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Problems in the development of fish protein concentrates

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Most species of fish are edible and most of the abundant kinds are widely enjoyed as human food in one part of the world or another. In general it is problems of preservation and distribution that limit the wider use of fish in improving the world nutritional picture. Conversion of a general food, such as fish, into a food additive, such as fish protein concentrate (FPC), can only be justified if it offers some overwhelming advantage in economic feasibility, in price, or in acceptability to the consumer.

Some 40% or more of the world fish catch is presently converted directly into an animal feed protein concentrate, namely fish meal, production of which in 1967 exceeded 4 million tons. Fish meal is made by the relatively simple process of cooking, pressing out most of the oil and about half the water, and drying the press-cake (usually after addition of the concentrated press-water). The product, containing 65–70% of protein, fluctuates considerably in price but at present sells in world trade at about US $175/short ton (8·7 US ¢/lb). It will be convenient to use US units throughout, as nearly all literature values are so expressed. On a protein basis this corresponds to about 2 ¢/lb for the original fish (with 15% protein) and is the cheapest form of stable, processed fish in commerce. When, in 1961,

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there occurred a rapid and widespread growth of interest in FPC for human food, the possibilities of upgrading fish meal were naturally a prominent item in the deliberations of various working parties. It was appreciated that use of selected raw material, improved plant and process hygiene, and appropriate food packaging would increase the price but even if doubled it was considered likely to prove acceptable in the postulated consumer countries. Indeed, at that date (1961), when the world fish meal price was about 6 ¢/lb, a figure of 15 ¢/lb came to be widely regarded as an upper limit for any form of FPC. The most widely quoted draft specifications (Food and Agriculture Organization, United Nations, 1961) envisaged three types of FPC, one being an upgraded fish meal, one a partially defatted fish meal, and the other a virtually fat-free, odorless, tasteless product not detectable if mixed with some cereal-based food such as bread.

Despite evidence that in certain countries (e.g. Malaya, *cf.* Thomson & Merry, 1962) the strong flavour of fish meal was acceptable, despite expert opinion at working parties that in amounts of about 20 g/day (containing up to 2 g of oxidized fat) it would be safe to feed it to young children, the view has gradually hardened in various official quarters, including the United Nations Protein Advisory Group, that to be acceptable to the poverty-stricken, protein-starved peoples of the world a food must also be acceptable to the sophisticated palates (and even to the aesthetic concepts) of the well-fed. Specifically, any suggestion of an upgraded animal feed supplement must be avoided.

Most of the attempts to manufacture a tasteless FPC and to introduce it into some staple food such as bread have, in fact, used fish meal, rather than fish, as the raw material (e.g. in S. Africa, Morocco and Chile). The problem is to extract both water-soluble flavours and almost every trace of lipid material. Any remaining lipid is liable to oxidize during storage of the FPC, with production of off-flavours. This demands the use of solvent mixtures comprising mainly a lower aliphatic alcohol with a little water. Thus in South Africa, where more solvent variations have probably been studied than anywhere else, the preferred extractant was ethanol containing 10% of water (Loetscher, 1962). The residual moisture content of fish meal (about 10%) is taken into account, as is the water content of raw fish if that is the starting material for solvent extraction, e.g. in the Canadian process using 2-propanol (Power, 1962) subsequently extensively studied and preferred in work by the US Bureau of Commercial Fisheries (1966).

Fish is a poor starting material for the preparation of a permanently tasteless and odourless dry powder. It is poor in natural antioxidants, and its lipids are very highly unsaturated. Even after multiple extraction with a lower aliphatic alcohol (chosen largely for its ability to break lipid–protein bonds), up to 0·2% of lipids remains. Personally I have not yet encountered a sample of ostensibly tasteless and odourless FPC that had not acquired a slight fish meal-like taste and odour after storage. It is claimed that the US research product, if made from the lean fish 'red hake' (*Urophycis chuss*), does not revert in this manner, but it is admitted that so far it has not proved possible to obtain such a stable product from the oily 'menhaden' (*Brevoortia* sp.) (Snyder, 1967). Species differences in lipid composition may be significant in this respect, but there is also the possibility of non-lipid precursors of reversion flavours.

Apart from flavour instability, solvent-extracted FPC has a gritty texture that is detectable in the mouth even after very fine grinding, when it feels chalky. A colleague of mine, who faithfully followed the recipe for a milk shake based on a proprietary US protein concentrate containing FPC, was left with the impression of a mouthful of chalk (an impression shared by the staff of the milk bar where the milk shake was prepared). For use in bread, fine grinding is essential, and it is costly. Thus Snyder (1967) has mentioned concern over grinding costs and a recent price list from a US supplier of FPC quotes a charge of 1·5 ¢/lb for grinding from 30 mesh to 100 mesh, and of 4 ¢/lb for further grinding to 300 mesh (both regardless of quantity).

A tasteless FPC only improves a food, such as bread, nutritionally; in other respects it is a useless, or even an undesirable additive. Holme (1967) has reported on the limitations for cereal product fortification of all samples of FPC so far examined by him; among other findings 'It is definitely true that at 5% and more FPC the quality of bread, as we know it, is decreased. Colour, taste, volume and structure are detrimentally affected'. To base a national programme of diet improvement on nutritional aspects alone is to invite either permanent subsidy payments or permanent enforcement by decree. It seems to me to have no chance of genuine commercial viability. Despite subsidies from national or international agencies, all attempts to date to introduce FPC into staple cereal foods have failed to get beyond the trial stage, e.g. in S. Africa, Morocco and Chile.

