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Modern Approaches to Food Safety*

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ABSTRACT

Microbiological food poisoning is by far the most serious hazard associated with the British food supply at the present time. Intolerance to food components, either naturally occurring or added, is also common among consumers but safety problems connected with the use of approved additives are extremely rare.

Modern approaches to food safety reflect the rapid and progressive changes taking place in the food industry. They include the use of control procedures aimed at preventing microbiological hazards, the development of improved and more rapid tests for toxicity of ingredients and the careful monitoring of changes in the diet.

There is an urgent need for better understanding of the relationships between diet and disease, of the microbial ecology of foods, of the mechanisms involved in food intolerance and a need to understand more fully the structure/activity characteristics of toxic molecules.

INTRODUCTION

The safety of his food supply has been a major concern of man since ancient times. Much of ancient Hebrew dietary law, for instance, has its origins in the minimisation of risk associated with the consumption of certain foods; issues which were well understood by the people who drew up those laws. The title of my contribution suggests change, and hopefully progress, in our thinking about food safety, and this is a theme that I will return to, but I will start by examining the sources of potential hazard.

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THE NATURE OF FOOD HAZARDS

Without a doubt, when viewed from a world perspective, the biggest hazard associated with the human food supply is its inadequacy in many parts of the world. The inadequacy of nutrient supply is by far and away the most important single reason for premature death in the world human population. It is well to bear this fact in mind when considering the safety of the food supply in a developed country like the United Kingdom where food supplies are more than adequate and nutritional deficiency plays only a minor, and usually readily avoidable, role in human disease.

Hazards associated with the United Kingdom food supply are of three types: those stemming from the presence of disease-causing micro-organisms or their toxins in food as consumed, those associated with the presence of naturally occurring toxic chemicals present in foods and those associated with chemicals that may be added during food processing or which may occur in food products as a result of contamination, either accidental or deliberate.

Pathogenic micro-organisms

Foodstuffs may act as vehicles whereby living food poisoning bacteria gain access to the human body. The most common cause of bacterial food poisoning in the United Kingdom is *Salmonella* which is endemic in poultry-rearing establishments and can be spread to man by the consumption of inadequately cooked poultry meat or, more usually, by cross contamination at the retail outlet or in the kitchen from chicken to precooked or fresh foods that will be consumed without further cooking.

There are a number of bacterial food poisoning organisms, and in some parts of the world protozoa and parasitic worms can also be spread via the food supply. Many of these latter agents are currently rare or even absent in developed countries, but the continually increasing international trade in processed foods means that we would be unwise totally to ignore them; certainly they are of considerable concern to the commercial organisations engaged in international trade.

Microbial toxins

Toxic chemicals produced by micro-organisms play a role in many food poisoning diseases, but in some cases the toxins elaborated by micro-organisms in the food are the direct and only cause of disease. The highly virulent toxin of *Clostridium botulinum*, for instance, will persist in food long after the bacterium producing it has died out. It is a highly potent toxin causing the often fatal, but fortunately very rare, disease botulism. In some

cases the toxins produced by micro-organisms during growth in foods will subsequently survive heat treatments which destroy the micro-organisms themselves.

Microbial toxins occurring in foods which have attracted a great deal of attention in recent years, are the various types of mycotoxin produced by moulds growing in some food materials; cereals, nuts and some fruit products, for example. Some of these are known to be vigorous toxins which occasionally cause problems in animals through contaminated feedstuffs in the United Kingdom, but are fortunately unknown as a cause of human disease in this country. The potential hazard is there, however, and the threat calls for continuous monitoring of vulnerable raw materials.

Natural components

A very large number of naturally occurring toxicants have been found in foods, most notably in plants, but also in some fish. Even in some stable foods there may be a wide variety of plant toxicants: glycoalkaloids in potatoes, favogens in some pulses and glucosinolates in brassicas, for example. In addition to pre-existing toxicants others may be produced during processing, storage and cooking: the products of non-enzymic browning reactions, pyrolysis products of amino acids and mutagens such as polycyclic aromatic hydrocarbons and nitrosamines, for example.

