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Contents

1. [illegible]

By comparison with vegetable [illegible], fish is a [illegible] contributor to the world supply of protein, supplying a [illegible] of [illegible]. However, fish protein is [illegible] excellent. It has considerable supplementary value in the diets of a number of countries, for instance in the developing countries of S. E. Asia, which are of interest to this meeting.

Fish protein is a major dietary [illegible] for a [illegible] of populations.

We should also consider the contribution of fishery [illegible] in developing countries to their export potential. For instance, there is an increasing international trade in frozen and [illegible]. Almost invariably these are high priced, luxury commodities in [illegible] demand in the developed countries. Indeed, some developing countries may have to balance the relative priorities of their protein deficiency problems and hard currency needs.

These two facets of the fishing industry tend to present somewhat different problems in the application of [illegible] preservation technology. In some part this conflict results from different patterns of consumer acceptability between countries producing, for instance, shrimp and importing countries with sophisticated tastes. Food legislation requirements in developed consumer countries importing tropical produce may also be at variance with local standards of food hygiene at points of production. Observation of consumer-acceptance standards in certain tropical African situations indicates very clearly that some populations will accept wet fish in a condition that, say, the European consumer would regard as one of advanced putrescence. Then again, some of the interesting fish fermentation products of S. E. Asia have attributes which, while desirable in many respects, may present acceptability problems elsewhere.

A third facet of the fishery complex that we should consider in a number of developing countries is a pattern of operation in which the catching operation is conducted by vessels from developed countries

[illegible]

[illegible] different stages [illegible] affected [illegible] by factors such as the ground of catching, the time of year, the nutritional state, conditions of catching etc..

These points are made in this introductory section because it should be stressed that the rational exploitation of fisheries must essentially be an interdisciplinary exercise. All too often one finds in the organisation of fishery administrations a separation of functions of the biologists on the one hand and the physical scientists and technologists on the other. At the industrial level also, the interests of the catchers and the processors are held to be discrete and this can make for inefficient operation. The results of research on the

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[illegible] either at home consumption or the export market. The first prerequisite for the utilisation of science, in the improvement of product quality and the economics of production, is the careful identification and evaluation of the essential stages of handling and processing and of the factors that determine the acceptability and price of the product. This may seem self evident but all too often in the past these considerations appear to have gone by the board and the scientist has followed a line of fashionable basic research of little relevance to the immediate problems of the country. This, of course, is not a criticism of the situation that applies in developing countries alone. The author is on record as pointing out[1] that much of the work that has been carried out on considerations of toughening in cold store and oxidation problems (which occupied much of the research effort on cold storage from the 1950s onwards) has very little relevance to the commercial development of freezing at sea; and that other factors, relatively unexplored, can be of greater importance in situations where storage periods are short and the fish passes rapidly to the consumer.

Obviously, however, information that is applicable immediately to the improvements of fish preservation in developing countries is in existence. In addition to that already evaluated for tropical species,

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2. [illegible]

2.1 [illegible]

[illegible]

Both microbial attack and [illegible] damage of the [illegible] type are, as mentioned above, dependent on physiological condition prior to death and the methods of catching. Fish in good nutritional condition, with a high potential for adenosine triphosphate production, tend to be more susceptible to tissue damage whereas their relatively high rate of production of lactic acid reduces rate of microbial attack. However, the main factor in the control of both types of damage is undoubtedly a reduction of temperature, very rapidly in the case of tissue damage since [illegible] control is of immediate necessity. Removal of haem pigment by 'bleeding' is also accelerated by chilling.[1]

2.2 Icing[4]

Storage in ice is the most common method for chilling and maintenance in the chilled condition in vessels and ashore. Other methods are also available, such as storage in refrigerated sea water and maintenance under chilled air, but storage in ice

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Chilling in ice, before freezing many such species, is relatively little used however.

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cutting the fish while alive or dead to allow bleeding. The fishermen of other countries involved in cold water fisheries have found however, that gutting and laying down in ice produces an adequately white fillet from a conventional icing operation for wet sale. Unless extreme care is taken to gut and ice very rapidly, however, such treatment may not be adequate for some tropical and sub-tropical species. Considerable care had to be taken in this respect with *Sardinella* caught in the N.W. and S.W. African fisheries for instance[8].

It would be prudent for countries contemplating an export industry of tropical fish species, in fillet form particularly, to mount an investigation to ascertain optimal conditions for bleeding on a cost/benefit basis. Some progress along these lines has been made during the development of European factory trawler operations. It would appear that thermal control by icing, of the blood clotting times in the tissue and of the development of *rigor mortis* like effects in the blood capillaries can be beneficial for some species (see below).[1]

Icing can control the rate of *rigor mortis* and hence some types of "drip" loss. Undoubtedly, icing techniques can be of very considerable benefit to the industry in developing countries in this respect. Some observations in my laboratory during the last year[7] do indicate, however, that the muscle of some species such as *Tilapia*, can be subject to cold shock effects by very rapid chilling in ice *pre-rigor*. This causes a *rigor* like hardening of the fish within minutes of slaughter and yet the muscle is biochemically readily distinguishable from the commonly accepted *rigor mortis* condition. To our knowledge, this condition has not been reported previously of fish species although somewhat similar difficulties have arisen in the meat industries of some countries in recent years when they have attempted accelerated chilling operations. We do not, as yet, know how many species are affected by this phenomenon or how far it could present technical difficulties. By analogy with "true" *rigor* it might be expected to lead to troubles in mechanical filleting operations; for instance, in some patterns of handling. Also, rough handling while fish are in such a condition could give rise to damage by shattering effects[1].

In the introductory section, reference was made to the value of the fishery for crustaceans in developing countries. Icing is, of course, of considerable value in lowering the rate of microbial attack and of autolytic reactions precursing the appearance of the "black spot" discolouration condition that can affect shrimp and lobster.

In common with some other fish products of tropical origin, shrimp for instance, has from time to time been rejected by the public health authorities of importing countries as the result of unacceptably high counts of microorganisms of public health significance. The quality control scientist can give considerable help to plants in developing countries in maintaining standards of hygiene and the maintenance of adequate chlorination conditions in plant water supplies etc., for ice making and the handling of iced fish. Undoubtedly, however, there is still a requirement for a major educational programme on handling hygiene in a number of developing countries. The author has vivid recollections of two handling stages in the separation of shrimp from ice prior to freezing in South America and S. E. Asia respectively. In both instances, the catch had been carefully handled and stowed in the vessel. Baskets of shrimp and ice destined for the plant in the first country were simply immersed in the poluted water of the dockside until the ice had melted. In the second, ice and shrimp was taken to an ultra-modern plant and then left in the sun for the ice to melt: within seconds, the shrimp could not be seen for flies.

I do not propose to introduce into this paper the use of additives to ice. In the past, substances such as nitrite have been advocated and, more latterly, antibiotics such as the tetracyclines. Regulatory conditions vary from country to country. Advantages in keeping quality from the use of the "safer" compounds are often marginal. Tarr[10] has reviewed this field and there is an expensive literature.[eg. 11,12,13]

2.5 Chilling with refrigerated sea water[14,15,16]

Refrigerated sea water minimizes development of spoilage caused by aut lytic and bacterial activities in much the same way as ice. The use of sea water does present its own problems, however. Problems of salt penetration and water logging can arise. Potentially hazardous anaerobic conditions must be avoided. While refrigerated sea water can be used, particularly on fatty species, for longer-term storage, its great advantage over ice is for shorter term chill storage when the difficulties are minimal. Near water fisheries, producing material for freezing ashore and, perhaps more importantly, freezer trawler operations, come to mind particularly. In the latter, early chilling and bleeding are necessary prerequisites for the production of high quality frozen fish.

While there is, to date, only a limited evidence on the factors that control, for instance, salt penetration into muscles of tropical and sub-tropical species, it would appear from work on others that this is unlikely to occur significantly until the muscle is well into *rigor mortis*. Work is required as a matter of some urgency on species other than the tunas (already covered) since patterns of operation which allow fish to be handled into chill conditions rapidly have obvious advantages in maintaining quality (other than "cold-shock rigor" effects). Studies on the optimal conditions for handling tropical fish would be of particular value to developing countries contemplating (or engaged in) freezing operations aimed at the export industry. These should be conjoint biochemical/engineering exercises tailored to the particular problems of individual tropical marine and lake fisheries. The bases of such a pattern of operation have been worked out by Polish, Canadian, British and Russian fishery technologists over the last few years[1]. With particular respect to the salt penetration problem, it appears that lowered temperature controls the onset of reactions reducing high energy phosphate content in the muscle and these in turn control the rate of entry of salt.

2.6 Super chilling

There have been various approaches to the super-chilling of fish[17,18,19] in which flesh temperatures have commonly been reduced to $-1^{o}C$ to $-3^{o}C$. One of the earlier procedures involved the hermetic sealing of whole fish in galvanized iron boxes which were then cooled in a continuous stream of brine maintained at -2^{o} to $-3^{o}C$. More recently, fish have been stored in ice initially and the temperature has been reduced subsequently. At -3^{o} the fish tends to harden but above this it may be soft (depending on time/temperature). The concensus of opinion appears to be that temperatures of the order of -2^{o} can give a considerable extension of keeping time over a fish maintained at 0^{o} in ice and that fish so prepared may be suitable for smoking. The economics of such preservation are debatable and present evidence would appear to indicate that any advantage in the introduction of such operations into developing countries is likely to be marginal.

3. FREEZING, COLD STORAGE AND THAWING

3.1 Factors in choice of freezing at sea or ashore

In a discussion of fish freezing, two basic situations have to be considered. The operation can be carried out entirely at sea or the fish can be brought ashore for freezing. Probably, the second of these situations is of greater interest to developing countries currently, but where such an operation has developed in the past, it has been found not infrequently that the near-water fishery ceases to produce sufficient material to support the plant within a few years. The company is then faced with the prospects of either eliminating or reducing operations - or freezing at sea, possibly with a view to secondary processing (see below). Consequently, the forward planning of an off-shore (as distinct from inland water) fishery in developing countries should take into account the biologists' forecasts of potential production. The possible necessity for a first stage in which the chilled fish is brought ashore for processing or freezing whole should be considered, together with a second stage in which freezer vessels bring back whole fish for thawing, reprocessing and probably re-freezing ashore. A third stage, in which the vessels undertake complete factory operations at sea, may also be contemplated. Probably, it is unlikely that any country would wish to undertake the last stage without prior experience in depth. Where such an operation has been mounted from developing countries, this has usually been carried out by vessels from developed countries with the port providing backing-up facilities. Indeed, even the first stage has often been a conjoint exercise in practice between a fleet of catchers from developed countries coordinating with a shore based factory facility in the developing country.

Heen[20] has recently discussed specific problems and techno-economic considerations in shore based fishing industry and he has made some interesting comparisons with the development in recent years of freezing at sea. Undoubtedly, in developed countries, the proportion of fish frozen ashore is likely to continue to decrease and, as indicated above, it may well be that similar developments will be the pattern in the underdeveloped countries.

Heen observes that it is generally accepted that fat fish tend to lend themselves better to freezing and thawing than lean fish; and that it is very important to understand the peculiarities of the raw material when considering the best way to convert it into useful products. Some of the physiological considerations have already been introduced into this paper in the context of chilling and it has been pointed out that the interdisciplinary approaches to fish preservation are the key to successful preservation. In his considerations on the basis of land based industry, Heen stresses the need for continuity of supply-and, by implication, the necessity of combining the first two stages referred to above in what the author takes to be the current Norwegian situation. This requirement for continuity is stressed particularly in relation to the labour situation. Quite possibly for some time to come in some developing countries, a "casual" labour force will remain a practicable proposition for operation. Certainly, competition for labour between the fishing industry and others often appears to be less intense than in most developed countries currently. This, of course, is relevant to the cost/benefit analysis of any pattern of operations that an applied researcher may suggest.

