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NEW SOURCES OF FOOD PROTEIN

Chairman: R. L. M. SYNGE, BA, PhD, FRIC, FRSE, FRS, Nobel Laureate, *Agricultural Research Council Food Research Institute, Earlham, Norwich*

The alleviation of the world protein shortage

By A. A. WOODHAM, *Rowett Research Institute, Bucksburn, Aberdeen*

It is difficult to anticipate the steps which will be taken during the next few decades to cope with the problem of providing adequate food for the ever-increasing world population. Curbs on population growth brought about by war and by contraception may play a part in eking out the world resources but the extent of this contribution is impossible to predict. In any event the nutritionist is not concerned with this aspect but only with ensuring that the best use is made of the available foodstuffs. Protein foods may be of plant or animal origin but, because animal protein originates through the conversion of plants, plant protein must be considered to be of primary importance. Measures aimed at increasing the supply and utilization of plant protein will ultimately benefit the human population of the world whether or not animals are used to convert some of the plant protein into meat, milk or egg protein. According to a recent United Nations publication (United Nations, 1968) 63 million tons of oilseeds are being at present employed either as crop fertilizers or animal feed. The conversion of plant protein into meat is inefficient, 4 tons of vegetable protein yielding approximately 1 ton of animal protein, and one can envisage the eventuality that even the efforts of modern husbandry research to improve animal productivity will not compensate for a wasteful use of plant protein resources. Mankind will then be compelled to forego the luxury of meat-eating. Before this stage is reached, however, governments must come to grips with the wastage of protein brought about by overproduction in certain protein-rich areas coupled with economic conditions which do not allow the transfer of this surplus protein to areas where it is badly needed. Not only must waste be eliminated but maximum use must be made of the conventional sources of protein, and search must be continued for new sources. It is the purpose of this paper to mention some of the avenues which appear worthy of study.

The primary protein sources available for feeding consist of seeds, leaves and tubers. Seeds in general contain relatively large amounts of protein and constitute the most important class of protein food for man and for non-ruminant livestock. Many, such as cereals, also contain considerable amounts of carbohydrate and can therefore contribute energy as well as protein to the diet. Tubers and leaves contain

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more fibre and water and relatively less protein and are suitable for ruminant feeding. Separation of the protein of such materials from the fibrous residue appears to be the obvious way of utilizing them directly for human and for non-ruminant feeding. Processes have indeed been devised for the concentration of the protein in green leaves, and the leaf protein concentrate thus produced has been shown to have a satisfactory nutritive value for chicks, rats, pigs and man (Duckworth & Woodham, 1961; Duckworth, Hepburn & Woodham, 1961; Waterlow & Cruickshank, 1961). Studies of amino acid composition of green forage crops suitable for the production of leaf protein concentrate have been made and comparison with seed crops showed that the highest average yields of essential amino acids per acre were obtained from the forage crops (Akeson & Stahmann, 1966). Stahmann (1968) has suggested that the use for ruminant feeding of the fibrous residue remaining after the removal of leaf protein concentrate may make it possible for the production of protein from green plants to compete with other sources of protein. He points out that the nations most needy of the results of such research will be slow to carry it out and it therefore behoves the United States to continue urgently with research designed to improve acceptability by removal of chlorophyll and undesirable flavours, and experience gained in the US with regard to soya bean on this aspect, and with regard to the introduction of texture into leaf-protein products, should be utilized. In recent years the texturing of protein isolated from soya bean and groundnut has received a good deal of attention but it has generally been thought that such products will be so expensive that they may only be considered suitable for use in sophisticated dietaries such as those found in the protein-rich nations. Some simulated meat products are now comparatively cheap, however, being made by a process which avoids the complex spinning procedure employed originally, and some nutritionists hope to see such products gain acceptance in the developing nations (Carter, 1967).