While acute toxicity in man attributable to natural toxicants can often readily be recognised (favism, ergotism, latherism for example) chronic effects are less readily established, and it is difficult on the basis of current knowledge to assess the possible consequences of long term exposure to the very low levels of many natural toxicants that are found in food.

The potential problem of natural toxicants is exacerbated by the emergence of significant subgroups such as health food enthusiasts and vegetarians within the population, and the growth of ethnic minority groups whose consumption of 'exotic' foods may lead to very different patterns of exposure from the average traditional UK diet. The development of new agricultural cultivars and the exploitation of novel food species also pose potential threats although it is worth noting that recognised hazards may be reduced by selective breeding as in the case of the low erucic acid, low glucosinolate strains of rape which are now such a feature of our early summer landscape and of our agricultural economy.

Long term nutritional effects

A different safety issue is raised by the present high level of concern in our society over what is seen as the inappropriate balance of nutrients in our diet

as opposed to specific concerns about the nutritional quality of particular foodstuffs. Factors governing the selection of foodstuffs to make up the diet are many and complex. Availability, cost and personal preference are obvious, but physiological factors and possible reaction to minor food components having psychophysiological effects, although more subtle, are possibly significant. The evidence relating dietary intake of particular food materials to disease (saturated fatty acid intake to the incidence of coronary heart disease for example) often falls short of proof but there is sufficient consistency in the evidence available from numerous studies to indicate the likelihood of causal relationships and the effects of long term consumption of inappropriately balanced diets are a legitimate concern where issues of food safety are being considered.

Chemicals in food

Of course all foodstuffs are chemicals, but here I refer to chemicals which would not naturally be food components but which may be added to processed foods in order to enhance their attractiveness, facilitate processing or act as preservatives. I also include chemicals gaining access to foodstuffs either by accidental contamination or by malicious tampering.

Here, of course, we are dealing with an extremely wide range of chemicals encompassing substances derived from agricultural practice, such as fertiliser and pesticide residues and residues from the treatment of animals with antibiotics and hormones, general environmental pollutants such as heavy metals and a wide range of chemicals used in food manufacture including processing aids such as emulsifiers and raising agents, preservatives, colouring agents and flavour additives.

In addition to these minor components of processed foods we must also bear in mind the occasions when accidental contamination may occur with such chemicals as bleach and disinfectant or by cross contamination with traces of potent taint-causing materials such as packaging components or herbicide residues. Fortunately, although such materials may well damage the eating quality of products, they rarely present a safety hazard. The same cannot be said of those rare, but today too frequent, incidents of malicious tampering which, although falling outside the scope of the present discussion, nevertheless present a serious issue for the food industry.

HAZARD, PUBLIC CONCERN AND LEGISLATIVE ACTIVITY

One of the major problems facing anyone concerned with food safety is the almost complete mismatch which exists between areas of known

quantifiable hazard on the one hand, and public concern and legislative activity on the other. The evidence for the existence of a major microbiological problem is clear, as is that for various forms of food intolerance in the consumer population. There is, however, little evidence for the existence of adverse effects caused by food additives, naturally occurring toxicants or mycotoxins in the United Kingdom. These latter subjects, however, figure prominently in media comment and, together with the possible link between diet and disease, they rate prominently as causes of concern expressed by members of the public.

Each year in the United Kingdom some 20 000 cases of microbiological food poisoning are reported. These represent perhaps 10% of the cases actually occurring, and the evidence is that the situation is deteriorating rather than improving. Each year a small number of people die as a direct consequence of food poisoning. Microbial food poisoning is undoubtedly the most important problem concerning food safety in the United Kingdom today.

It is also clear that many people show distressing reactions to specific food components, both natural and added. Food intolerances, which if they involve immunological reactions to food components are usually called food allergies, embrace as causative agents a very wide range of chemicals and can result in a number of different symptoms. They reflect the abnormal sensitivities of particular individuals rather than basic problems with the food supply since the majority of people can consume with complete safety the items which will precipitate an uncomfortable reaction in sensitive individuals.