3.2 Quality as improved by freezing and cold storage

A common comment of reviewers is that the cold storage of fish cannot improve the quality of material frozen and placed in store from a condition that was unsatisfactory prior to freezing. Certainly with respect to off-flavour and odour resulting from microbial deterioration in the wet condition, this is substantially a fair observation. However, recent improvements in our understanding of the factors that can affect the texture, particularly, in frozen fish lead one to the conclusion that the statement is not invariably correct.[1] This is particularly the case of material frozen in a pre-rigor condition, which is subject to thaw-rigor effects at defrosting. Such effects for instance, can lead to gross distortion of very poor texture and considerable weight losses, and can be controlled quite effectively by a short period of cold storage under what would commonly be considered to be rather poor conditions. At temperatures of the order of -5°C to -10°C the metabolic actions that would cause contraction at thawing, or cooking from the frozen state, proceed quite rapidly while the tissue is held rigid by ice and the energy is presumably dissipated as heat.

Recently, in our laboratory we have been examining the possibilities of eliminating an off-flavour found in freshly caught Tilapia from a number of tropical fresh water situations. This is variously described as "muddy" or "manurial" according to intensity and appears to derive from the presence of an unidentified thio-ether.[21] We have succeeded in removing this by leaching from wet fillets but, rather more interestingly, we have also had some success in eliminating the compound by manipulating an enzyme system innately present in the tissue, at sub-zero temperatures.

In our experience, also, the acceptability of some very soft fish such as sub-tropical Melucius spp. can be improved by a period of storage at temperatures somewhat above those that would commonly be considered to be desirable.[1] Under these conditions, the flesh undergoes a certain degree of cold storage denaturation (see below) and toughens without incurring too high a penalty in terms of "drip" loss during thawing.

Having noted this, it must be recognised that a considerable body of information has accumulated over the years, particularly on temperate water fish but probably of a quite wide applicability, on the freezing and cold storage of fish ashore and on time/temperature.

tolerances for lipid deterioration, protein denaturation and general quality loss. While recognising the necessity for an intelligent flexibility in his approach to the unknown problems of freezing, handling and processing unfamiliar species in developing countries, the applied scientist must take due account of these soundly based general principles.(cf. 21,22)

3.3 Considerations of freezing technique

It is not my intention to attempt to discuss the physical considerations in the freezing and storage process. These have been very well debated in recent years and excellent discussions of the basic prinoiples have been presented in publications aimed at the scientist and industry right down to factory forman level.[24,25] While it is no longer considered that extensive damage can derive from the growth of ice crystals intracellularly, it is agreed generally that the growth of large ice crystals during slow freezing operations is undesirable and that the fish should pass through the thermal arrest as quickly as is possible within the framework of economic operation. Various maximum times have been debated for a passage through the arrest down to -5°C. For instance, in "quick freezing" as defined in the U.K. no part of the fish or packet of fish takes longer than 2 hours to cool from 32°F. to 23°F, ensuring an adequate margin of safety; in practice, differences in acceptability (as measured by texture scores on the thawed cooked material) are usually not detectable until the time taken to cool the centre down from 32-23°F exceeds something of the order of 4 hours.[25]

3.4 Whole fish *versus* fillet freezing[1,23,26,27]

We have discussed above the prehandling of fish and its storage prior to freezing in the context of quality; and, briefly, the minimum requirements of equipment to freeze fish. We must now consider the form in which the fish is frozen, and the conditions of storage.

Notwithstanding the desirability of gutting, it has been seen above that some communities accept only intact fish. Whole fish or gutted but unfilleted fish are frequently frozen also for other end-uses. For instance, they may be used to even out the market fluctuations in wet fish supply and used in the thawed condition for reprocessing such as smoking-or sold as steaks or fillets after thawing; alternatively the gutted, but whole-frozen material may be sold direct to the housewife. There is a growing world market in frozen fillets. These may be packed either discretely or as blocks, possibly interleaved with film. Steaks are also frozen individually.

3.5 The use of "dips"[1,28,29]

Unlike the situation in whole-fish freezing, there are possibilities of manipulating fillets prior to freezing so that a texturally improved can be produced at thawing. Also, there are possibilities for the use of additives that limit deteriorative change in the frozen state or improve flavour. Particular reference, perhaps, may be made to the increasing use of brining and polyphosphate treatments as aids to the improvements of yield and quality. Effects on yield are particularly relevant to the high priced fishery commodities such as shell fish. They are of considerable current interest in the context of developing tropical fisheries since studies on the manipulation of water-binding properties of warm water species are very scarce. In relation to the tropical environment, with inherently higher microbial contamination risks than those occurring in most temperate climate plants, attention should be drawn to the inherent risks of pathogen contamination attending the use of dipping procedures for fishery products, and the necessity for adequate control.

In some situations there may be advantages in comminuting fillets prior to freezing.[30,31] Certain Japanese trawlers carry out this operation at sea and minces are also frozen ashore for use in fish sausage preparation. With such materials, the possibilities for exploitation with additives are enhanced considerably. Clearly, they have implications in the technology of developing fisheries. For instance they may provide new bases for the production of fermentated fish products or even out the supply position for traditional industries in S.E. Asia.

3.6 Methods of freezing

Three basic methods for freezing fish were available.[20, 23, 32] Refrigerated metal plates may be placed in contact with the fish; a continuous stream of air may be blown over the product, or the fish may be immersed in a low temperature liquid.

Fairly high air speeds are necessary to avoid excessively low temperatures of operation if air blast freezers are to produce a successful product. Such freezers are of two types, operating either on a continuous or batchwise basis. Continuous operation normally employs a standardized process on a product of constant freezing time. Batchwise systems tend to be more flexible but may be less economic for many purposes. A variety of cross-flow and series-flow blast freezers has been described.

In plate freezers, fish are frozen between pairs of refrigerated metal plates. Usually these are spaced horizontally in shore-based equipment. The plates are movable to achieve the closest possible contact with the fish and care is taken to maximize contact by design features in the packaging on the one hand and adequate defrosting to avoid the build up of nodules on plates on the other. Vertical plates are used at sea.

The third type of freezing is immersion in liquid such as refrigerated brine or some inert low temperature substance. Brine has been used extensively in the tuna industry with great success over the years. Operations of this type are conducted predominantly at sea.

3.7 Freezing at sea and ashore: current developments (1, 32)

Freezing at sea presents problems that do not occur in operations ashore. These result largely from limitations of factory trawler operations, in terms of space and the times available for unit handling operations, with their attendant pressures on crews. Essentially, the problem revolves on the balances between freezing rates, stowing rates for the frozen material and the biochemical demands on fish as a raw material for freezing. Such concepts were given little attention until considerable difficulties arose during the last decade in the sale of sea frozen fish in competition with the wet fish. Basically, the problems have been the avoidance of discolouration and textural deterioration - the latter in combination with severe drip losses either prior to freezing or at thawing. Bacteriological considerations have proved to be relatively unimportant.

The housewife in an importing developed country tends to look for a white, translucent, glossy fillet of good odour, if she is buying a wet fillet prepared from thawed material. The re-processor, on the other hand, looks for high yield from frozen material, freedom from textural and flavour quality difficulties and good processing character generally. We have seen from an earlier section that flavour change is reduced by chilling; and also that textural change associated with accelerated rigor conditions of some types can be reduced similarly. Also, effective bleeding, which is necessary to produce a fillet of good colour can also be encouraged by chilling although the optimum temperature is debatable.(cf. 1, 33) Consequently, the aim on modern factory vessels is to chill and gut fish as rapidly as possible and to control the development of rigor carefully in the context of the subsequent freezing operation and any prior processing such as mechanical filleting. In practice, the optimal time scales will depend in large measure on the nature of the species, its nutritional status on a particular fishing ground at the time of the year (very considerable seasonal variations) and the catching rate.

The simplest situation is encountered in the freezing of whole fish.[1, 26] If an acceptable bleeding regime has been employed at low-temperature, it does not matter much whether the fish is frozen before, during or after rigor provided that this information is available to a competent plant manager when the material is landed. In fillet freezing however, the situation is very much more complex, particularly if the aim is to prepare material for direct sale to consumers rather than for inclusion in fillet blocks destined for the production of thawed fillet portions, precooked- or precooked fish fingers.

The efficiency of filleting some species mechanically while <u>in rigor</u> is a matter for some dispute. Consequently, for safety, the fillets must be frozen either before or after the development of rigor. Considerations of timing and space conservation are indicative of a <u>pre-rigor</u> filleting operation at higher catching rates. The necessity for adequate bleeding is counter-indicative so that, in practice, a nice balance has to be drawn by the factory manager. Furthermore, the fish has to be well chilled since <u>pre-rigor</u> fillets are very susceptible to contraction prior to freezing.

The desirability of <u>pre-rigor</u> fillet freezing on economic grounds on the vessel, renders the closest collaboration with plant and cold store managers ashore a matter of paramount consideration, since the mishandling of this material prior to thawing can lead to disastrous yield losses if the material is allowed to contract uncontrolled. Since rigor is itself dependent on the physiological condition of the fish at the time of death, it can be seen that fillet freezing at sea, if it is to be successful, must be a highly sophisticated interdisciplinary exercise involving the collaboration of the biologist, the Captain of the vessel or his Fishing Master (who effectively control the catching rate and the handling of the gear) the Factory Manager on the vessel and the Store and Processing Managers ashore. Unfortunately, this desirable state of affairs is not achieved invariably even in integrated fishing companies in developed countries. It is to be hoped that developing countries will learn from the mistakes of others.

Ranken[23] has recently evaluated modern techniques and equipment for freezing whole fish at sea from the designer-engineer's standpoint, taking into consideration biochemical perameters. He makes the point that vertical integration of catching, shore processing and distribution within the industry has not proceeded far enough in some countries so that even whole fish freezing at sea is not always done in the way best suited to the market, although it may be the most economicable purely from the owner's point of view. He points out also that, in addition to the types of consideration indicated above, the best methods for freezing whole fish at sea depend on the type of vessel, port and shore processing facilities, distribution methods and consumer preferences. Ranken[23] relates the basic methods of freezing, (air blast, contact, vertical plate freezing at sea and immersion)to the type of vessel and the fishery as a whole. In practice, pre-chilling,as it is developed on vessels,has been almost exclusively through the medium of refrigerated sea water. Systems of chilling tanks have been integrated with the various manual and mechanical lines operating in different vessels for heading,washing and gutting. After preparation and bleeding, the fish are held chilled as necessary to fit in with the freezer cycle as indicated above.

Commercially a wide range of vessels is currently freezing a range of packs from a consumer size fillets, through blocks of mince or fillets for industrial processing ashore, to large blocks of whole fish of the order of 50 kilos.

Moal and Gousset[34] have described the development of freezing at sea and ashore in the context to the consumption of frozen fish in tropical West Africa. They point out that the systematic "working" of fishing grounds off W. Africa has largely been the result of non-African developments. They calculate that a consumption of frozen fish in W. Africa will increase to something of the order of 10,000 tons in 1970 but that a key factor in consumption will be an improvement in quality and price. Efforts will be directed locally to encouraging shipboard freezing in brine of all species suitable for processing, whereas other fish will be plate-frozen.

