9**). It is the main ingredient in the manufacture of a variety of products, generally called kamaboko, by processes which include the addition of

Fig. 1 Gutting machines in the handling line on board [Crown copyright]

salt, starch and other substances, grinding and cooking. It is stable in cold storage but, for good results, especially the desired (white) colour and high gel strength in the final product, should be made from fish that has undergone little or no spoilage. Typically, the yield of surimi is 20 per cent of the raw material weight. Much of the Japanese production has been on factory ships equipped with plant for production of the large amounts of fresh water required for washing. Several million tonnes per year of the large resource of Alaska pollock have been used to provide fabricated products based on surimi, some of which have become established in world markets. At present, work is being done in the United States of America and other countries on adaptation of methods and plant for the manufacture of surimi from a variety of underutilized fish including fatty species that pose particular problems of colour, texture etc. (7).

3.4 Refrigeration

The wide use of refrigeration is an important feature of the high standard of living enjoyed in economically advanced societies. There are many applications: ice rinks for recreation, domestic refrigerators for convenience at home, production of ice for a range of cooling jobs, plant for storage and transport of foodstuffs, air conditioning, preservation of various biological materials, medical purposes etc.

Refrigeration in the fish industry, unlike most other preservation techniques (such as salting, drying, smoking and heat processing) which make substantial alterations to the texture and flavour of fish, is employed to maintain the product in more or less an original state, with as little change as possible. There is no doubt that the use of refrigeration, especially for the freezing of fish (see Table 1), is likely to continue to increase, in developing countries as well as in the developed countries.

A glance back at the last sixty years or so will enable a view of the major developments in refrigeration in the fish industry. Many changes were introduced in the period of expansion from 1950 to 1970. The production and use of ice for the chilling of fish on a wide scale was a major step. The conditions required for good results from the freezing and cold storage of fish were established about fifty years ago and this enabled growth of the frozen fish trade. A high proportion of the major developments have been associated with the fishing vessel itself, where the need for preservation of the catch together with the limitations imposed—lack of space and need for reliability and simplicity—make special demands on the designer of a refrigeration system. Three important innovations are the boxing of fish in ice, the storage of fish in refrigerated sea water and the freezing of fish at sea. They have been adapted as required and are employed widely.

Much fish is sold in the 'wet' or unfrozen state, often termed 'fresh', at retail and as raw material for processed seafoods. Careful handling and proper treatment from the point of catch is of fundamental importance. Written recommendations on the handling of fish on vessels are widely available. Typical of these is the *Recommended international code of practice for fresh fish* published jointly by the Food and Agriculture Organization and the World Health Organization (**10**). Careful bleeding, gutting, washing and chilling of the catch as soon as possible after capture is recommended. Best present practice based on observations in northern waters has been described by Strom *et al.* (**11**).

The use of melting freshwater ice for the chilling and storage of fish has been a mainstay. Suitable systems for the production, storage and transport of ice are readily available. While production on board is possible, the carrying of ice from the port is usually preferred. Ice is also used in the processing factory, especially for fish that are stored for a time before processing, and in the markets for fish on display.