The more exacting requirements of man and non-ruminant farm animals with respect to protein has led to the idea that individual feeding-stuffs might well be split or fractionated in some way to provide products of superior quality for those classes requiring them and leaving a residue which would still be suitable for ruminant feeding. The possibility of doing this mechanically with green leaves has been mentioned. Other possibilities include chemical treatment of feedstuffs which contain mixed proteins in order to separate high-quality proteins from poorer ones. Cereal seeds contain such a mixture of proteins, and it is known that those proteins containing most lysine and sulphur amino acids are the water-soluble albumins and the salt-soluble globulins (Wall, 1964). Between them these two fractions account for approximately one-fifth of the total protein of barley, wheat, maize and rice. Separation, accomplished easily by means of extraction with aqueous salt solutions, leaves a residue deficient in the amino acids mentioned but still apparently suitable for feeding to ruminants. Oilseeds contain differing proportions of these protein fractions; groundnuts for example contain 90% of the total protein in the form of a mixture of globulins. The salt soluble protein of groundnuts has been divided into two fractions by the use of inorganic salts (Johns & Jones, 1916; Jones

& Horn, 1930; Tombs, 1965) and it has been found that one of these possesses a superior amino acid composition and a correspondingly good nutritive value (Macheboeuf & Tayeau, 1942; Sure, 1920; Woodham & Dawson, 1968). Though attractive in principle the fractionation of conventional protein feeding-stuffs presents difficulties. Obviously there are technical problems associated with the handling of large volumes of liquors and protein slurries which must be processed rapidly before damage has been caused by micro-organisms. A more serious objection with barley-seed protein fractionation is that chick growth trials have so far failed to confirm the optimistic speculation which resulted from amino acid analysis. Low lysine availability may be a part of the answer because supplementation with pure lysine does produce a significant improvement in growth on the isolate, but the increased growth is not of the order that would be expected on theoretical grounds from the amino acid composition.

The oilseeds commonly used for livestock feeding are confined to a few types, notably soya bean, groundnut, coconut, cottonseed, sunflower and sesame seeds. Soya bean is the predominant oilseed grown in Asia, cottonseed in Central and South America, groundnut in Africa and coconut in Oceania (Orr & Adair, 1967). Other types of seed may be used in the locality where they are grown but these are rarely of wide commercial significance. There is considerable scope for extending the areas in which plant protein might be grown, and in such underdeveloped areas there may be the choice of using seeds of established nutritive value, or of using new types of seed known to be suited to the soil and climate, but of doubtful nutritional qualities. Even where the first course is open the results may not be completely successful owing to poor acceptability of a food strange to the consumers. An example is to be found in the attempted introduction of soya bean into Uganda during World War II. Lack of education in the use of soya resulted in rejection, and a prejudice against this highly nutritious food became rooted in the area (Dean, 1958).

The introduction of high-protein seed crops of types which have been little used for feeding in the past necessitates rigorous testing for toxic factors, as well as studies of nutritional value, agronomic characteristics such as yield and harvestability, and ultimately, of course, consumer acceptability. Nevertheless considerable work on the potentialities of hitherto little-used seeds is now in progress. Canadian workers are particularly active in this field because of the desire in that country for increased self-sufficiency. Crambe seed, originally introduced into the US as a home-grown source of erucic acid to obviate the need for importing rapeseed for this purpose, has been shown to yield after oil extraction a residue containing high-quality protein (Clandinin, 1961). The material is however goitrogenic for monogastric animals and contains toxic thioglucosides, and the success of crambe seed as a feeding-stuff for non-ruminants is dependent upon satisfactory detoxification being achieved. Solvent extraction (VanEtten, Daxenbichler, Peters, Wolff & Booth, 1965), dry heat, autoclaving or steam-stripping (Korsrud & Bell, 1967*a*) and ammoniation (Kirk, Mustakas & Griffin, 1966) have all effected improvements, and the ammoniation procedure has also been applied successfully to tung meal

(Holmes, Spadaro & Watts, 1967). Coxworth (1965) has examined nineteen plant species as possible crops for the Canadian prairie region and favours *Atriplex hortensis*. Other potentially useful meals have been made from *Camelina* (Korsrud & Bell, 1967*b*), *Pepitaria* (Bressani & Arroyave, 1963) and *Macadamia* (Sherrod & Ishizaki, 1966), but the first two, like crambe and tung, contain toxic components and continuing studies will eventually decide whether or not it will be feasible to incorporate them at economically useful levels in animal diets.