Karnicki and Kordyl[35] have described the developments in Polish tropical fishing since 1963 and the methods that the Polish fleet have developed to combat the particular difficulties of operating in W. African waters with an ambient deck temperature of about 30°C. In addition to the use of the pre-chilling in refrigerated sea water tanks, these workers refer to the use of flake ice for handling larger fish and stress the necessity to control <u>rigor</u> and autolytic activity generally in the flesh. Reference is also made, in agreement with other workers (cf. Jones[1]) to the necessity for control of catching rates.

3.8 Cold storage[22, 36, 37]

In its original conception,cold storage was used as an adjunct to freezing in suppressing the developments of the spoilage microflora. It was found quite quickly, however, that cold storage,in turn, presented special problems inherent in this form of preservation ;and a a considerable science has grown around the problems, for instance, of lipid deterioration, off-flavour development, discolouration and protein denaturation. As we have seen, there are possibilities of some measure of control of some of these difficulties (particularly in fillets) by the use of additives. Equally, cold storage itself can be manipulated to improve the textural quality of fish with undesirable characteristics such as softness or (in combination with polyphosphate treatment) serious "break up". However the main quality problems to be avoided continue to be those associated with poor design or management of cold stores. Considerable attention has been devoted to these over many years. It is not my intention to go into a detailed description of well established principles although, obviously, the design problems of stores operating in hot humid tropical situations will tend to be more severe than those in many developed countries. Lorentzen[illegible] has recently presented an excellent review of basic operational requirements in the latter. While lower temperatures are undoubtedly desirable for the longer term storage of many products, the present trend overall appears to be the adoption of a temperature in the region of -30°C as the maximum safe economic temperature at which fatty fish and white fish may be stored together for long periods. However, the author is aware of exporting industries operating stores economically at higher temperatures. A major difficulty in stores is dehydration, effectively freeze drying, leading to "freezer burn". Movement of the air within the store accelerates such a transfer. Fish is frequently "glazed" to avoid dehydration. Good cold store design and practice reduce the temperature between the refrigerated pipes and fish and restrict the movement of air. The heat leak into the stores is a critical factor. Important variables are the size of the store and the nature and thickness of the insulation. Small stores may economically be of "jacketed" design although the author understands that there are many difficulties in putting theory into practice in this field.

The keeping quality of fish in cold store varies very considerably according to species and much work has been carried out on time/temperature tolerances of economically important species. The major problems that can arise tend to centre around the stability of lipids in fatty species and the stability of protein more generally.[38] Additionally, questions of autolytic degradation relating to the flavour deterioration and textural quality loss in other senses may also be of concern[39] together with carbonyl-amino reactions.[8] Deteriorative reactions, in general, are temperature-dependent. As indicated above, their limitation in store has to be considered against the general background of the economics of cold store operation.

including for instance, the use of the store for food commodities other than fish. Consideration of the servicing of developing fisheries with new cold storage facilities should give very serious consideration to the biochemical character of the species to be handled. For instance, in the case of fatty species, the differential fatty acid composition and the presence of naturally occurring pro-oxidants, or oxidants or anti-oxidants such as tocopherols are highly relevant. The nature of the muscle proteins and of their environment are important. Factors such as muscle pH, as affected by glycolysis and the hydrolytic liberation of free fatty acids from the lipids both affect denaturation reactions in store.

It may perhaps be stressed again at this point that such factors relate, in part at least, to the condition of the fish at the point of capture to handling conditions prior to freezing and the freezing procedure employed so that the operation should be considered as a whole. Brine freezing, for instance, is not to be recommended where oxidation problems present a major hazard.

While the general trends towards lower storage temperatures are to be welcomed, the observation made in an earlier section on the possibilities of controlling rigor determined "break up" and "drip" loss, by periods of storage under frozen conditions but at considerably higher temperatures, should be borne in mind by store designers.[illegible] In such treatment, obviously, there is a requirement for technical control of a high standard throughout the operation.

Calculations relating to possible cold store designs and operation should also involve very careful evaluations of the probable turnover situation, to avoid overdesign. In the development of freezing at sea, it has been found that problems of consumer acceptability relating to factors other than the freezing and cold storage operation have been far more critical in a situation where fish is thawed and passes to the consumer rapidly through wet fish channels of distribution. Indeed, it could be argued that (considerations of "evening out" the market apart) time spent in cold store represents a dead loss to the operation overall and should be minimized.

3.9 Liquid nitrogen refrigerant[40]

In this context also, we should refer to the increasing use of a frozen storage prior to processing such as canning, smoking and drying, or refreezing after processing. The use of frozen fish for these purposes as discussed in the relevant sections on other types of processing.

In recent years, there have been considerable developments in the use of liquid nitrogen as a refrigerant both for the freezing process and for maintaining low temperatures during subsequent cold storage and transport. There has been some commercial involvement and further developments are awaited with interest. Whether sufficiently large supplies of liquid gas are likely to be available in the developing countries in the reasonable future appears to be an open question at the moment. However, it is interesting to note that earlier difficulties in controlling rates of freezing to avoid cracking the tissue and subsequent distruption on thawing appear to have been surmounted and that Breyer, Wagner and Seliber[40] have recently presented a plan for the processing and cryogenic freezing of fish fillets on a mother ship. The liquid nitrogen for the operation would be generated aboard ship and it is suggested that the method might be specially suitable for the developing nations since it proposes utilisation of existing small fishing vessels and provides flexibility of operation without high capital costs. The factory ship itself would not be a high speed vessel but rather a mobile fish processing plant. The possibility of incorporating a total energy power plant system is discussed in the plan together with a tentative evaluation of the economics of such a plant at a capacity of 25 tons per day of frozen fillet. Breyer <u>et al</u>[40] suggests the particular application of individually quick frozen fillets to the export market. They point out also that the by-products of the frozen fillet blocks, fish meal, or fish protein concentrate are also products for export or domestic consumption.

<u>1.10 Thawing</u>[41, 42, 43]

Earlier in this section, the question of thawing, processing and refreezing was introduced. This is of particular concern to the exploitation of freezer-trawlers, bulk-freezing whole fish at sea. The problems that can arise, in terms of discolouration, off flavour development, textural difficulties and yield losses have been introduced elsewhere. At this point I would merely draw the attention of the working party to the excellent paper of MacCallum and Seple[43] on 'Commercial Aspects of Reprocessing and Marketing of Sea Frozen Fish.' Of particular interest in this context is the consideration given, in evaluating the overall situation, to the question of thawing.

While in many smaller scale operations that one can envisage, (particularly in tropical situations) thawing may present little difficulty, the optimal usage of frozen fish "buffer" stores to serve processing industry or 'short' wet markets can involve demands for very rapid thawing. Very little information is available on the behaviour of tropical species other than the tunas and species of the N.W./S.W. African fisheries. One would expect that, in general, tropical and sub-tropical species should stand up to thermal shock better than the cold water species reported upon to date. Merritt[41] has reviewed the various methods of thawing currently available, classifying them broadly into those depending on heat conduction through the thawing material and others. Methods of most current interest are thawing by air blast, water, heated plates, dielectric treatment and electrical resistance. Other methods such as infra red and microwave heating are considered to be of no value for large scale operations.

While natural convection in air at ambient temperature may be all that is required in many tropical plants, increase in air velocity reduces thawing times and the economics of operation may well in practice demand further increases in temperature and humidification. However, modern air blast thawers in use for cold water species such as cod commonly use recirculation of humid air at temperatures as low as 20°C; and there are indications that this is the maximum temperature that can be employed with safety. Obviously there is a potential field for study here with tropical species of greater muscle stability. Indeed, the whole basis of economic considerations in the tropical situation are likely to be different when heating costs differentially are calculated. Continuous air blast thawers of two types - cross-flow and parallel flow - are in use and it may be of interest that the Torry kiln, commonly used for fish smoking (see below) is also adaptable for employment as a batch thawer.

Another approach to thawing is by immersion in (or spraying with) water.[45] In his discussion of physical considerations, Merritt considers that temperatures should not exceed 18°C. However, as in the case of air thawing, water temperatures considerably in excess of this are commonly available without incidental heating costs in the tropics; and this, together with the likely greater stability of most of the species of interest, leads to quite a different situation.

Conduction thawing, whether by air or water at high temperatures obviously requires a strict bacteriological control. This is particularly the case with water thawing, and here again, it must be pointed out that the situation is very different from that applying to a cold water microflora controlled by chilling during pre-freezing handling.

Thawing between heated plates presents none of the difficulties with water-logging that can accompany the incautious use of water thawing techniques. Commonly, warm liquid is circulated through a doubsimilar in many ways to a plate freezer. It would appear likely that the incidental expense of the equipment in the tropical situation may well not be justified by comparison with simple air blast facilities. Such arguments are likely to apply even more in the case of dielectric thaws and electrical resistance thaws.

It may be of interest to note the comparative cost of thawers rated at 1t/h. for use in temperate regions. Air blast thawers are quoted by Merritt[41] in the region of $45,000 - $60,000, with more than half the cost for conveyers; spray thawers at $51,000; plate thawers $30,000; and dielectric and electrical resistance thawers $72,000. The batch Torry-type thawer has been installed as several units at an initial cost of roughly $18,000. It would appear that with the considerably reduced heating costs consequent upon the high ambient temperatures we commonly found in developing countries, some type of air blast thaw, possibly adaptable to smoking operatings along the lines of the Torry kiln, is likely to be the method of choice in developing countries. Should their fisheries develop along similar lines to those elsewhere, critical evaluations of potential muscle stability and bacteriological problems would be worthwhile beforehand.

3.11 The Scientist as a "troubleshooter" in freezing operations.[1]

From the foregoing sections, it will be apparent that a range of disciplines can contribute to solutions of the economic, operational and marketing problems that arise from time to time in the freezing industry. The bacteriologist, clearly, is of value in identifying and eliminating points of contamination that can present a public health hazard. The physicist and engineer can fruitfully collaborate in the solution of design problems. Both must consult with the bacteriologist and biochemist when such problems impinge (as inevitably they must) on quality considerations. However, it is perhaps the biochemist and chemist who can contribute most to the solution of the general run of consumer acceptability problems that arise in practice during day to day operations.

If we consider the probable course of development of fisheries in the tropics, it would appear that while the special problems of environment may lead to somewhat different solutions to design requirements in such equipment as thawers and stores, basic engineering considerations may not be dissimilar in general from those that have applied in other fisheries. The major difficulties that are likely to arise in practice, on the basis of experience with the variety of species taken in commercial fisheries elsewhere, are likely to arise in the context of the special problems of handling and utilisation on species not hitherto preserved by freezing.

Having noted this it should be recognised that certain general principles have emerged, particularly in the last decade and that these are of potential value to freezing operations already in production in developing countries and in the avoidance of difficulty in new projects.

I have not discussed in this paper the accumulated knowledge of factors determining a flavourous quality of fish in the wider sense; but two reviews on the flavour chemistry of fish have appeared from my laboratory in recent years (eg. 8) and it is clear that, where atypical flavours for the species result from contamination of the flesh on particular fishing grounds, leaching techniques, or the use of flavour additives (such as monosodium glutamate and 5'ribomononucleotide mixtures) may often be of value on limiting or eliminating the difficulty without resort to changing the grounds.

Burning after-tastes and rancidity not uncommonly accompany poor storage conditions. The position may be aggravated by inefficient bleeding, and hence haem catalyses of lipid oxidation; or partial deterioration of fish with attendant lipid degradation prior to freezing. The use of anti-oxidants, improved glazing or packing techniques, improved bleeding (with rapid gutting and chilling) or more rapid operation prior to freezing may be indicated, together, of course, with improvement of general cold storage technique.