I referred above to price, and mentioned a 1961 target of not more than 15 ¢/lb. Admittedly price levels have risen since 1961 (fish meal has risen from about 6 ¢/lb to 8·7 ¢/lb) and Snyder (1967) estimates a price of not more than 25 ¢/lb including profit. This presumably relates to raw material at 1 ¢/lb (US Bureau of Commercial Fisheries, 1966), which is also that of raw material for fish meal manufacture (Chapman, 1967), but Holder, Kidd, Magyar & Ross (1967) consider that, in Canada at least, fish could not be landed profitably at less than 3 ¢/lb. Assuming 7 lb of fish to make 1 lb of FPC (as stated by Holder *et al.* 1967), this would add 14 ¢/lb to the price of the latter, giving 39 ¢/lb on Snyder's (1967) estimate. Holder *et al.* estimate a production cost of 38 ¢/lb for a plant handling 100 tons/day of raw material, and a price to the consumer of 49 ¢/lb. It is noteworthy that a commercial quotation by the only US manufacturer of FPC is at 42 ¢/lb for 100 mesh size, in lots of 1000 tons and over. Smaller quantities are more expensive (up to as much as 54 ¢ for orders of from 1–2·5 tons). This plant has a capacity of 100 tons of raw material per day. The US Government has placed an order for 1000 tons at the above price and size grading, for use in its overseas aid programmes.

Thus we have come a long way from the original concept of a product selling retail at not more than 15 ¢/lb. A good deal of the cost of FPC must be attributed to the need for thorough extraction. Thus the commercial US firm referred to make FPC by 2-propanol extraction of a feed-grade product which itself has been partially defatted with 1:2-dichloroethane. The price of the feed-grade inter-

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mediate, in comparable size grade and tonnage, is 18·9 ¢/lb, i.e. it costs over 20 ¢/lb for the additional extraction. It is of interest to note what the customer would pay per unit of fish protein in various forms. Since different species of fish sell at widely different prices through normal food channels, the most realistic base-line is either the price paid for fish intended for fish meal manufacture (say 1·0 ¢/lb), which happens to agree with the US Bureau of Commercial Fisheries (1966) estimate for FPC raw material, or the estimate of Holder *et al.* (1967) of 3 ¢/lb, which will allow for greater care in handling the catch. Some comparisons are given in Table 1.

Table 1. *Protein cost as various products*

Product and protein content (%)	Price (¢/lb protein)
Raw fish, 15	6·7–20·0
Fish meal, 65	11·5
Feed grade FPC, 100 mesh, 75	25·2
Food grade FPC, 100 mesh, 81	51·9

I agree with the US Bureau of Commercial Fisheries (1966) that FPC must be based on whole fish, and not on what we are accustomed to regard as the 'edible portion'. I return, however, to my opening paragraph. I cannot accept that a case has been made out for FPC in the degree of sophistication now envisaged. I feel that if comparable resources had been devoted to studying alternative ways of processing whole fish, something with better commercial prospects would have emerged. To take just one approach. If whole fish were comminuted, enclosed in a suitable container (possibly of plastic) and heat-processed, the result would be a tasty, stable product, and a food in its own right. True it would not be a concentrate, but I am challenging the whole concept of concentrating fish at the expense of much of its food value and all of its appetite appeal. It might be argued that FPC could be made from species not accepted for food, including very small fish. My answer would be that little or no effort has been made to make these species acceptable by suitable processing. It is only fair to add that the Food and Agriculture Organization of the United Nations has always regarded FPC as only one approach, and includes other comminuted materials such as fish pastes, sauces, and sausages in its thinking (Hamlisch & Kreuzer, 1967).

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The production and use of leaf protein

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The proposal that a new foodstuff should be made and used encounters different forms of scepticism from different groups of people. But every proposal will meet scepticism in some form. Although irrational scepticism, or 'instant opposition', may in practice be the most troublesome, it may be disregarded in the context of this meeting and the remaining forms may be arranged as a quasi-logical sequence of questions: Is a novel food needed? Would the one proposed contribute significantly to meeting the need? How would it be made? What would it be made from? How would it be used? What is its relationship to other comparable proposals?

The first question is answered by the fact that we are holding this meeting and by Woodham's paper, the second can be subdivided into three parts: Would the product be available in places where it is actually needed? Would it be feasible to make enough of it to be of practical importance? What evidence is there about its nutritional value?

Most of the people who are now in greatest need of extra protein live in the wet tropics. Furthermore, they do not live in urban areas, or even in the shanty-towns that are insidiously growing around them, but in country districts with poor communications. One very important practical need is therefore for a method of producing protein from a local source. The quickest and most practical way to increase the use of leaf protein in these regions is to encourage the use of leafy vegetables. Nevertheless, although most communities could with advantage eat more vegetables, an upper limit is set by human physiology. This limit can be circumvented by separating protein from fibre mechanically. Quantitatively, this method of making protein would be unrivalled in tropical regions with regular heavy rainfall. Even in Britain we can get 1·4 tons of extracted protein from a hectare in a year; this is as good as the protein yields claimed for soya or groundnuts in climates adapted to them, and we expect to reach 2 tons. In Mysore, 3 tons per hectare has already been reached. There has as yet been little agronomic work on leaf protein production and no work at all on breeding plant strains suited to this purpose.

The amino acid compositions of protein samples from leaves of different species, ages and cultural background are similar (e.g. Pleshkov & Fowden, 1959; Chibnall, Rees & Lugg, 1963; Gerloff, Lima & Stahmann, 1965). I am unconvinced that any of the apparent differences are greater than the possible error in the determinations. This is not unexpected because what is loosely called leaf protein is a mixture

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