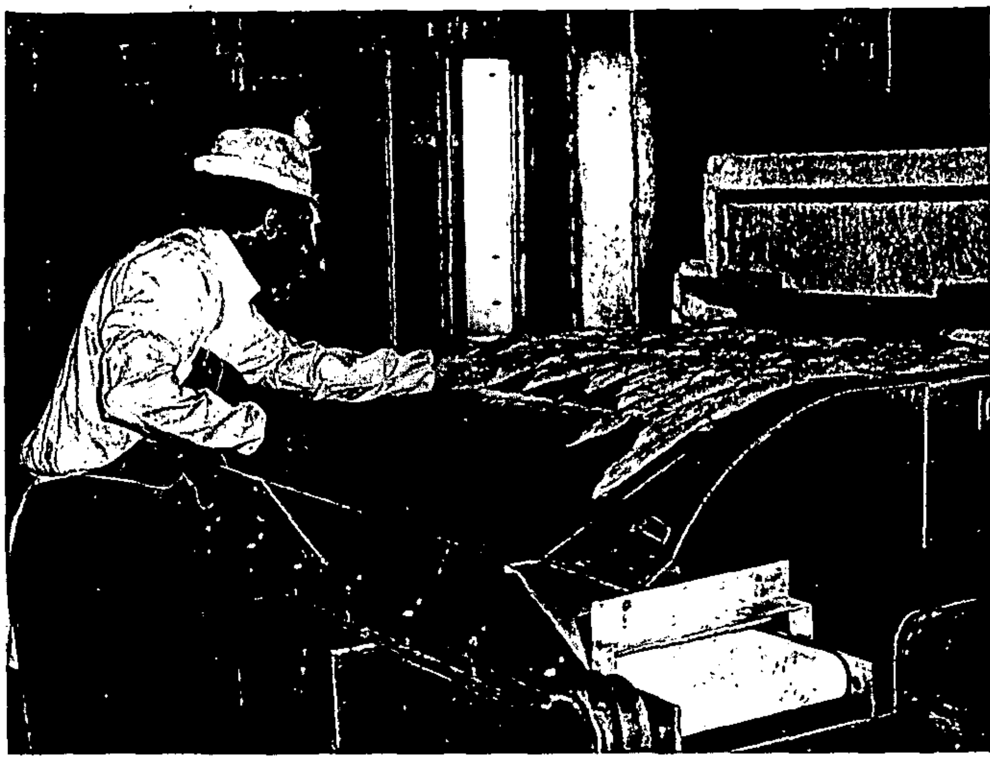

Fig. 2 Individually frozen fillets from a continuous air blast freezer [Crown copyright]

Boxing, or containerization of fish at sea, has proved to be beneficial in many fisheries as an alternative to bulk storage in ice. There is usually a lower stowage rate with boxes, typically 30 per cent lower than with bulk storage, but this is offset by increases in quality and yield and ease of handling. Boxing enables the holding of fish undisturbed until they are required for processing and distribution. In this regard, suitable chill rooms ashore, somewhat similar to the hold of the fishing vessel, are essential for best results in practically all cases.

A fair number of attempts have been made to extend the shelf life of chilled fish by the inhibition of bacterial and biochemical spoilage which are the main causes of deterioration. Some additives, for example nitrite and antibiotics, have been prohibited by government authorities. Physical methods, notably superchilling and irradiation, have been given some attention but have not found favour because of inconvenience and lack of acceptance in some quarters. At the present time potassium sorbate shows some promise (**7**). Sorbate is a widely accepted food additive, commonly used to inhibit mould and yeast growth. Another method receiving attention and study is the use of modified atmospheres containing carbon dioxide to extend the storage life of chilled fish (**12**). The possibilities here are dependent on the availability and cost of suitable packaging and containers but probably are not as great for fish as for some other foods.

Refrigerated sea water, cooled directly by mechanical refrigeration, was introduced into certain fisheries, notably for salmon, herring and mackerel, where it was difficult or impossible to ice the catch adequately because of high catching rates associated with the purse seine and some other types of gear. In recent years chilled sea water, water cooled by the addition of ice, has found favour, especially the 'champagne' system in which essential circulation is induced by compressed air, bubbled through the mass of fish and ice/water. These systems are particularly suited to the storage of pelagic fish and no doubt will be used more widely as exploitation of some presently underutilized fish such as mackerel increases.

The freezing and cold storage of fish has enabled the evening out of supplies and distribution to inland markets. The conditions for good results are fairly easily obtained (**13**). Unfortunately results are often poor because the need for cold storage at $-30°C$ for fish is not fully appreciated. Temperatures above $-20°C$ are commonly encountered. Good cold storage conditions are essential; the maintenance of low temperature and prevention of dehydration and oxidation are key points to be observed by the operator. Storey and Graham (**14**) have reported on important studies of weight loss in cold storage in which these factors were discussed. There have been only a few substantial advances in freezing since 1970. Improvements have been made to continuous air blast freezers for individually quick-frozen (IQF) products (Fig. 2). One advanced design features a conveyor of sheet stainless steel and an ability to operate for long periods, up to 22 hours, between defrost shutdowns (**15**).

Prefabricated insulated panels are now normally used in the modern cold store. In a recent development described by Stoecker (**16**) cooling coils, fans, condensing units and piping are installed in a penthouse on the roof of the store. This arrangement is convenient for service and maintenance and simplifies air distribution.

Cooled air is discharged into the store through short ducts and air is returned directly to the penthouse through a grid at roof level.