Losses of sweet, meaty characteristic flavour and an increase in bitterness are the result of autolytic deterioration of the flesh either prior to, during or after freezing. The identification of the point of autolysis leads to the production of fish with the desirable attributes of sea-fresh material. Again, the use of monosodium glutamate/5'prime ribomononucleotide additives is a useful palliative.

Amine-like or ammoniacal off-flavours can result from a number of causes. Spontaneous degradation of trimethylamine oxide and ribomucleotides in cold store is possible; storage temperatures should be lower. Bacterial attack prior to freezing can give rise to such off-flavours which are carried through to the frozen state: more rapid operations prior to freezing - and adequate chilling - are indicated. Attack by bacterial enzymes (formed prior to freezing) in store can also produce increased ammoniacal off-flavour: again lower cold storage temperatures are indicated. As further control procedures, leaching prior to cooking and the use of the flavour additives referred to above may be a help, particularly if the material is to be refrozen after cooking, prior to sale.

"Sulphydryl", "lower fatty acid", putrid flavours are also the result of bacterial attack prior to freezing, (although some sulphide compounds can be natural contaminants in flesh): control is as above.

A number of quality defects of texture, with "drip" and low yield, are readily identified and controlled. Toughness, with attendant "drip" loss can be associated with a number of causes. Low pH is commonly involved. This can be associated with nutritional status (related perhaps to ground and season), with the fishing method(since, for instance, a low degree of exercise prior to death results in high lactate accumulation in the muscle post-mortem): or it can be associated with the processing regime prior to freezing.

The solutions of changing fishing grounds or even methods for catching may be impracticable on economic grounds. If this is so, there are possibilities of raising pH in fillets by the use of polyphosphates. Alternatively, the crew can allow a maximum period of struggling as the fish comes to the deck alive; some lactate is then translocated and some buffered physiologically. Or the crew may even allow incipient spoilage to raise pH if flavour is not a prime consideration.

Another cause of toughness, very commonly occurring in cold stored material, is protein aggregation reaction. This is more readily recognized if accompanied by poor surface gloss at cut surfaces and a characteristic "grey" appearance of the flesh, together with high "drip" loss. Lower cold storage temperatures and possibly the use of polyphosphate and/or brine dips are indicated.

A third cause of toughness and "drip" loss is the effect of high-temperature rigor. This has been observed in some subtropical species, but very little work has to date been carried out on tropical species proper. There are indications that effects, such as "honeycombing" in canned tuna for instance, may be related to this type of condition although bacterial spoilage is also involved. High-temperature rigor effects take two forms. When the flesh is attached to the skeleton, toughening is accompanied by gross "break up" at the filleting stage and is seen at thawing. Control is by chilling prior to freezing. If the condition has not proceeded too far, polyphosphate/brine treatment of fillets and interleaving with plastic film prior to refreezing can help. The other type of high-temperature rigor effect occurs in fillets removed from the bone pre-rigor. In these, "drip" is accompanied by gross shrinkage of the muscle but little, if any, "break up".

Soft, mushy flesh can be the result of low acidity. This, again, is associated with the nutritional condition of the fish and conditions of catching. Control is by procedures exactly the reverse for those used in the control of pH-dependant toughness. Direct acidification of the muscle may be possible in some types of frozen preparation such as fillets or minces. As discussed elsewhere, a degree of cold storage denaturation may be of advantage.

"Short", granular texture in cooked frozen products results essentially from the cooking of <u>pre-rigor</u> material. As control procedures fish may be allowed to enter <u>rigor</u> prior to freezing: they may be "conditioned" by higher temperature cold storage to allow causative reactions to proceed in the frozen state; or they may be thawed slowly and cooked from the thawed condition. In this case the causative reactions proceed prior to and during the thermal arrest.

Low yield associated with "drip" losses can occur either as the result of contraction effects of protein denaturation or excessively low pH and are controllable as above.

There are a number of common quality effects of appearance in frozen fish. These, also, are readily controlled. The characteristic grey colour accompanying protein denaturation has been referred to above. Such fillets are opaque, they lack gloss, but have a smooth surface. <u>Pre-rigor</u> frozen fillets also tend to be opaque but the opacity is associated with a light-scattering effect from a surface of sandpaper-like consistency caused by the cutting of <u>pre-rigor</u> monofibrlds "end on". The eating quality of such material can be excellent but, should the appearance present an insoluble marketing problem, filleting can be delayed. Alternatively, if the economics of the operation allow it, the fillet can be recut at thawing. This is a doubtful solution, however, as it would be better to freeze the whole fish.

Badly broken or "gaping" fillets meet with considerable consumer resistance in developed countries and the exporter from a developing country would be well advised to take advantage of the earlier experience. Of the established causes of gaping, rough handling when the fish is in <u>rigor</u> (for instance, by manipulation on deck or transference between catcher-and freezer-vessels) should be avoided, particularly with those species in which very strong <u>rigor</u> is developed and in which the connective structures are weak. Some advantages can be derived in the fillet freezing operation from the use of polyphosphate/brine dips and compression in interleaved blocks prior to freezing.

High-temperature <u>rigor</u> effects when the muscle is attached to the skeleton produce very bad "break up" in addition to toughening and "drip" loss. Control is by the methods indicated above.

Bending and knocking in the frozen conditions can partially shatter the fish which may be unfilletable at thawing. Uncontrolled, over-rapid freezing in liquid gasses can produce similar effects.

Excessive delays in freezing, particularly of ungutted whole fish can lead to "break up" problems. Currently, these are imperfectly understood. In some species they may represent some weak form of "high temperature rigor" effect, even at relatively low temperatures, on a weakened connective structure. Very little is known about such effects in tropical species, if they do occur. Polyphosphate dips, etc., as above may help.

Contracted fillets are of varying acceptability in developed countries. In some, this condition is taken as a sign that the fish were frozen fresh, and welcomed. In others the unfamiliar appearance is rejected. In Britain, for instance, the fillets would be regarded as shrunken and distorted. Such difficulty is commonly associated with a pre-rigor cut and contraction prior to freezing with the flesh unattached to the skeleton, in which case pre-freezing operations should be speeded up under chilled conditions, avoiding rough handling. Alternatively, the distortion can result from "thaw rigor" in which case, "conditioning" in cold store or slower thawing are called for. It is debatable whether analogous "thaw-rigor" "break up" effects are encountered in practice in whole fish thawing.

In the context of secondary processing and refreezing, the distortion of fish sticks can give trouble from time to time. Invariably such sticks are found in practice to be cut from blocks frozen pre-rigor. Control is by the substitution of in/post-rigor frozen blocks or "conditioning" the pre-rigor frozen blocks in store prior to thawing.

Various discolouration reactions can be encountered in frozen fish. Generalized or sub-dermal red/brown discolourations in the surface region can result from carbonyl-amino reactions or, particularly if more pronounced at the surface, they may result from haem pigment contamination possibly associated secondarily with carbonyl-amino reactions. Control of carbonyl-amino reactions is by (a) the manipulation of reactant concentrations by suitable treatments such as autolysis control, leaching, prior to freezing, (b) the use of anti-oxidants or sulphite as permitted by regulation, (c) the lowering of store temperatures and the use of glazes and adequate packaging. Haem pigment contamination is readily controllable, as we have seen, by adequate attention to bleeding techniques and chilling.

In the case of fillet freezing operations, delaying filleting, until *rigor* is well advanced, also avoids a common situation where blood pigments are expressed to the surface of the fillet during incipient *rigor* contraction.

Discoloured belly flaps result from gut breakdown and are controllable by early evisceration.

Discoloured, desiccated surfaces are frequently associated with "freezer burn": lower storage temperatures and the use of glazes or more suitable packagings is indicated.

Tuna processors are seriously concerned with a problem of "green tuna" associated with the chemical modification of the haem pigment. The picture would appear to be still one of some confusion but there are indications that the breakdown of trimethylamine oxide (see above) may be implicated. In practice, processors commonly test small portions of the flesh before canning the main bulk.

For some special markets, the discolouration of skin pigment may be a major factor in saleability. This field is currently under exploration particularly by Japanese workers in the context of carotenoid stability. It may well be of increasing concern for industries serving populations demanding intact fish.

3.12 Transport of frozen fish[45, 46, 47]

Economic consideration in the transport of frozen fish are taken to be somewhat outside the scope of this paper. Attention should perhaps be drawn nevertheless to the presentation of papers on economics of modern distribution of frozen fish products, the transport of frozen fish, and the economics of fish marketing at the F.A.O. conference on the Freezing and Irradiation of Fish in Madrid, 1967, by Holiman, Foley and Crutchfield. It is indicated that far more intensive economic studies should be carried out and national and international levels into the cost and operations of freezer vessels for instance and the influence of sea frozen fish on national markets in the context of transport costs. Questions of the economics of consumer pack production as against industrial blocks at sea are raised, in the context of processing and transport costs at sea and ashore. Specifically in relation to the current situation in a number of developing countries, it is interesting to note that Moal and Gousset point out that in W. Africa the state of the roads, and the dispersion of the retail outlets at the present time, preclude the extensive use of refrigerated trucks for the distribution of frozen products. They point out that fundamental principles of refrigeration merchandising, as commonly understood, can be adopted only to the extent that allowance has to be made for the African consumer who buys fish only when he intends to eat it immediately.

4. DRYING, SALTING AND DEHYDRATION

4.1 Background[3, 48,49]

Primitive drying to preserve fish has been practiced for centuries and quite sophisticated attempts of dehydration involving patenting go back for almost a century, as Jason[48] has pointed out in his excellent review. The term "dehydration", as distinct from drying, has come into conventional use, as being restricted technically to any process of drying by controlled artifical means. Thus hard drying without salt to produce stock fish in the Scandinavian manner, would not be regarded in this sense as dehydration, nor would the sun drying operations often seen in developing countries qualify.

4.2 Physical considerations[48, 50]

The physics of fish drying has, in the past, been the subject of considerable research. Work has been carried out on water migration within the material, its removal from the surface, mixing with the surrounding atmosphere - and, on the other hand, on the emmision of heat from source, its transfer to the surface, conduction within the material, providing latent heat for evaporation and partial enthalpy of dilute solutions. Most work has been on basic theoretical aspects of fish drying, however, carried out on Gadus calarius and Clupea harengus which are biochemically quite different in many respects of muscle stability from fish of tropical waters.

4.3 Natural drying[3]

Natural air drying is found throughout the world. The fish are gutted, split, possibly beheaded and often hung on a drying rack. The drying rate in the initial stage depends solely on the rate at which water evaporates from the surface and this depends upon the surface area exposed to such factors as temperature and the relative humidity and velocity of air flowing. Obviously, these factors cannot readily be controllable. When the surface of the fish is partially dried the drying rate slows down and is determined by the rate at which the moisture can reach the surface from the inner layers by diffusion. This, in turn, depends on such factors as the fat and moisture content of the flesh. Cole and Greenwood-Barton[3] have described a range of simple arrangements for sun drying in the tropics. Fish may be set to dry in the open sun, sometimes on mats and sometimes on drying racks. Often they are laid on the sand. These authors stress the necessity to take full advantages of prevailing wind and the avoidance of sandy or marshy areas to avoid contaminating with dust on the one hand and the effects of high relative humidity on the other.

