PRESENT-DAY PROBLEMS IN FOOD SCIENCE*

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Our subject of food science is approaching a point of philosophical crisis. The first twenty-five years of my professional life were years of battle against apathy or active opposition to the very concept of food science and technology. Nowhere did the controversy over the recognition of our discipline bite deeper than in the home of scientific orthodoxy — the United Kingdom of Great Britain. But the years passed, and, so gradually that it is hardly possible to date the point in time, food science became recognised by the universities and then by the public. Now, even our Royal Society of London, which is, I believe, one of the most conservative scientific organisations in the world, recognises and actively takes an interest in food science.

If conservative Britain has capitulated to the claims of our subject, the rest of the world has gone further. Food science is even fashionable. After all, no nation can breed good citizens in full health and vigour without good food and this cannot be provided without our skills.

This being so, the food scientist is indeed a happy man. All of us in this field belong to a kind of club or society. Wherever we travel in the world, we find others of like interests. The trends in these interests are my topic for today. In the time available, I shall only attempt to deal with the potential of biological or chemical synthesis of protein for use as human food.

The idea of synthetic food is not new. For example, synthetic vitamins have been in use for many years. Vitamin C, first isolated by that great Hungarian, ALBERT SZENT-GYÖRGYI, in 1928 [1] was synthesised by HAWORTH in 1934 [2] and soon become a cheap chemical of commerce. During the Second World War the Germans used the Fischer-Tropsch process to convert coal into crude oil. The paraffin fraction boiling between 320 and 450 °C from this process was oxidised to fatty acids using a permanganate catalyst and a reaction temperature of 105 °C. The resulting acids were purified by forming soaps and then reconverted to fatty acids, fractionally distilled at reduced pressure and esterified with glycerol at 180 °C in presence of a zinc catalyst. After further purification and bleaching, the fats so produced were converted

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into margarine. The flavour was not very good but it kept well and on clinical trial was absorbed by the human subjects studied. Eventually four factories were engaged in the manufacture, the bulk of the product being supplied to the German army and navy [3].

Synthetic carbohydrates can be prepared but they are very expensive and are not likely to compete with natural products in the foreseeable future, except possibly in the form of synthetic alcohol. This, of course, is made by catalytic hydration of ethylene, and while not a synthetic food, has a food sparing effect in that carbohydrates which would otherwise be used for the production of alcohol, are released for food use.

By far the most important possibility is the production of synthetic proteins. Since natural proteins vary in nutritional value depending on the amino-acid pattern of the individual source, synthesis may contribute to nutrition by supplementation of the limiting amino acid or acids with the synthetic counter-part. This, of course, is an existing and well-established use in animal feeding. Compounders of feeding-stuffs for poultry and pigs do not add expensive chemicals to their products without the certainty of a hard economic return in improved growth rates. Perhaps the most striking use so far of synthetic amino-acids was the experiment of WINITZ [4] who fed fifteen healthy young men for nineteen weeks on a completely synthetic diet. All emerged fit and well at the end of the experiment. The diet was administered in liquid form and while perfectly nourishing, it required no digestion. Without the pleasure of chewing and tasting, it must have been very dull and uninteresting. Nevertheless physical and mental health without evidence of deficiency disease of any sort was a triumphant direct justification of a century of nutritional research.

A diet such as WINITZ used would only be applied to special experimental or clinical circumstances. In practical nutrition, cost and attractiveness alike would dictate a different approach. In terms of strict synthesis the amino acids must be polymerised to proteins before a food acceptable for general human application can be obtained. Now since the structure of natural proteins is specific, their synthesis is of great complexity. However, random protein polymers are not difficult to prepare [5]. If such polymers can be digested by the human gut, then the principal obstacle to obtaining synthetic protein for food use lies in the availability of a cheap source of amino acids. Considering the structural variety of proteins naturally occurring in human food, this is not altogether surprising. However, the potential source of amino acids is from an unexpected and unrelated line of research.

Investigation of conditions on the earth's surface prior to the first emergence of living forms has suggested that an electric discharge such as lightening passing through a gaseous mixture of ammonia, carbon monoxide and water results in the formation of glycine and other amino acids [6, 7].

More recent work has produced some striking results by passing mixtures of ammonia, steam and methane gas through catalysts of common solids such as one would have expected to find in the earth's crust throughout the ages (for example, quartz sand, silica sand and volcanic sands have been used). At temperatures of about 1000 °C, all the amino acids common to protein except for cystine, methionine, histidine and tryptophan were produced [5, 8].

The method for synthesising proteinoid polymers is to heat the mixture of dry amino-acids to 170 °C for six hours and then purify the polymers by the normal methods of protein chemistry. The composition of the polymers can be varied over a considerable range by altering the proportions of amin o acids present and by having other substances such as hypophosphite and polyphosphate present in the reaction mixture. Molecular weights of up to 8500 have been obtained.

So far these proteinoids have not been synthesised on a commercial scale but they are said to be susceptible to breakdown by proteolytic enzymes and are usable by micro-organisms and experimental animals [9].