Thermal insulation forms an important part of most refrigeration systems. The methods and materials available today enable the building of safe and effective chill rooms and cold stores for fish and fish products. Insulation of the wooden fishing vessel is a special case where precautions are necessary and the use of insulation should be subject to restrictions in order to prevent wood rot (**17**). Wooden fishing vessels, however, are falling out of favour as other materials are introduced. In Atlantic Canada, where they make up most of the fleet and where there is a strong tradition of building in wood, fibreglass-reinforced plastic is favoured for many new vessels of small and medium size.

Freezing at sea was introduced about thirty years ago, mainly to enable vessels to spend long periods at sea, especially in distant waters where icing of the catch provided insufficient storage life. It has enabled the production of very fresh fish. There are difficulties with sea-frozen fish, however, principally discoloration due to a lack of time for adequate bleeding before freezing, texture defects due to muscle contractions associated with *rigor mortis* and the need for thawing (**18**). Possibly the main role of freezing-at-sea vessels in future years will be to provide fish, especially during periods of glut of the more perishable species, for later processing ashore. Under some circumstances, freezing at sea would appear to offer substantial economic advantages, even on fishing vessels of modest size. For example, recent work by the Canadian Institute of Fisheries Technology on the Georges Bank scallop fishery has shown that freezing on board would result in improved fish quality and allow large increases in yield.

Refrigeration plays a major role in fish preservation world wide and there is a continuing expansion of refrigerated facilities in both developed and developing countries. Some evolutionary changes in refrigeration systems themselves, now taking place, will help to ensure wider application. Refrigeration systems are becoming more reliable and easier to use. In recent years the screw compressor has been introduced into the larger installations, in favour of the reciprocating compressor.

Microprocessors are now being used to control and monitor industrial refrigeration systems (Fig. 3). Pearson (**19**) has described a number of important new microcomputer applications of this kind and pointed out that standard programs are available for most industrial refrigeration applications.

In a review of these and other current trends, Stoecker (**16**) has discussed the safety and environmental issues associated with refrigerants—chlorofluorocarbons and ammonia. He has suggested that improved containment of these refrigerants may well be a major challenge in the years immediately ahead. Success in this no doubt would lead to greater application of refrigeration.

3.5 Salting and drying

The consumption of traditional salted and dried fish products has remained high, especially in developing countries. Salting techniques have remained largely unchanged, although there has been an increase in the use of refrigeration to chill wet salt fish to about 4°C to prevent the development of 'pink' spoilage in storage due to the action of salt-tolerant bacteria present in solar salt. Some processors use evaporated salt because it is free of pink spoilage bacteria.