4.4 Dry salting

Dry salting may be regarded as a development of simple drying. Jarvis[51], has described methods of preparing dry salted fish in warmer climates. Where humidities are low, the approach is relatively simple. In high humidity areas, artificial heat is required to lower moisture content to acceptable levels. In the latter case, for instance, in W. Africa the fish may be dried on grills over open fires - and hence it is often broiled in the process. There has been some concern about this form of drying as a possible contributor to the high incidence of primary carcinoma of the liver commonly occurring in parts of the tropical world. Nitrosamines can be formed and the flesh can be contaminated with polycyclic compounds from open fires. Presently, no firm evidence on causal relationships appears to be available, but this is a field that obviously the chemist and the epidemiologist should investigate, by comparison for instance, with a current interest in the contamination of staple tropical foods, such as groundnuts, with mycotoxins.

Developments of such drying at the simple technological level commonly involve salting and smoking. Indeed the three approaches are often used in combination.

Dry salting under tropical conditions reduces the moisture content to varying degrees from the original 75 to 80 per cent of water. A survey of Singapore markets for instance measured water contents ranging from 36 to 65 per cent, whereas those from Aden range from 33 to 39 per cent, the fish being prepared in the dry atmosphere of the Gulf and Red Sea areas. At the higher end of the moisture range, S. E. Asian products have a life of only a few weeks whereas most of the dried fish sold through Aden is marketed in Ceylon and E. Africa three months or more after processing.[3]

In such types of preservation, the main preservative action of salt is the removal of water by osmosis rather than the suppressing of the spoilage microflora. Heavily salted material is difficult to dry naturally in the humid tropics, however, as it tends to absorb moisture from the atmosphere. Obviously, a balance of factors is involved.

Most salt used for curing in the tropics is prepared by the direct evaporation of sea water, with occasional refinements. Cole[3] makes the observation that fish salted in pure sodium chloride tends to produce a "flabby pale yellow" product without the characteristic flavour of salt fish. He notes that very small quantities of calcium and magnesium salts are invariably present in commercial salt and that these whiten and stiffen the fish, imparting a bitterness that most salt fish consumers like. At the same time, the author has seen a fish of very bad colour produced from material cured with some crude commercial solar salts. The presence of copper and iron salts in trace amounts is particularly condusive to a carbonyl-amino reaction that, in addition to precursing excessive quantities of brown pigment and the production of off-flavours, are also a potential hazard to nutritional quality.

A hazard in dry salting operations is the presence of a salt-adapted microflora that causes "pinking" in fish of too high a moisture content. The bacterial count of salt can be reduced by long term storage under tropical conditions. The microflora is relatively inactive when the fish is held under concentrated brine or in fish of very low moisture content. Consequently, where "pinking" difficulties arise, a salt pickle technique should be used together with rapid drying, possibly accompanied by hot smoking.

Acceptability of salt fish products in some developing countries follows a pattern quite different from others. Fish that a European would consider of good quality is not necessarily preferable of those affected by the flavours of rancidity, pink or partial decomposition. It will be seen therefore, that there are possibilities of tailoring products, with the help of chemists and bacteriologists, to market requirements. The scientist can also play a major part in new product development along the lines. For instance, a new salted fish mince cake preparation currently under investigation by M.I.T. and the new Fisheries Institute in Guaymas, Mexico, shows considerable promise, particularly for the utilisation of shark.

The more traditional approach, if it is to be carried out satisfactorily involves immersion of the fish in brine. In practice in the tropics this situation is best contrived by dry salting in layers in a vat or tub so that the brine builds up and covers the fish.(3) Tanks should be shaded to reduce the temperature. Prior to salting, large fish, especially tuna and mackerel, should be bled at sea (haem pigment has undesirable effects on oxidation and carbonyl-amino reactions). Although, in some operations, fermentation may actually be encouraged, and in others relatively poor material - for instance, that unsuitable for freezing-may be dry-salted, it is undoubtedly best practice in most circumstances to process fish as fresh as possible.

At landing the fish should be washed immediately in 10 per cent brine, beheaded (except when the market demands the head's retention) and then split to expose maximum surface for salting. Much of the backbone is removed except from the smallest fish and scoring cuts are made. Fish are then soaked in brine prior to salting as described above and dried, commonly on racks. Ideally, fish should not be dried on mats as these offer very little protection from dust. Additionally, the Dermestid beetle shelters under such mats during the heat of the day and emerges at night, when the temperature falls, to consume the drying material. It is not my intention to introduce into this paper a major consideration of the problems of insect infestation of fish. This can be controlled in large part by attention particularly to the avoidance of putrefraction prior to handling in the case of the dry salting operation; but obviously, the storage entomologist has a major contribution to play in the preservation of dried produce in many tropical situations.

Exposure to direct sunlight should be avoided with fat and semi-fat species since light accelerates lipid oxidation. The situation is aggravated by the known catalyses of lipid oxidation by high salt concentrations. To take account of diurnal variations in humidity, Cole and Greenwood-Barton suggest that fish be taken under cover at night and subject to pressure to flatten the fish and equilibrate moisture contents.

4.5 Dehydration

A number of more sophisticated techniques of drying have been developed that dispense with requirements for salting where natural conditions of drying are not quick enough to avoid putrefraction (although the simpler procedures can be used for overcoming the difficulties and uncertainties caused by the weather in salt fish drying). Much of the earlier work on wind tunnel drying was developed in N. America and Norway. For instance, Linton and Wood[52] showed that optimal air velocities over the fish should be between 200-300ft. per minute. Slower velocities decreased the rate of drying while faster velocities led to little improvement and merely added to the power costs. Optimal air temperature was considered to be 24°C (27°C max.) with relative humidities of 40-55 per cent. More recently, Jason at the Torry Research Station, Aberdeen, has developed and patented a programmed tunnel dryer together with a major British shipbuilding company.

Cutting and his collaborators[49] have described approaches to the drying of minced fish. This is a generally applicable approach, obviously capable of extention to a variety of species. The flesh is pre-cooked, removing some 20 to 40 per cent weight as liquor, spread on trays and dried in a plant based on the Torry mechanical fish smoking kiln. Air speed is considerably lower than in the Canadian practice referred to above (10-15ft. per second) and temperatures were higher (65-70°C) at the end of the operation (having at the start of drying been even higher at 80-85°C). Wet bulb temperatures in the operation was controlled at above 50°C initially to avoid proliferation of the microflora. It is believed that high temperatures may be more generally acceptable for tropical species.[53]

4.6 Freeze-drying variants, particularly AFD[50,53,54]

Among the more exciting developments in dehydration during the last 20 years have been those of the variants of freeze drying, particularly accelerated freeze drying (AFD) in its various modifications. Heat is applied to frozen material from both sides, the escape of water vapour being facilitated by the use of, for instance, expanded aluminium sheet between the product and heating plate. Under these conditions, the removal of water vapour from the vacuum chamber rather than the fish becomes a limiting factor at the commencement of drying (pressure about 1 mm. Hg.). With charges of the order of a ton of fish the evacuation rate is about 86,000 litres per second. Heat transfer problems also arise as a limiting factor in the reduction of drying times, and other modifications to plate surfaces have been advocated, involving physical penetration of the flesh with heated surfaces.

Product stability problems have been encountered, particularly carbonyl-amino and lipid oxidation reactions. Control is by packaging in inert atmospheres and by manipulation of composition before freezing (see above).

Other approaches, along the lines of dehydrofreezing, in which the material is part dried and then frozen, have been, in the main, less well received; and, even accelerated freeze drying has severe limitations as an economic process for fish species other than those of high innate value. Cutting[53] has presented a very critical view and the situation has not changed significantly.

4.7 Fish protein concentrates (F.P.C.)[55,56,57]

In 1946, a patent was filed for a method of dehydration involving heating in oil under vacuum. It is understood that this method has not been adopted commercially for fish, but it has certain points in common with developments of considerable interest currently aimed at the economic production of fish protein concentrate. Lovern[55] pointed out in 1966 that it is ironic that some of the most protein deficient populations are engaged in the large scale exportation of protein in the form of fish meal, with Peru as the outstanding example, together with Chile, Southern Africa and Morocco. This situation has, of course, been recognized by the Agencies and considerable activity has been directed in these countries to diverting part of the fisheries production to direct local human use as F.P.C.. Lovern commented that none of these exercises had developed beyond the point of pilot plant production but there have been further developments since 1966, for instance, in Morocco.

F.P.C. can be defined as a stable fish preparation for human consumption, with the protein content higher than that of the original fish. While commercial fish meal itself has potentialities as a fish protein source for Man, it is not, in the ordinary way, intended for human consumption, being prepared to lower standards (see below). Apart from the microbial hazard, fish meals are subject to, for instance, lipid oxidation. Such reactions are potential hazards to Man insofar as feeding has to be considered in the long term rather than for a few weeks or months as in the production of pig or poultry meat. Nevertheless, Lovern reports another interesting facet of the consumer-acceptability picture in this context. In Peru, the Indian population in the Sierra apparently appreciated the flavour of oxidised fat but eventually suffered illness.

The Protein Advisory Group of the United Nations Agencies has a close interest in the development of F.P.C. programmes, encouraging the development and production of virtually odourless and tasteless materials with very low lipid contents, of the order of 0.75 per cent and below, with effective removal of "harmful" solvent residues.

Other approaches to the F.P.C. production problem are fish protein hydrolysis produced chemically or enzymically followed by concentration. These, of course, have much in common with the traditional S.E. Asian production of fish sauces. However, the potentialities of such developments in tropical countries are best considered under the section of this paper that covers these fermentation procedures.

In the extraction type of process for the removal of lipid and/or water, progress has been made in the development of the use of improved solvents but it would appear that the scientist may be able to make further contributions to a process involving precooking and pressing prior to drying. No oxidation problems occur up to that stage of processing if fresh raw materials are used; but when the press cake is dried further into meal, oxidation can set in rapidly, particularly if open flame drying is employed. Further work on the suppression of oxidation would appear to be very well worthwhile in the context of the avoidance of difficulties at the drying stage. At least one manufacturer of solvent-extracted fish meal adds antioxidant to solvent[56]; and this results in uniform distribution of antioxidant in the remaining oil in the meal as well as stabilising the recovered oil. It would seem though that the efficient addition of acceptable antioxidant at the press cake stage would provide a major breakthrough in F.P.C. technology.

Another approach to the problem of oxidation is the employment of fish with flesh of low oxidation potential. An outstanding example of this is the production of meals from sardines caught in some W. African waters. It would appear that analytical programmes aimed at the identification of fish species of high tocopherol content are well worthy of support. Other approaches, to the incorporation of anti-oxidants, are the use of wood smoke, suitably prepared or treated subsequently to remove possible contamination by carcinogen and the substitution of relatively inert oils such as peanut oil for the original oil. This, of course, is a variant on the type of drying than referred to above.

Technically, the solvent problem remains an important consideration in the development of F.P.C.[57] particularly that of the highest quality (type A, PAG). Solvents must remove both lipids and the other precursors of off-flavours and odours. Lower alcohols such as methanol, ethanol and 2-propanol have been employed. However, methanol is such a poor fat solvent that it has been of use only for the upgrading of cruder F.P.C. (type B, PAG). Questions of residual toxicity also arise with solvents. Two-stage processes involving successive extractions with hexane and ethanol may have advantages where solvent costs are a major consideration in the economics of the process. 2-Propanol-water systems have proved of considerable value for white fish meals. Fatty fish present more of a problem and the use of solvent mixtures incorporating non polar constituents such as hexane and ethal acetate is preferred. In this field as, in many others of fish preservation, all the indications are that an intelligent flexibility of approach according to the nature of the raw material is indicated rather than the adoption of over-rigid patterns of operation. It would appear that the removal of the last traces of flavour precursors is one of the areas that requires particular attention since the problem of "reversion" to fish-meal-like flavours has not been fully resolved.