Thus far we have considered novel species of plant proteins, but it is worth while investigating the possibility that particular strains of the conventional vegetable foods may possess nutritive characteristics superior to those of the majority. Groundnut is not ranked highly as a non-ruminant protein supplement and for man it is inadequate without an additional lysine source such as milk, fish or soya bean. It is likely, however, that some strains of groundnut may possess, for example, higher levels of lysine than the majority. A. K. Chopra (1967, personal communication) has found total lysine levels ranging from 2·47 to 4·20 g/16 g N and methionine from 0·80 to 1·05 g/16 g N in a range of groundnuts which included Indian and United States strains. These were grown under identical conditions and the differences must be attributable to genetic rather than environmental conditions. Again, Wessels (1967) found that Valencia groundnuts displayed a significant response to threonine whereas Natal Common and Egyptian Giant varieties did not. Although these differences may not be sufficient to justify selection for protein quality, there remains a distinct possibility that differences in nutritive value known to exist between commercial groundnut samples (Duckworth, Woodham & McDonald, 1961) may not be due entirely to different processing techniques (Woodham & Dawson, 1968).

Not only has the selection of seeds for protein quality been neglected hitherto by the plant geneticists, however. Dean (1958) has pointed out that selection of leguminous seeds for tropical countries, which are the chief centres of undernutrition, has hardly begun and much research is still needed to find the varieties that are best suited to conditions of limited and uncertain rainfall, high temperatures and poor soils.

The use of solvent extraction, ammoniation, etc. as means of improving the nutritive value of plant proteins has been referred to above in connexion with the use of less well-known types. That the processing normally used to extract the oil from the major oilseeds may also have an influence on nutritive value is also fully realized. The case of soya bean where too little heat may fail to inactivate the trypsin inhibitor, while too much may render lysine unavailable, is often quoted. As our understanding of the influence of processing methods on protein quality grows, it is reasonable to expect that variations in quality due to processing will lessen. Under such circumstances variations in quality due to inherent differences in the seeds or other vegetable material may assume greater importance than at present. Because of this possibility, studies of the effect of environment and manuring upon cereals and also of varietal differences for barley and for groundnut are being studied. This work comprises a UK contribution to the International Biological Programme.

So far only protein in the form of green plants and seeds has been considered. There are indications that fish may contribute even more largely to the world's protein supply than it does at present. While prospects for the use of fish protein concentrate do not, chiefly for economic reasons, seem now as good as they did a few years ago, there is an increasing interest in fish-farming for the production of entire fish for human consumption. So far as livestock feeding is concerned fishmeal seems likely to maintain its supremacy in competition with other conventional protein concentrates.

Yeasts grown on hydrocarbon residues may contribute useful amounts of protein, but the full potentialities of this source must await the completion of all the necessary toxicity and animal feeding tests. Similarly the transformation of methane into protein by means of micro-organisms which has been described by Hedén and his co-workers (Hamer, Hedén & Carenberg, 1966) may eventually be developed into a viable commercial process. The commercial production of algae has been referred to at various international meetings during recent years and work at some centres in Europe and Japan has produced highly encouraging results.

Some of the new protein sources referred to here will be dealt with in greater length by others and accordingly the emphasis has been placed rather on those aspects not covered elsewhere. In particular the importance of utilizing fully already established protein sources has been stressed. Whereas for the development of new sources much exploratory work is still needed to establish not only methods for economic production, but also to define clearly the permissible limits of use, the conventional sources have already been tested and are in a large measure understood. The establishment of new oilseeds calls for the application of techniques already worked out for the seeds in common use, and even genetic selection of high-yielding, high-quality plant materials calls only for the application of methods already widely practised by plant breeders. For this reason it is felt that the short-term attack on the problem will be by means of plant proteins, some already established and some as yet little-used. Studies of the potentialities of mixtures of existing types of protein foods so that each may be used to the best possible advantage for particular dietaries, human and animal, as well as fortification of foods known to be deficient in certain nutrients will all play an increasingly important part. While this work proceeds the development of sources such as yeasts, algae and microbial protein will continue and these may be expected ultimately to contribute, some significantly, to the overall world supply of protein.

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Problems in the development of fish protein concentrates

By J. A. Lovern, *Torry Research Station, Aberdeen, Ministry of Technology*

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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