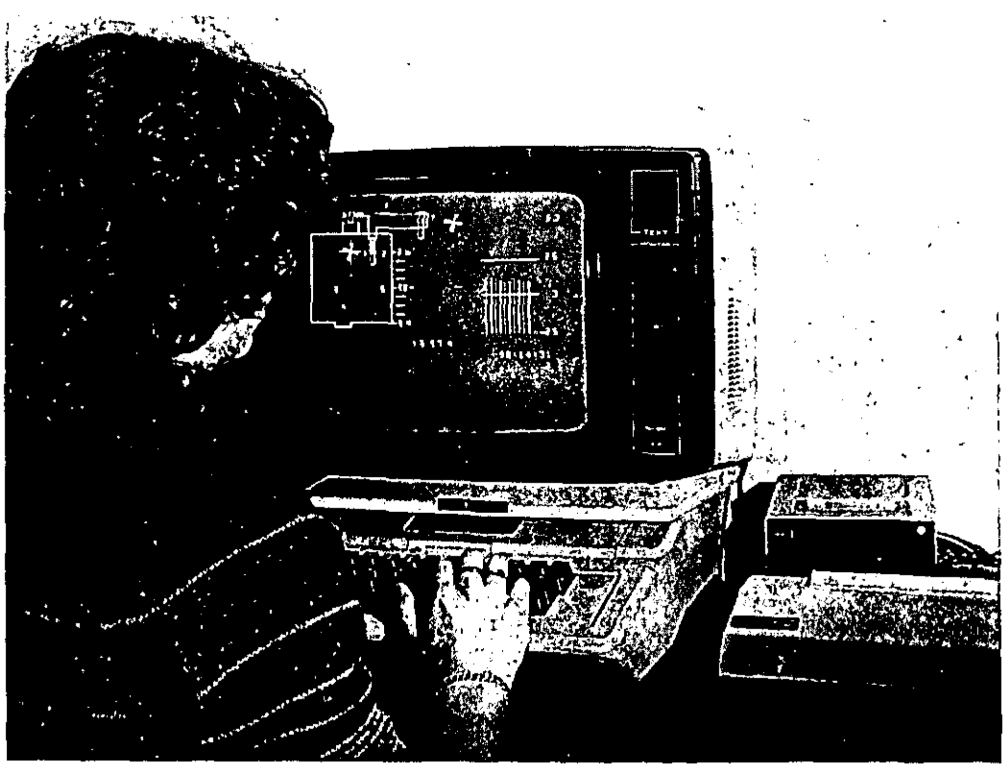

Fig. 3 Control and monitoring of −30°C cold store refrigeration [Crown copyright]

The main developments have been in the design and operation of dryers, mostly for the drying of salt fish. Various suggestions for making use of solar heat have been put forward. Attempts have been made in some developing countries to improve the utilization of solar heat for the drying of fish, for example by the use of a simple plastic 'tent'.

The mechanical dryer, consisting of cabinet, heater and air-circulation system with exhaust and make-up air, was introduced widely during the years of expansion, 1950–70, to replace 'natural' drying out of doors. It is giving way to the heat pump dryer (Fig. 4). In the heat pump system, drying air is recirculated over the refrigerant evaporator (cooler) to remove moisture and then over the refrigerant condenser to provide heat. This enables drying more or less independently of weather, even when conditions are too hot and humid for natural drying or for the mechanical dryer. Thus output can be increased while, usually at the same time, energy costs are reduced and control of drying conditions is easier. For a modest increase in first cost, the advantages are considerable. Strommen *et al.* (**20**) have set down design criteria for heat pump dryers for salted and unsalted fish.

In work at the Canadian Institute of Fisheries Technology on the drying of salt fish, there has been some variation of drying conditions (air temperature and humidity) during the course of drying. Tests in a pilot scale dryer and in a commercial dryer have had promising results. This work is aimed at further development of the heat pump dryer, for greater versatility and higher output, with a view to the production of a variety of cured fish products including the mild cures that require refrigeration.

Fig. 4 Dried salt fish from the heat pump dryer

3.6 Smoking

As mentioned above, the introduction of mechanical smoking kilns has been accompanied by a shift towards mild cures. Some traditional cures cannot be produced economically in a mechanical kiln and, with recent advances in packaging and the wide use of refrigeration, which allows an acceptable shelf life, the mild cures are preferred. Thus the trend has continued.

A notable example of traditional smoking is the bloater (similar to red herring) industry of Atlantic Canada. There is a substantial production in large 'smoke houses' with natural ventilation and fires on the floor. Bloaters do not require refrigeration and are exported mostly to the Caribbean region.

As with the drying of fish, improvements have been made to the design and operation of plant. Automatic brining machines and mechanized smoke producers and microprocessor controls for the mechanical kiln have been introduced. Further improvements over the next few years are likely. Work towards physical measurement of aerosols in smoke, with a view to filtration of aerosol particles from smoke, is in progress at the Canadian Institute of Fisheries Technology. If successful, this approach will reduce tar deposits on the product and on the surfaces of the kiln and simplify the measurement and control of smoke density. Quality control will be improved and the levels of carcinogens in the smoked product will be reduced.

Of course sometimes smoke flavour is added in liquid form, for example in canned products. It is unlikely that liquid smoke will displace conventional smoking altogether, however, because of the desired physical properties imparted by the combined effects of smoke deposition and drying.

3.7 *Canning and heat processing*

In canning, including the heat processing of canned products, there has been a number of distinct improvements although no spectacular changes or new applications. By and large, canning operations in the fish industry have remained as they were twenty years ago, but there are a few new developments of interest such as plastic cans and continuous retorts not yet widely used for fish. The microprocessor is being introduced in control of the retort to enable close control and ensure the required heat penetration without overheating, which might have adverse effects on product properties, especially texture.