Perhaps the major problem facing the food scientist and technologist in the F.P.C. field is still that of acceptability. Undoubtedly, there is a strong resistance in many populations to the acceptance of high protein foods as bland, white powders. At a time when technologists in the plant protein field are seeking to simulate flesh-like texture, it seems ludicrous in some respects conciously to disrupt texture as in current F.P.C. approaches. One avenue of research and development that seems well worth persuing in the present status of food technology would be the application of some of the techniques used in the preparation of defatted odourless fish meals for F.P.C. production to the processing of structurally intact fillets of fatty species. Recent developments in flavour chemistry could undoubtedly be put to good use in simulating flavours "tailor made" to local tastes.

4.8 Fish meals for animal feed etc. (59,60,61)

Much of the background to commercial fish meal production has been considered in the preceding section. Fish meal consists essentially of the ground dried carcases of fish, the body oils of fatty species being recovered before drying since oil production is a critical economic consideration.(Also, as we have seen, oil content affects drying rates). Moisture content must be of the order of 10 per cent maximum since mould growth can be encountered a few per cent above this. However, if the moisture content is reduced below 5 per cent, the meal may be damaged during manufacture, by overheating - Another factor is the antioxidant properties of water: there is a balance of considerations of oil and water contents. Apart from the obvious undesirability of oxidative rancidity development, there are also very considerable dangers of spontaneous combustion if precautions are not taken.

Formerly much of the fish meal produced was used simply as an NP fertilizer, but meals are now usually incorporated into compound feedingstuffs, often for feeding to livestock in the developed countries. In the past, the use of high protein concentrates might well have been regarded as highly wasteful when, with some relatively minor improvement they could have been used for direct human feeding. However, the recent spectacular increases in conversion rates in for instance, "factory" poultry-raising exercises shows promise for the use of meals in the production of highly desirable and readily acceptable fresh animal flesh protein in some developing countries. In this context, the questions of potential long term toxicity in meals subject to a measure of rancidity, or of contamination with polycyclic compounds deriving from the operation of direct flame dryers, are less relevant than those applying for instance, to the long term feeding of children.

In the common pattern of production, raw material (whole fish or the waste from other fish processing) is chopped mechanically, and cooked and dried directly when the material utilized is of a non-fatty nature. Frequently indirect steam heating is used. Such operation is known as "dry reduction" and is often continuous.

Usually, however, in tropical industrial fisheries the raw materials are densly-schooling clupeid species. With these, the oil is pressed out after cooking, the fish being pretreated by a wet reduction process in which live steam is the heating agent in direct contact with the chopped fish. At the next stage, direct dryers are commonly used, the material being heated by parallel flowing flue gasses and hot air from a furnace. Very high temperatures are used and the drying time may be as little as 15 minutes.

Simpler direct driers are being replaced currently by air lift systems on the larger scale industrial level. However, I would judge that there is an extensive demand in many countries, that are currently taking an increasing interest in the development of their fishery resources for effective, simple and cheap small scale fish meal manufacturing units. One has in mind for instance, some of the Caribbean islands which have on the one hand a chronic shortage of first-class protein feedingstuffs for their developing pig industries (with a consequent drain on their currency resources to import compound feedingstuffs from N. America) while at the same time there are growing efforts to exploit the Caribbean fishery in general both by local operation and in the basing of far ranging shrimp vessels. In some situations considerable amounts of offal can result from the processing of the latter's catches. In recent years, fish meal has increasingly been sold on its nutritional value rather than on its protein content alone. This followed the observation that protein can be damaged during processing, notably by the reaction between the -amino residue of the protein lysine and carbonyl compounds. The limitation of temperatures and oxidising conditions helps in this respect and there are also possibilities of control through the manipulation of fish after catching to minimize the concentrations of reactive sugars. Economically, the recovery of the "stick water", by evaporation until the solid content rises to about 50 per cent and either its direct sale, or admixture with presscake for the production of meal, is important.

As mentioned above, fish meal is subject to oxidative heating, if not treated carefully; this also tends to precipitate damage to proteins. The material leaving driers contains very reactive oil residues: it must be allowed to cool before grinding; and after grinding, sacks must be stacked loosely for a period of weeks before the meal can be handled further safely.

Obviously, the production, utilisation and further development of fish meal is very much an interdisciplinary exercise in which the engineer, chemist, microbiologist and the nutritionist must work closely together.

In the nature of the fish meal operation as it has commonly developed, yet another discipline- that of the odour chemist - has been in considerable demand and may well become increasingly so. I have referred briefly to the reversion problem: in the vicinity of meal factories, there is very commonly a major air polution problem. A number of approaches to a solution have been made: closed systems of meal production, a variety of "scrubbing" techniques and the admixture of effluent gases with odour-masking agents are being employed or contemplated. The optimal economic solution may well vary according to local conditions. Probably this last problem is not as relevant to the situation in some newly developing fisheries as elsewhere. Obviously, however, if uncontrolled, it could conflict, for instance, with the development of new tourist industry.

5. SMOKING (3, 61, 62)

5.1 Background: factors in curing

Smoking is a method of preservation effected by the deposition of naturally produced chemicals resulting from the pyrolysis of wood in combination with drying and often salting. The salting aspect is of particular relevance to the situation in some developing countries where communication difficulties limit the direct utilisation of fresh fish by the population. Elsewhere the tendency has been towards lighter curing and this would have to be taken into consideration in the context of any proposed development of export industries. Another divergent pattern of smoking between developed and underdeveloped countries is that the latter tend more towards the use of hot smoking, which involves considerably greater degrees of cooking than the methods of smoking commonly practiced in Europe.

5.2 Chemical and physical considerations

Although the present day methods of smoking are essentially not dissimilar from those in operation centuries ago, this has been a field in which chemists and physicists have made major contributions to economics of operation and questions of quality control. In the latter context, there is continuing interest in questions of minimizing potential hazards arising from the presence of polycyclic hydrocarbons in some smokes.

Foster[64] in a physical analysis of the gaseous phase - aerosol complex has shown by reference to Simpson's chemical analysis[64] that under a given set of conditions, concentration of the particle phase has a fixed relation of that of the vapours, and that while the chemical compositions of both phases are similar, particles contain a greater proportion of components of high molecular weight. In other respects the early concentration of physical research on possibilities of increasing rates of deposition of the particulate phase on fish surfaces proved to be unfruitful, as it was shown later that the vapour phase was the effective agent in the smoking operation. Consequently, efforts devoted to the electro-static deposition of particles were of relatively little value in improving kippering technique. This abortive approach stemmed from a failure to appreciate that fish is essential a wet biological material rather than a dry inert block. At the danger of over be-labouring the point it seems opportune to indicate that in smoking as in other processing operations the interdisciplinary approach is a prime necessity.

Sophisticated equipment has been devised for the continuous monitoring of "smoke" densities.[61]

The chemistry of smoke has been studied for many years.[64] Flowing compositional studies on the alcohols, carbonyls and low fatty acids[65], investigations extended to polyphenol and polycyclic aromatic compounds. This work has been of subsequent value in refinements of traditional smoking techniques,[64] using the principle of dipping in smoke solutions followed by drying. Furthermore, it has been relevant to the development of antioxidant studies of potential value to the preservation of fatty fish in the dry and frozen conditions. The possible utilisation of some of the compounds for the suppression of spoilage microfloras has also been under consideration in view of the known preservative actions of smoke. While perhaps such background work is of relatively little application to the modification of some of the simpler, primitive smoking techniques encountered in many tropical situations, it has been, together with biological and bacteriological studies and the development of drying theory, of considerable value in the introduction of sophisticated techniques of considerable commercial application, such as the well known Torry kiln, now found throughout the world.[62] Very probably, similar approaches could be made to the automation of some of the traditional hard-smoked, precooked fish products of the Orient.

5.3 Quality

When fish is to be smoked in the lightly salted and uncooked form most populations prefer a lightly coloured, translucent flesh of good surface gloss. In practice, this implies the use of raw material in reasonably good biological condition.[1] Where, as is increasingly the case in a number of countries, the product is prepared from thawed, sea-frozen fish, this must be free from the surface defects considered in the section on freezing.

5.4 Methods

Space does not permit more than passing reference to the various methods of preparing fish for smoking. There are a number of excellent reviews on the subject. Neither do I propose to discuss traditional smoking, A variety of kiln-types of varying degrees of complexity and arrangement is available. The Torry kiln,[62] developed at the Torry Research Station at Aberdeen, is one of the more successful mechanical kilns and this type of design has made increasing headway during the past decade. This is perhaps the more surprising against a background of a large number of unsuccessful commercial efforts ranging over 30 years. Cutting comments in his excellent review on smoking[61] that the comparative failure of many attempts in the past had been because kilns were designed either by practical fish smokers without the necessary grasp of engineering or by engineers without an adequate appreciation of the conditions demanded in a satisfactory smoking regime. It would appear that, even now, all the parameters have not been established and that much useful work could be carried out to extend the types of consideration mentioned above to smoking operations in developing countries attempting to introduce an industrialised fishery. Such research should of course, take account of local tastes.

Smoked fish can be frozen and there are possibilities for the development of export industries. Requirements for cold storage are similar to those discussed with fresh fish.

6. CANNING[58, 66, 67]

6.1 Background

Canning preserves fish by killing the microflora by heat treatment and the prevention of their invasion of the food subsequently. Additives may be used to complement the preservative action and to increase acceptability through the manipulation of appearance, flavour and texture.

6.2 Microbiological considerations

Bacteriology is undoubtedly of paramount importance among the sciences in such operations. In practice, complete sterility is rarely, if ever, attained so that the canning bacteriologist tends to consider "statistical sterility" in his control work; or even "commercial sterility" or "commercial stability",[68, 69] implying that food is free of pathogens and that it will keep for two years or so under normal circumstances. It should be emphasized in the context of this paper, however, that considerations of the maintenance of canned produce in accpetable condition in a tropical environment are very different from those in many developed countries with lower ambient temperatures. Keeping times tend to be much lower and there is far greater tendency for cans to "blow" or corrode.

The general principles covering the differential heat stability of microorganisms likely to present a hazard in fish canning are reasonably well established. Particular attention has, of course, been devoted to Salmonella, Staphylococcus and Clostridium spp. For safety, it is essential to carry out processing at a temperature low enough to destroy the most dangerous of the pathogenic spores, Clostridium botulinum, which proliferates under conditions of low oxygenation and at non-refrigerated temperatures. Time/temperature regimes equivalent to 4 mins. at 120°C are indicated. "F values" (the equivalent time in minutes to treatments at 121°C or 250°F) are commonly used in calculations of this nature. n practice, other microorganisms are often more heat resistant than Clostridium botulinum. But excessive heat treatment affects the organoleptic qualities of the product and a solution that frequently is suggested is that handling likely to contaminate the produce prior to canning with thermophilic organisms be avoided. Obviously, this is more difficult under the environmental conditions pertaining in many tropical developing countries than elsewhere. Useful lines of research, that could profitably be extended to the develo ment of canning of unfamiliar species, have been prosecuted on the effects of substances that control osmotic environment within the can as an aid to the suppression of the microflora.

It will be seen that an essential prerequisite in a rational canning operation is the processing of fish of minimal count and the avoidance of contamination of the pack through the use of spices and other additives of poor bacteriological quality. Consequently, when the fish is to be canned some time after catching, careful attention should be given to the principles of chilling, as indicated in the earlier section. Or, if the fishery is a considerable distance from the point of catching, adequate attention should be given to scientifically based chilling/freezing/thawing technique.