By contrast it is virtually impossible to produce evidence incriminating food additives and contaminants as causes of human disease. Having made that point, however, it is important to emphasise that it is far easier to demonstrate cause and effect in the short term scenario involved in a microbial food poisoning incident or in the triggering of a hypersensitivity reaction than in the case of the consumption of very small amounts of a minor food component, perhaps over a large proportion of the lifespan of an individual.

This dilemma brings us straight into one of the most important issues concerning food safety evaluation. It is customary in determining the safety of a food additive to carry out an extensive range of animal experiments aimed at determining its toxic threshold. Often toxic effects are seen only at high dose levels, but the data need cautious treatment if the findings are to be extrapolated to the human food situation. Test animals may respond in quite different ways from human beings. Within any particular population of animals or human beings there may be a wide range of individual sensitivities. Intakes of the chemical may well vary widely depending on

dietary patterns. There is little statistical validity in attempting to extrapolate from experiments carried out on a small number of animals at high dose levels over short periods of time to the situation in which very large numbers of human beings may be consuming small quantities of the same material over very long periods of time. The models used for this extrapolation are simply inadequate.

In defining an Acceptable Daily Intake (ADI) an attempt is made to take such problems into account by applying a (usually) 100-fold safety factor to animal test data. In practice this means that the highest concentration of a chemical which is found to have no effect in an appropriate range of animal tests (expressed as an intake weight per kg of animal body weight per day) is divided by 100 to give an acceptable daily intake for a human being and results are expressed in terms of an intake weight per day for a 65 kg adult. This is the amount of a chemical which may be consumed without any toxic effect each day for the whole life of an individual.

It is reasonable to argue that such a calculation provides an adequate safety margin and certainly there is no reason to doubt the validity of that assessment. Nevertheless, there is an illogicality in the situation. If a similar calculation were made for many of the toxicants known to occur as natural components of food materials, then the intakes of many would exceed their calculated acceptable daily intakes. Bread, potatoes and tomatoes would disappear immediately from our diet by virtue of the natural toxicants present in them. We can perhaps take comfort from the strictness of the criteria applied to the assessment of safety of food additives. In my opinion it is more prudent to focus on the clear evidence that the extrapolation models we are using at the present time are inadequate.

Although we compensate for this by taking an extremely conservative view of the available data the underlying message is of an urgent need for better understanding and refinement.

THE CHANGING NATURE OF FOOD SAFETY EVALUATION

Consumer perceptions

The food supply industry has always been, and will continue to be, in a state of gradual, progressive change. In an ideal world there would perhaps be no need to give any thought to the use of food preservatives, emulsifiers and stabilisers, antioxidants, permitted colours and added flavours. We would harvest our foods fresh from the earth and eat them immediately. We do not, however, live in such a world. Even primitive man found it necessary to store foods to bridge the gap between times of the year when they could be harvested, and the time when they must be consumed. Today the growth of

dense urban communities has led to the evolution of a high technology food production and distribution industry and has created a situation in which the use of food additives is essential. Today's sophisticated consumer has every right to expect that the food he or she buys will be of a familiar and reliable quality, and that it will be safe to consume. This can only be achieved by the use of an armoury of food additives.

The consumer also has a right to expect full information about the additives used by the food processing industry in the manufacture of the products on sale. The active interest shown by UK consumers in recent years about the composition of food products is, of course, welcomed by any responsible section of the food manufacturing and retailing industry. The enhanced awareness of these issues on the part of the consumer represents one of the major factors influencing our approach to questions of food safety evaluation. It is easy to forget, however, that many of the additives which are used today, and which are widely debated, are by no means recent additions to the food scene. Many of the processing aids, preservatives, colours and flavours used today were seen as powerful allies by the Victorian domestic cook, and indeed, some have played a major role in food preparation for many centuries.

The first factor, then, leading to changes in our approach to food safety matters is the changing perception of risk on the part of the population in general. Whether the perceived risk arises from the overall nutritional balance of the diet or from the presence of chemicals or micro-organisms in the food itself is irrelevant to the argument. The fact that there is a growing awareness of food safety issues leads inevitably, and quite properly, to a tightening of regulatory control. To quote Section (2) of the Food Act 1984 'Ministers shall have regard to the desirability of restricting, so far as is practicable, the use of substances of no nutritional value as foods or as ingredients of foods'. In other words the use of additives should be kept to the minimum commensurate with need.