Of course, with the availability of new materials with a host of different properties, a variety of packaging systems have been developed for food products. Aseptic processing, in which containers are filled under sterile conditions, has found a number of applications. For some fish products, the retortable pouch offers a cheap alternative to the can. Because of its flat shape, the pouch has a relatively short process time which can benefit quality in some instances.

3.8 Byproducts

Roughly one-quarter of the world catch is converted into fishery byproducts, mostly fish meal and oil. The raw material is composed of waste fish from processing operations, unsold fish and 'industrial' fish caught specifically for byproducts manufacture. Industrial fishing has been restricted in recent years in the interests of conservation of stocks.

Significant improvements have been made in the design and operation of the fish meal plant. Stainless steel is used in multiple-effect evaporators and other equipment in order to provide durability and ease of cleaning. Measures directed towards fuel saving, principally the recovery of heat from the fish meal dryer, have been devised and are employed by some operators. The 'low-temperature process'—cooking and drying at reduced temperatures—is now favoured in some applications on the grounds of superior quality of meal and oil. This has been promoted to some extent by the demands for fish feed for aquaculture. Perhaps the foremost advance has been improvement in the design of indirect (steam-heated) dryers. The modern dryer is compact and easily operated. It employs extended heating surfaces mounted on the shaft or rotor, replacing the earlier arrangement which depended on a heated jacket and shaft. The direct-fired dryer, used for much of the world's production, is giving way to the indirect dryer which enables better control over meal temperature and is more desirable from the point of view of odour abatement.

Environmental considerations, particularly the need to prevent or abate odour from the fish meal factory and, as far as necessary, to avoid the discharge of liquid effluents high in solids and fish oils, have been prominent. Technical advances have been made and recommendations drawn up (**21**). Methods of odour abatement including chemical absorption and thermal incineration are employed in some factories. Good results are much dependent on efficient factory management.

Fish meal and oil manufacture is the main method of disposal of waste fish. There are, however, quite a few fishery byproducts including glue and gelatin, pearl essence, chitin and chitosan, marine animal leather, biochemical and pharmaceutical products, zoo and pet foods, bait and fertilizer. Many of these use relatively small amounts of raw material and are being displaced by cheaper alternative methods.

Liquefied fish proteins have been promoted in recent years as cheap alternatives to fish meal. Fish silage, in which the natural fish enzymes liquefy the fish in the presence of acid added to prevent putrefaction, has been of greatest interest. It has been produced on a commercial scale in a few countries for many years, mainly as a feed for pigs and more recently for farmed fish. Fish protein hydrolysate, in which proteolytic enzymes are added and heat is used to prevent bacterial action, has also been of interest. It has been produced commercially in France, beginning about twenty years ago (**22**).

While some decline in emphasis on fish meal and oil manufacture has been due to curbs on industrial fishing, another factor has been market prices, which have not been high enough to encourage much investment. (The price of soya virtually dictates the price of fish meal and other competing feedstuffs.) After a long period during which fish meal manufacturers did not pay processors for waste fish etc., the price of fish meal has increased to the point where the demand for raw material is substantially higher. Since fish meal is a versatile feed that is easily stored and transported and the oil is of comparatively high quality, it is likely that fish meal and oil manufacture will remain the main method of fish waste treatment for many years to come.

4 TO AD 2000 AND BEYOND

Some further observations can be made on past developments and future needs.

In some countries that played major roles in the advancement of fish handling and processing, strong support and attention to research and development was given by government bodies over the period 1930–70. One can point to a number of successful industrial developments that arose directly out of work at publicly funded institutes in which engineers participated in a multi-disciplinary approach to problems. Major examples are the mechanical dryers and smoking kilns, storage in refrigerated sea water and freezing at sea.

In a few cases, notably Canada and the United Kingdom, there has been a decline in support during recent years. The result has been an erosion of the high level of expertise built over several decades and loss of valuable services to industry, not only research and development but also advisory, information and training services. Thus industry has been placed at a disadvantage.

In Canada the change has been rather precipitous, to the point where industry no longer has such easy access to much technological expertise. It is now not as easy as it was to keep abreast of important work, much of it unpublished, being done around the world. Also, in what amounts to a national crisis in information retrieval, reports and articles published during the years of great expansion and development prior to 1970 are being lost and forgotten. As a consequence, advice is sought abroad when it is, and should be, available at home and valuable resources are being devoted to duplication of work when they could be used to tackle important new questions.