6.3 Physical principles and quality considerations

The physical principles determining passage of heat into the can are well established.[70] They relate to external transference (such as the heat capacity and movement of liquid heating media, especially in the context of flow along the can wall), transference through the wall and convection and/or conduction within the can. Considerations of transference accross the wall only arise practically with non metal "cans". The heating regime of choice depends in part on the balance of quality factors, which vary in turn with species and on the nature of the market. Heat penetration can be accelerated by a selection of suitable canned geometry, as for instance, the flat cans favoured for sardine and brisling canning. Van den Broek[66] refers to the possibilities of agitating the can during processing as is used for vegetable products. However, this is likely to prove disastrous for delicately textured species which normally require a considerable "firming up" period subsequent to cooling before they can safely be shipped out of the factory.

Ideally, high temperature/short time processing is advantageous in minimizing destruction of essential nutrients during canning operations. In canned fishery products, however, heat conduction problems within the can severely limit possibilities for the adoption for such procedures. Commonly, steam heating under pressure is employed, although other possibilities such as dielectric heating are of commercial interest with some packaging materials.

Acceleration of cooling subsequent to retorting is usually carried out by contact with cold water. As a number of unfortunate incidents (particularly with canned meat products) has indicated, extreme care must be taken to ensure the purity of cooling water. The vacuum set up within the can frequently draws small quantities of the cooling water into the pack. If for instance, the water is contaminated with salmonelli, the results can be unfortunate for the consumer.

6.4 Operational and chemical considerations

Present-day canning operations in developed countries are often of very large scale and highly automated. Considerable care is taken to avoid spoilage. In some operations, preprocessing storage is accompanied by salting so that the addition of salt later in the actual canning process is eliminated.

Fish is commonly precooked before retorting. Precooking may take place either before or after packing into cans. The object is to remove the water released from the flesh during coagulation of the proteins so as to avoid a mushy pack. Insofar as this water loss also represents potentially some economic loss, approaches to its avoidance by the addition of compounds such as carboxymethylcellulose and polyphosphates have been made. An increasing knowledge of the possibilities of manipulating water-binding capacity of proteins may well be of value in this context.

Precooking can be carried out by a variety of processes. For instance, in the Norwegian brisling cannery, vegetable oils have been used as heat transfer media. In some operations such as that of W. African sardine cannery of my acquaintance, it has been found in practice that precooking in oil can give rise to serious stability problems in the can, if the fresh oil supply is not replenished at an altogether uneconomic rate. In such situations, hot air cooking is commonly practiced, often in the cans, which are then inverted mechanically for draining. Alternatively, infra-red heating can be used to good effect with some species.

A voluminous literature has described the research and development effort over the years on the development of suitable cans for fish, particularly in the context of difficulties arising from the organic sulphur content and that of trimethylamine oxide. (see 66) A number of protective coatings or lacquers tend to become soft on heating and this can give rise to sticking problems. The phenolics are of relatively limited value, presenting some problems of off-flavour development and being flexible only in very thin layers. Oleoresin lacquers have good all-round properties being of good chemical resistance and of low price and versatility. Epoxide lacquers have also good all round properties in many respects. Inorganic additives such as zinc oxide are of value as additives to lacquers for some purposes. Other inorganic treatments, such as the "protecta-tin" process (stabilization with phosphate, chromate and a wetting agent at high pH) are useful in some situations. In others, vegetable parchments are of value, for instance, in the canning of crustaceans and some smoked fish. The object is to avoid sticking and "break up" within the can and discolouration reactions.

It is not proposed to cover other types of pack (for instance the glass jar) in this paper. Canning operations in general follow much the same type of train. After precooking the material is placed in suitable cans (if this is not already been done), together with any additives. The can is then "exhausted" to remove air from the can which is then closed and sealed. It is then heated ("retorted"), and cooled. Some of the additives in use have been discussed above and many of these have firmly established scientific as well as empirical bases for use. For instance, glutamates are well established flavour additives and there are further possibilities of development with the newer 5'ribomononucleotide additives. Vegetable oils are used frequently, so that the questions of oil stability and flavour arise.(8) Tomato sauces are also extensively in use and can present problems, for instance, with discolouration through browning reactions.

Exhausting can be carried out by a variety of processes, including the heating of the can contents either before or after packing, filling the head space with steam or sealing under a mechanically applied vacuum.

Processing and retorting are a critical stage in the canning operation, involving, as we have seen, a delicate balance between the requirement to lower the bacterial count to acceptable limits on the one hand and to avoid acceptability problems on the other. Sticking and scorching of flesh adjacent to the walls, undesirable off-flavours resulting from carbonyl-amino reactions and the breakdown of trimethylamine oxide (together with associated discolourations in the product and excessive shrinkage of the musculature) have all to be avoided. Batch systems of operation have considerable advantages in terms of flexibility at this point of the operation although in the large scale production of standard size packs, continuous systems are often more economical.

Retorts are of a variety of basic types: horizontal, vertical, static and rotating. During retorting, it is essential to avoid air pocketing in the retort if rapid heating rates are to be obtained.

Cooling subsequent to retorting is a critical stage in the operation. As well as the bacteriological hazards referred to above, the processor must consider the avoidance of any aggravation of undesirable reactions set in train by the sterilization process.

After cooling, a period of storage prior to shipping is indicated for many species. Not only is a period of "firming up" a useful insurance against damage during transit: also, flavour often improves very considerably. Indeed, under some circumstances, material that showed incipient lipid oxidation prior to canning, with attendant rancidity, often improves in flavour considerably after a period of storage in the can.(8)

Obviously, the author is unable to cover the very wide range of considerations that arise during the canning of individual species. Reference has been made elsewhere to the discolouration problems of tuna resulting from the reactions of haem pigment. In relation to other types of product, some coverage has been given to carbonyl-amino reactions which can be very troublesome in some canned produce.

This is a general field of operation in which the scientific "troubleshooter" can be of very considerable value to the industry. In addition to the types of reaction touched upon above, considerable advances have been made for instance, in such varied canning problems as the control of struvite formation in the can and the ultra-rapid freezing of brisling direct from the net when they are destined for subsequent canning. The volumes edited by Borgstrom[71] contain a considerable coverage of the individual problems of the major species of commercial canning interest and doubtlessly much of this knowledge can be extrapolated to new species.

7. FISH SAUSAGE[72,73]

Fish sausage manufacture is a large scale industry in Japan although it started as recently as 1953. It has been watched with keen interest in other countries, and provides an excellent illustration of the beneficial effects of a well trained body of fishery scientists and fish technologists working closely with a developing industry. As Amano has pointed out, the traditional "kamaboko" industry (manufacturing a unique type of fish product resembling in some respects meat loaf) provided an excellent basis for the development, which accelerated with an introduction of vinylidene floor casings and improved closures. Perhaps the key to the acceptibility problem in Japan has been the utilisation of chemical additives to suppress the activity of the micro-flora in the absence of any significant heat sterilisation, together with an understanding of the factors controlling a resilient factor ("Ashi") in the product which is particularly desirable to the Japanese consumer. This in turn followed work on the factors controlling the stability of the muscle myosins - work which was also a major importance in connection with the development of freezing and cold storage technaques.[cf. 30,31] Much work had also been carried out in Japan on the preparation of fish jellies, in the context of treatment with salts, including the polyphosphates.

Starch, animal fat and spices are commonly mixed with fish for sausage production together with permissible colour additives and preservatives. It will be interesting to see how this industry progresses in a general world atmosphere of increasing legal restrictions on the use of many bacteriostats.

In addition to the use of more common additives and flavours, it may be of interest to note that the Japanese fish sausage industry was one of the first food preservation operations to bring into use 5'-ribomononucleotides as flavour enhancers.[8] Keeping quality is variable. Conventionally prepared sausage are said to keep up to some two weeks under refrigeration but only 3 days in the absence of preservatives at room temperature. Amano comments that with the use of "legally permitted chemical preservatives" fish sausage can be distributed at normal ambient temperatures in Japan for consumption over a period of three weeks. Of the recent developments in the world field of fish preservation in general, this has perhaps been the most striking, in terms of the intimate involvement of the muscle biochemist and the food microbiologist.

8. FERMENTED PRODUCTS[3, 74, 75, 76]

8.1 Background

During discussions in the earlier sections of this paper, reference has been made to consumer preferences in some developing countries for strongly flavoured products rather than the bland or sweetish character commonly appreciated in many European countries, Japan and North America. Frequently, strongly flavoured fish products are used as condiments, particularly when dry. In S. E. Asia, a number of unique patterns of preservation have developed that produce often very strongly flavoured sauces and pastes. These may well have potential for development in other tropical countries where questions of economics may limit the adoption of the more expensive drying techniques or refrigeration.

Van Veen in his excellent reviews of this field[76] comments that the tastes and dietary habits of the rice eater differ from those of the American or European. The diet is often monotonous and dominated by rice so that fish pastes and fish sauces with curries and spanish peppers are much in demand as flavorous additives.

He indicates also that, as in the case of almost all other types of processing that have been considered, the quality of this class of fish products is influenced not only by the method of preservation and the kinds of microorganisms present but also by such factors as the nutritional condition of the fish, the activity of the enzymes of the tissues and impurities in salt.

A wide range of fish sauces is prepared throughout S. E. Asia - in Thailand, Cambodia, Vietnam for instance - and also in parts of China. They are less well known in Indonesia and practically unknown in India. Some progress is being made in their development in W. Africa. They are produced particularly in countries where sun drying presents difficulty. Consequently, they are potentially of value throughout the humid tropics. Essentially they are a composite products of near-total lysis by the tissue enzymes and a highly adapted microflora in the presence of high concentrations of salt.

8.2 Preparative methods

Nuoc-Mam is produced mainly in Vietnam and adjacent countries. In its simplest form it is a clear brown liquid prepared by the maceration of small fish, which are salted, placed in earthenware pots, tightly sealed and buried in the ground. Pots are then dug up after a period of months and the supernatant liquid that is formed is decanted. Commercially, larger vats are used commonly with a ratio of 5 parts of salt to 6 of fish.

The length of time for fermentation varies considerably with the nature of the fish and the salt concentration. A year or 18 months is not unusual for the fermentation of larger fish. Often, additives of high carbohydrate content such as caramel, roasted rice or corn, or mollases are added later in fermentation, prior to separation of the solid materials. This produces an improvement of flavour and colour. By lowering the pH through the production of lower fatty acids it also improves keeping quality. The main nutritional value of such products lies in the content of lower peptides and amino acids produced from the lysine of protein.

8.3 Microbiology

The microbiology of the fermentation has been studied to some extent and is of a particular relevance since the development of a suitable microflora is a basic prerequisite for the production of Nuoc-Mam of desirable flavour. There appear to be considerable possibilities of developing this potentially useful field further, possibly in combination with the study of enzyme additives. For instance, fresh proteolytic pineapple juice is used in some areas and there has been some success with the utilisation of fungal enzymes.

8.4 Flavour chemistry

Some work has been reported on the flavour chemistry of fish sauces. The free amino acid composition is of course, of considerable relevance. The aromas appear to relate predominantly to the lower fatty acid composition, although it has been suggested that the lower "carbonyls" are of the major significance. In our laboratory currently, we have a programme of work on the basic flavour chemistry of fish sauces in terms of the differential composition of the flavour volatiles on the one hand and the nitrogenous non-volatiles on the other. This is aimed at the provision of practicable quality control standards for the development of fish sauce production in W. Africa although, of course, it is also relevant to S. E. Asian practice.

8.5 Variants

Other types of fish sauces are made throughout S. E. Asia. "Patis" is a product of the Philippines prepared from the fermentation of a number of species of fish and shrimps. Progress has been made in increasing speeds of fermentation by the use of suitable fungal enzymes and undoubtedly work along these lines could be of considerable significance for the area in general.