Up to this point I have been concerned to establish that it is possible to produce synthetic protein-like materials by chemical methods and by a comparatively simple route which does not seem to be impossibly expensive if developed industrially. However, while the route I have discussed up to this point is one for the future, proteins produced by microbial synthesis or by plant synthesis are rapidly becoming articles of commerce in the United States, the United Kingdom, France, Sweden and elsewhere. Some of these processes have been developed in attempts to find a cheap source of protein for under-developed countries, others have been designed to exploit a rich market such as the domestic market of the United States, others have arisen from a desire to upgrade a by-product of little economic value in its original form and still others to dispose of an industrial effluent which would otherwise be an embarrassment to get rid of by normal sewage disposal methods.

Thus the present world protein market, traditionally faced mainly with the disposal of milk powder, is now about to be faced with the disposal of biologically synthesised protein.

Now there is quite a lot in the literature on this topic but the most interesting information is not published, or if published is not open to easy verification. These are the important questions — "What do they look like, what do they taste like, what physical properties do they possess and what do they cost to produce, Are they chemically stable, are they of high nutritional value and are they completely free from toxic side effects?" Before this became such a popular topic of scientific discussion, one large British company invested heavily in a protein plant using ground-nuts as the source. It was an economic failure, having been designed before the hazards of aflatoxin had broken on the world and the advent of this complication so increased the cost of the process that it was abandoned. Nevertheless that experience highlighted the harsh fact that no new protein will succeed if it does not compete favourably with skim milk protein in price or alternatively show some special or superior quality characteristic.

I would now like to outline a number of processes which are in use or are under consideration at the present time. Many of these are receiving widespread publicity but few if any can claim to have established their permanent worth.

Historically one should mention the early work of PIRIE who, long ago, pointed out that the cheapest way of synthesising proteins was to use almost any kind of green leaf, and extract the protein leaving the indigestible cellulose behind. He has published extensive information on the preparation of this product and on its properties and nutritional value [10]. His main object was to provide a cheap source of locally available protein for protein-deficient countries with simple equipment which could be used at village level. One or two projects using his equipment are now in progress in India and elsewhere. The logic of his arguments and the simplicity of the equipment required were admirable and should have attracted wide-spread support. However, it appears that the limited success so far achieved may be due to the psychological issues involved. Protein-deficient peoples may be suspicious of protein-rich societies offering them a strange green food of unfamiliar taste and which the wealthy societies do not eat themselves.

Recently, the Swedish Sugar Corporation has reopened investigation of the extraction of leaf protein as a means of upgrading sugar beet leaves which would otherwise simply rot in the field and Prof. Dr. B. HALLSTROM [12] of the University of Lind has developed a process on a small scale which, by controlled heat coagulation of the protein, yields the familiar green protein concentrate of PIRIE (which he proposes for use in animal feed compounding) plus a near colourless, bland fraction which would provide a basis for human food products.

Following leaf protein, one of the next processes to attract attention was spun soya protein as developed by Odell of General Mills Inc. of the United States [13]. In principle the process is simple, but in practice it is complex and required a very large capital expenditure to develop it. It consists of dissolving soya protein in a suitable solvent, passing the concentrated solution through fine spinarettes submerged in a coagulating bath to produce a bundle of hair-like threads. These are subsequently dried and stretched. This process provides a unidirectional structure to the product which can then be built up into materials with textural properties similar to those of, for example, meat. Furthermore these textured proteins can be delicately flavoured at will. As a result, the products have sold well in the United States and a new and very large factory producing them has been built and is now in operation. The process is complex and expensive, and attempts have been made in both Britain and the United States to introduce a meat-like texture to proteins by less expensive means.

Some substantial success has also been achieved by heating soya flour with alkalised water to about 90 °C and then extruding through a die at very high pressure in much the same way as pasta products like spaghetti are produced. Quite impressive results have been obtained simulating minced meat products and suitable for use in pies, sausages and other comminuted foodstuffs. Promising as these soya-based processes are, the final products have the disadvantage of carrying a soya-like after-taste, however meat-like the first impression may be.

It is therefore interesting to turn to other processes based on fermentation. Five or six years ago a great deal of work was being carried out on the possibility of obtaining food protein from the cultivation of the blue-green algae. The Poles and the Japanese were particularly active in this field. However, recently much of the interest has moved to the cultivation of yeasts and fungal mycelia. Much of this work has not yet been published but in the past three months I have been fortunate enough to visit the plants or laboratories of what I consider to be the three most important of these processes. I can say a little about them without breach of confidence.

The so-called Symba Process has been developed at the Research Laboratories of Svenska Sockerfabriks AB at Arlöv, Sweden [14]. It was originally produced as a process for purifying starchy waste-waters but it could clearly be of wide application for the conversion of any cheap starch source into protein. The process depends on symbiosis between the two yeasts. Endomycopsis fibuliger (which produces the amylases to convert the starch to sugar) and Candida utilis (which uses the sugars as an energy source to produce protein). The product has a fairly strong yeast flavour, contains about 45% protein and is rich in vitamins of the B group. It is somewhat deficient in methionine bit with the addition of 0.1% of this amino acid it has a nutritive value comparable to that of casein.