We are today seeing vigorous debate arising from the implementation of this principle. Some of the points at issue are well illustrated by considering the use of colour additives. It could be argued that there is never any case for the addition of extra colouring matter to foods. But the reality is that food processing will often reduce or change the natural colours present in foodstuffs and that the colour of many manufactured food products is one of their attractions for the consumer. The consumer expects cola drinks to be brown, strawberry jam to be red and tinned peas to be green and responds vigorously and negatively when attempts are made to sell products whose colour is other than expected. There is a general acceptance on the part of UK regulatory bodies that colour is an important characteristic of food and that the need to achieve a particular colour constitutes a valid case of need

for the use of a colouring agent. This attitude seems entirely justified in view of the fact that there is no medical evidence that the consumption of permitted colours constitutes a general public health problem. Treading a path between the wish of many consumers to buy products with familiar colours, the general wish of Ministers to reduce the level of additives as far as possible and the pressure from a small proportion of the population to remove colours altogether is not easy. There is an obvious temptation to bow to the argument that because some consumers are happy with a colourless or only lightly coloured product, then it is appropriate to reduce or eliminate colour usage in that product for the whole population. But that argument poses important ethical problems and its resolution can have a major impact on industry and consumer alike.

I have made the point previously that changes in the food industry take place over a long time scale. It seems clear that we are entering on a phase when we shall see a steady reduction in the range and quantities of additives used in food production and of increasing difficulty in establishing the need to introduce new materials of this kind.

Technical changes

A second factor influencing our approach to food safety matters concerns the challenges stemming from technical changes occurring in the food industry. These include the development of international travel and trade with the consequent introduction into the UK of new food products from other parts of the world. Yogurts, lychees, soya-based products such as tofu and tempeh, are a few recent examples. With the development of significant ethnic minority communities we also see the introduction of fruits and vegetables which have not until recently formed a staple part of the UK diet.

Changes in food production technology are also reflected in changed levels of consumption of some food materials. Chicken and turkey have moved in a generation from being luxury items to the cheapest forms of meat. Improved production capability has vastly increased the consumption of mushrooms and the common mushroom has more recently been joined by its more exotic fellows, the oyster fungus and Shitake. To these obvious newcomers must be added the constant change which is taking place with the evolution of new 'improved' varieties of many of our common vegetables and fruits.

The awareness of potential problems resulting from such changed patterns of consumption is reflected in the care with which new cultivars emerging from the application of modern genetic methods to crop breeding are being evaluated for safety. When a problem is recognised, as in some of the early rape varieties, for example, it may prove possible to apply genetic

techniques, or food technology, to reduce or eliminate components likely to cause problems.

New major sources of nutrient material are only rarely introduced into the diet but the United Kingdom has seen one such development recently in the form of mycoprotein, a protein food component derived from a carefully selected mould grown in fermenters, which is now available on the market in a number of forms. It is an attractive high quality product which is growing rapidly as a replacement for meat products in a variety of prepared dishes. Undoubtedly it is destined to become a significant raw material for domestic cooking in the next few years as well as playing an important role in commercial catering and as the basis for a range of manufactured food products.

The introduction of a new major food component of this kind naturally poses substantial problems for regulatory authorities. Mycoprotein has been under development by Ranks Hovis McDougall for over 20 years and its development to the market has cost some £40 million. A major part of that cost has been the satisfying of extremely stringent, expensive and time-consuming safety evaluation tests.

Concerns over excessive calorie intake have led in recent years to a search for non calorigenic products that will replace fats in a variety of food applications. The challenge of replacing fats with molecules having similar physical properties is a difficult one and is by no means fully achieved. A partial solution to some of the problems is presented by sucrose polyesters which are currently undergoing examination by regulatory authorities. The size and shape of the sucrose polyester molecule renders it resistant to the action of the intestinal lipases which break down the glycerol triesters (triglycerides) present in normal fats. The benefits of such sucrose polyesters are significant and unique. Because they are not cleaved by digestive enzymes they are not absorbed and therefore contribute no absorbable fat or calories to the diet. But, just as important, they provide foods with the rich taste and organoleptic properties of full calorie, absorbable, fats and oils. There are also suggestions that they can play a major part in preventing the uptake of cholesterol from the diet. In spite of the chemical inertness of sucrose polyesters the possible use of such products on a large scale for food manufacture implies that their safety must be rigorously tested and assured and they are currently undergoing extensive examination with a view to obtaining regulatory approval for use in foods.