8.6 Fish pastes

As with the case of fermented fish sauces, carbohydrate materials are often added to fish pastes in their preparation. Such pastes are usually used as condiments for rice dishes. The ground fish is commonly mixed with salt in the ratio of three to one, and matured in vats for consumption either raw or cooked. "Bagoong", prepared from shimp is primarily produced by the lysing action of the natural enzymes rather than the microflora. While some chemical work has been carried out in relation to nutritional evaluation in terms of the crude nitrogenous constituents and inorganic salts, little information is available on the flavour contributing compounds other than an early study on amino acids.[77]

While touching upon S. E. Asian practice, reference should be made perhaps to the traditional hot brined and lighter salted products.

Undoubtedly, this general area of S. E. Asian fish products, particularly those prepared by fermentation and possessing strong cheese-type flavours, have considerable potential for use in developing countries more generally. Equally there is little doubt that there are considerable possibilities of improving and speeding production methods through a scientific understanding of the basic requirements for quality products in terms of the flavour chemistry, the microbiology and the biochemistry.

8.7 Other fermented products

Bacterially fermented herring and trout[78,79] are items of commerce in Scandinavia. They are not fermented to the degree common in S. E. Asia and retain structure.

Many consumers consider that a degree of fermentation is desirable in the more conventional anchovy packs.[78]

9. IRRADIATION[80,81,82]

It is perhaps symptomatic of the inbalance in fish technological work in the developing countries that when we turn from the traditionally well-established and effective but scientifically largely unexplored fermentation products of S. E. Asia to the highly sophisticated and controversial field of food irradiation we find very much more activity. It would, of course, be invidious to refer to specific examples. Undoubtedly, the successful developments of unequivacally safe products capable of being handled without recourse to refrigeration techniques is a glittering prize calculated to challenge the best of our young scientists.

Hobbs and Shewan[80] have reviewed the current views on irradiation sterilisation as seen from the European standpoint. It has long been recognized from laboratory experiments that fish and fishery products in general can often be preserved by irradiation. However, sterilization is not yet practicable because of the undesirable organoleptic changes that occur. Rather, radiation pasteurization is usually advocated, at doses in the range of 0.3 to 0.5 M rad or less. While a process would be economically feasible, the doubt preventing use is the possibility of increased health hazards.

With respect to the sterilisation cirterion in relation to the Clostridium botulinum problem, doses of the order of 4 to 6 M rads are required. This of course, is unacceptable organoleptically and some efforts have been made to increase safe doses by the use of chemical additives. On balance, Hobbs and Shewan conclude from the data available on the destruction of Clostridium botulinum toxins by irradiation, (rather than the organism) complete inactivation of preformed toxin in foods, cannot be expected.

Nevertheless, success has been obtained in some measure in the reduction of food infection microorganisms in sea foods more generally.[83] although "tailing off" phenomena appear to present a major problem.[84]

As we have seen, in practice organoleptic considerations govern the choice of pasteurizing approaches. These must of necessity be considered in conjunction with packaging, particularly that calculated to inhibit oxidation as in the case of vacuum packaging. The greatest extention of shelf-life is obtained by irradiation *in vacuo* at 0.3 M rad. However as Shewan and Hobbs point out, commercial utilisation of such a process must take into account use of good hygiene and low temperature storage. While also cautious in their approach, American workers[81] present perhaps a more hopeful appreciation of the field attempting to discuss the Clostridium botulinum Type E problem in perspective. Obviously, however, considerations for use in developing countries must be supported by bacteriological servicing of the highest order, and demand the detailed assessment of the incidence of occurrence of clostidia on individual species on specific grounds. It is of interest to note that an experimental irradiation unit has been operating at sea on an American research vessel. It appears that as in the case of freezing at sea, the rigor condition may be critical since pre-rigor fish were more suitable for irradiation than post-rigor fish.[85]

Goresline[82] has summarized a recent status of legislation on irradiation foods. A definitive statement on probabilities from a sister Agency at the working party would be of considerable value to our diliberations.

10. MARINADES ETC..

Marinades are produced mainly in Germany although found to a lesser extent elsewhere in Europe. Cold marinades are made from herrings and sprats by treatment with salt-vinegar brine, often together with special sauces. Cooked marinades are subjected to heating prior to packing in jelly. Fried marinades are heated in oil or fat prior to immersion in vinegar solutions.

A considerable volume of microbiological work[86] has been carried out on the spoilage microfloras that develop, more particularly in the context of additives.

Another group of semi-preserves, that is perhaps of debatable significance to the conditions applying in tropical developing countries, are the "tidbits" and anchovies produced in Scandinavia.[78] Salt, sugar and spices are added.

Maturation is mainly autolytic in origin. In many products of this type, however, a degree of microbial proliferation is taken to be involved in the development of desirable flavours.

A rather drastic variant on this theme for the production of fish ensilage for animal feeding by the AIV process.

11. FISH OILS[58]

While it may possibly be less relevant to the subject matter of the working party than some of the other operations discussed in this paper, the production of fish oils is a major industry, still contributing a significant proportion of the world oil supplies. The fish liver oils particularly were formerly the most important sources of vitamins A and D. Vitamin A can be manufactured synthetically, relatively cheaply but vitamin oil production should still be of interest in the developing countries where, as Cole had pointed out, that any manufacturing process using local resources reduced the strain on foreign exchange. It is known that some tropical species possess livers rich in vitamins and that these represent a little exploited resource of considerable potential nutritional significance that may well be worth developing. Tunas and, particularly, sharks of some species have potential. While the body oils are commonly a by product of fish meal production, liver oils are quite readily prepared by heat treatment and separation.

12. CONCLUSION

It will be seen that a very wide range of scientific disciplines contributes to the development of fish preservation technologies. Pre-eminent among these have been the biochemists, bridging the gap between the physical and biological sciences: but it is to be expected that the biophysicist will play an increasing role if only because frequently he has perhaps a readier appreciation of the engineer's problems. The successful exploitation of the work with industry must also involve close collaboration with the social scientists.

The role of the microbiologists in the practical control of putrefractive deterioration of fish species must on balance be considered somewhat disappointing. It appears to the author that the great contribution of the microbiologist in the development of the wide range of fish preservation technologies, and particularly as exemplified in the recent endeavours towards an acceptable irradiation technology, lies in the identification of potential public health hazards and their control. It could be argued therefore, on past experience that, where limited bacteriological service is available for research or control purposes, in developing countries, he should concentrate on the potential hazards to Man, rather than attempts at the identification of spoilage microorganisms and their complex changing interrelationships as putrefaction progresses. This is not to belittle the considerable volume of useful work that has been carried out in the field but rather to indicate a desirable order of priority in the context of useful, practically relevant work. The possible exception to this is the urgent requirement for work on fermentation. (see below).

Although there is still a place for the analytical chemist, interested in proximate analysis, the specialist for instance, in sophisticated lipid chemistry is more likely to make a contribution to an improvement in the technology of fatty fish preservation. Indeed both the lipid and protein chemists have played a major part in the development of freezing and cold storage.

It is interesting to note that flavour chemistry has now progressed to a stage where it is undoubtedly making very significant contributions to commercial preservation operations. Perhaps the outstanding example lies in the field of early flavour deterioration in fish muscle as explained by the muscle biochemistry of glycolysis and ribomononucleotide degradation. This has provided, on the one hand a new group of flavour enhancers, for use on a variety of foods, including fish sausage; and on the other hand recent developments in rapid analysis, including completely automated systems, provide the most satisfactory objective indices of quality currently available for a number of species.

This paper has not, in fact, dwelled on the major contribution of, particularly, the chemist and microbiologist to quality control operations. The prime necessity for these in the development of export industries in a new fishery is self-evident.

Throughout the paper, areas of likely potential in which the scientist could usefully make a contribution have been indicated together with the outline of preservation processes. It is apparent that the physicist can often give a lead to the engineer in his problems and that the engineer and the biochemist must work very closely together, as is evidenced by the development of freezing at sea.

A useful lession can be taken here for potential extrapolation to the situation as it may arise in the newer fisheries. Initially the approaches lay mainly in the hands of the engineer concerned with his refrigeration techniques on the one hand; and on the other with the chemist (rather than the biochemist) interested essentially in the problems of time/temperature tolerance in store. Both these lines of work, of course, were of considerable value to particularly the shore-based industry. But it was found that when the operation went to sea, at the commercial level rather than the research trawler vessel, entirely different considerations arose. For instance, fish was often stored only for relatively short periods, little longer than the fishing expedition. Consequently, work on extended storage was of little relevance. More to the point, however, the very high catching rates encountered raised major new problems, particularly in relation to the avoidance of undesirable _rigor_ effects and the preparation of fillets free from discolouration. Crash programmes of applied biochemical/engineering work were mounted and the problems were resolved within a few years. These difficulties might well have been anticipated had the vessel designers and the marine biologists, calculating likely catching rates and crewing requirements, engaged in adequate prior consultation with the freezing technologist and the muscle biochemist.

Among the greater challenges facing the fish preservation scientist currently, is the rationalization of fermentation procedures. This paper has discussed briefly current approaches of varying degrees of sophistication in S. E. Asia and elsewhere. Space has not permitted a discussion of fish silage preparations to any significant extent although this is essentially the approach to the preparation of F.P.C. from autolysates. Notwithstanding the comments above on the role of microbiologists in more traditional, Western preservation techniques, there is a strong possibility that he, together with the engineer, the enzymologist, the nutritionist and flavour chemist could revolutionize processing methods, quite possibly with repercussions in fish preservation patterns elsewhere in the tropical world and even in the developed countries.

In conclusion, it may be indicated that large numbers of practically relevant problems in fisheries technology have been all too readily apparent on any occasion that I have had privilege of visiting fishing communities in developing countries. This being the case, it is a matter of concern to observe, from time to time, competent scientists hired for fish preservation work but engaged in basic problems of little relevance to the immediate problems of the country. There is a great need for guidance in the identification of problems and of priorities. Equally there is an urgent need for the adequate integration of scientific work in what must of necessity be interdisciplinary approaches if they are to be effective. Finally, the question of training scientists for this type of work is worthy of rather more careful attention than is frequently the case. Not only is much of the experience gained by visiting workers from developing countries to the research laboratories of the Northern fishing countries irrelevant - much of it can be actively misleading.

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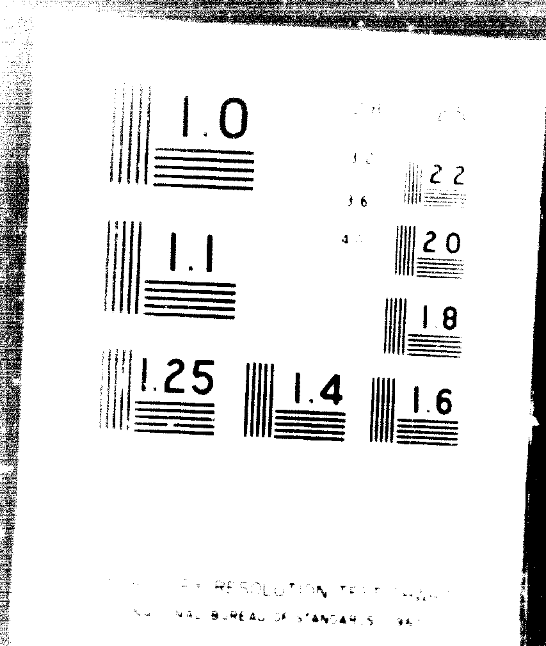

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