The research laboratories of the British company Ranks Hovis McDougall Ltd. have tackled a similar problem by an essentially different route. By using an amylase producing fungus (whose identity is held secret) in submerged continuous culture, they have provided means for producing a protein rich mycelium of near white colour and faint, mushroom-like flavour. This product is noteworthy in being very bland in flavour and with an inbuilt textural advantage from the mycelium filaments of which it is composed. A semi-scale plant has just been commissioned and providing no unforeseen obstacle is met, this process can be expected to be making an important contribution to protein supplies within a few year.

Considerable success has also attended the efforts of the international oil companies, Shell and B.P. in growing yeasts in purified paraffins or in gas oil. These products have already proved their worth in cattle feeding and are in production on a substantial scale at Grangemouth in Scotland. A much bigger plant is being built in France and although this too is primarily aimed at cattle food, it seems probable that this process will sooner or later be adapted for the production of protein for human use.

Having produced our protein by one or another or by a combination of these processes, it serves no useful purpose until the product is eaten and assimilated. It is only at this point that the difficulties associated with the biological or chemical synthesis of protein become overt. Having made the stuff, what are we to do with it? Three courses seem to be open depending on price and need. We may convert it to animal protein by using it to feed fish or livestock. This way we avoid the most formidable problems but use it in an inefficient way. Again, we may use it as an ingredient to add to other foods to enhance their nutritional value. The extent to which this can be done acceptably depends on many factors not the least important of which is the acceptability of the flavour conferred. However, some modest indications point to this as a possible application in protein-deficient areas of the world. Finally, the long-term objective must be to create directly from it, exciting and interesting new foodstuffs which will be widely acceptable for their inherent attractiveness. This last objective presents problems of nutritional desirability, toxicological hazard, and above all, problems of texture and flavour.

It is this complex of inter-related problems which makes progress so difficult and yet offers such great ultimate potential. Quite apart from the practical challenge, the scientific and technological problems involved are particularly exciting because they are interdisciplinary. In recent years, progress in the detailed chemistry of flavouring substances in food has been spectacular as a result of advances in chemical techniques. Nevertheless we have not made corresponding advances in the understanding of the physiological mechanisms underlying flavour and odour perception. To fully exploit the chemistry of flavour we must have more knowledge of the physiology of perception. Texture offers a similar challenge. Much is being done on the study of texture in natural foods, but so far, attempts to artificially introduce texture into semi-synthetic foods are relatively crude, with Odell's being one of the more sophisticated of these. However, we are still some distance away from simulating accurately the structures which give the crispness to lettuce or the bite of a good steak.

While all these topics are under active exploration in many laboratories and will yield to the efforts now being made so that in a few years we may expect great progress, two obstinate and intractable problems remain. In

English we have a saying "one man's meat is another man's poison". Why are some foods liked by one culture and disliked by another? Why, even within one culture, is there such a wide range of preferences for different kinds of foods? For example, while meat is acceptable in most cultures, there are still substantial numbers of people who are indifferent to it or who actively dislike it. The primates are essentially vegetarian and with unimportant exceptions only man amongst them is an active carnivore. Elsewhere, I have suggested that human attitudes to food are of deepseated genetic origin and that we rationalise inherited attitudes which are essentially instinctive. We therefore need anthropological, sociological and psychological investigations of food habits and attitudes before we can easily embark on a world-wide programme to adjust man's eating habits to the demands of a world rapidly becoming overpopulated. I consider this to be an underlying but little studied area of investigation of the utmost importance to the future. New foods demand an understanding of these attitudes if we are to exploit the scientific skills which have been deployed in their making.

In the time available to me, I have dealt with the major topic of "Present-Day Problems in Food Science" by choosing only one of the many subtopics open to me. Had there been time, I should have discussed also some of the exciting improvements in methods of food preservation which will come into general use in the next few years. Another vital topic is the relationship of agriculture, nutrition and food technology where we can look to great advances on a conjoint basis if these disciplines move more closely together.

As it is, all I have been able to do is to present you with a very superficial picture of current developments in protein production. I hope it may have stimulated ideas of some use to you here and I close by offering my warmest good wishes to this university during the next hundred years.

Summary

The subject of food science is approaching a point of philosophical crisis. Nowhere did the controversy over the recognition of this discipline bite deeper than in the United Kingdom, home of scientific orthodoxy. But with passing years food science became recognised not only by the universities and by the public, but also the Royal Society of London, one of the most conservative scientific organisations in the world, recognises and actively takes interest in food science. The reason of this interest is that no nation can breed good citizens in full health and vigour without good food. After this general statement about importance and aim of food science, its present-day problems are illustrated by the most important possibility of producing synthetic proteins, and it is shown that a complex of inter-related problems makes progress so difficult, and yet offers a great ultimate potential.

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