Advances and services such as those mentioned above have been promoted best where applied research was encouraged and where there was a healthy liaison between institute and industry. Institute staff including trained engineers have done much of their best work in factories and on fishing vessels. One lesson of note to be learned from this is that success is more likely where the staff are clearly separated from government 'policing' operations—fish inspection and surveillance of industry practices.

In some communities and organizations, emphasis on academic excellence and the scientific method, to the exclusion of practically all else, also discourages healthy liaison with industry. Such an approach mitigates against practice of the art of engineering.

Another aspect of the recent changes in arrangements for research and development is the increased stress laid on quick results. While in many instances this may be the best approach, too often the question of support for the longer-term project is not entertained by industry and official bodies.

What are the problems of the next twenty years and what solutions will be forthcoming? What technical advances will be made? No doubt there will be a few startling developments, through environmental and political changes, as well as by virtue of inventiveness and research.

There is every indication that, while the extension of fishery limits and other changes have resulted in improved management of fishery resources, the capacity of the oceans to provide wholesome food will be seriously reduced unless curbs are placed on pollution of the oceans and the environment. One must remain optimistic that the concerted effort required will be forthcoming and that annual landings of more than 100 million tonnes can be reached and maintained.

More international agreements will be reached to reduce pressure on certain stocks of fish and enable better use of resources. The catching of fish, in international and national waters, will be subject to greater regulation. More and more often, the catching rate will be restricted deliberately to enable the best possible treatment of the catch.

Generally, the prices of fish products, relative to the prices of other foods in the market place, has risen in recent years. This trend is likely to continue for some time in view of the value being placed on the nutritional benefits and as increasing numbers of people, including those in developing countries, are able to pay and hence compete for the limited amounts of fish products.

Developing countries will continue to increase their capacity to exploit their own resources for the manufacture of superior products for the domestic market. They will also increase earnings through the export of fish and fish products, including cultivated fish, to foreign markets. Development is much dependent, however, on the provision of increased numbers of trained technicians and engineers.

One great problem is that of seasonal gluts and scarcities. This problem, characteristic of the industry, has been aggravated in some respects by developments in fish finding and catching which have not been matched fully by an ability to handle and preserve large catches. Furthermore, little change in this respect seems possible. The use of aeroplanes and space satellites already have a place in fishing and evidently there is scope for further measures in detection and even control of movement of fish and shoals of fish, to enhance catching ability.

The contribution from aquaculture is significant and will increase in order to provide supplies of fish and shellfish. The cost of rearing fish, which consists largely of the cost of feed in many instances, is unlikely to allow much change in the present emphasis on species that fetch relatively high prices.

In the area of fish handling and processing, there are clearly a number of difficulties and problems that remain to be resolved. Some of the manual tasks are laborious and arduous; new and improved machines and methods are needed. Outstanding cases in point are the shucking of molluscs and the removal of parasites from fish.

Progress will be made in the manufacture of attractive products from fish mince and on the use of a wide range of species in surimi and analogue products.

Refrigeration techniques including chilled sea water and icing will continue to find wider application. One of the greatest problems facing the industry is the poor reputation of frozen fish. The potential of freezing and cold storage as a means of preservation has not yet been realized, mostly on account of a lack of attention to proper methods and product temperatures. It is to be expected that not only will refrigeration become cheaper and more reliable but also that the operator will become more aware of the need for low temperature/time throughout the cold chain. This will enable frozen fish to reach a generally high standard of quality.

There will be a lot of improvements based on the use of microprocessors. Already there are systems for the control and monitoring of refrigeration systems, cold stores, transport units, dryers, smoking kilns, canning retorts and other plant and processes. Of course, as in other industries, the fish industry will benefit from improved access to operational information that microprocessors and computers provide.

Looking towards future industrial activities, chilling, freezing, salting, drying and smoking and heat processing will continue to provide the basis for the various fish products. Refrigeration will remain the main method, largely because it is used to maintain the original characteristics of fish as food. Other known methods, irradiation and freeze drying, are not likely to make inroads because of high costs and consumer preferences. In conclusion, advances in fish handling and processing will be progressive rather than spectacular. Nevertheless, there will be remarkable changes in the industry, especially in the lesser developed countries. Much improvement will be made through the application of up-to-date engineering practices.

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