Toxicological evaluation

A third factor influencing current thinking about food safety issues concerns the need for, and development of, improved strategies for toxicological

evaluation of particular chemicals found in foods. The pressure to modify evaluation procedures comes from several sources. Currently chemicals for evaluation are subjected to acute and long term animal exposure tests using appropriate species in order to determine frank toxicity, to tests in breeding animals for indications of embryotoxicity and teratogenetic effects, to a battery of *in vitro* tests using microbial and mammalian cell systems as an indication of the presence or absence of mutagenic and carcinogenic potential and to multi-generation studies in animals for carcinogenicity.

Such test regimes present a number of problems: they are extremely expensive and time-consuming, they use substantial numbers of animals and involve the application of the LD_{50} test, the interpretation of which is to some extent suspect. The models used to extrapolate the findings from animal tests carried out at relatively high concentrations over short periods of time to possible impact on very large numbers of human beings consuming a product at low concentration over very long periods of time are clearly inadequate for the task. One of the consequences of the complexity and expense of the present testing regimes is that progress with the detailed evaluation of the whole range of food additives, and particularly of the large number of components used in food flavourings, is disturbingly slow.

These factors are leading to two major areas of development in food safety testing: the evolution of a system of decision tree planning in order to prioritise untested materials for evaluation and the development of new, rapid, less expensive test procedures which do not involve the use of live animals.

From a knowledge of the features of molecular structures that are involved in toxicity it is now becoming possible to predict the likely toxicity of a particular food component from a knowledge of its chemical structure. Such prediction may be enhanced and simplified by the use of appropriate computer modelling programs and such developments clearly point the way to a major evolutionary change in the whole concept of food safety testing. The development of new *in vitro* tests, particularly those involving whole organ technology, is currently receiving a great deal of attention. Such developments offer a way forward to the replacement of living animals as test systems and to the speeding up and simplification of safety evaluation. The introduction of new concepts and new technologies of course must be done with a great deal of care and caution but substantial progress has already been made and change is clearly under way. Undoubtedly animal tests and the tried and tested review procedures will be with us for some time yet but we can clearly look forward to their gradual modification and ultimate replacement by new approaches at a rate which is appropriate when viewed against the very long time scales of the food supply industry. The present procedures are geared towards ensuring the safety of the consumer

and it is this which must be the ultimate determinant of the rate and pattern of change.

Microbiological evaluation

To return to an earlier theme it is imporant to recognise that the United Kingdom faces a serious quantifiable and apparently deteriorating situation with regard to microbiological food poisoning. The conventional testing of food for microbiological hazard has, until recently, consisted almost entirely of carrying out microbiological tests on finished product and withholding release until the results of such tests are available. The efficiency and speed of those tests have been improved substantially in recent years with the introduction of new rapid methods for detecting specific pathogenic micro-organisms. Progress will continue as techniques generated as a consequence of our rapidly expanding understanding of the genetic composition of micro-organisms are applied to food analysis.

Nevertheless, it is now generally agreed in the food industry that this approach of post production testing is essentially negative. What is needed is a thorough understanding of the factors influencing the growth or persistence of dangerous organisms in a food product and modification of the recipe or of the manufacturing process in such a way as to eliminate the possibility of the final product carrying living pathogens or active toxins. This is the rationale behind the Hazard Analysis Critical Control Point (HACCP) concept: the basis of modern food process technology. HACCP consists of the identification of those critical points in the food processing operation where control can effectively be applied to prevent not only contamination but also growth or survival of a harmful micro-organism. An understanding of such critical control points is then built into the design of a safe process and the whole developed into a system of control involving proper training, specified procedures, supervision and monitoring. This approach, the elimination of hazard as opposed to the detection of hygiene failure, is rapidly becoming the norm in the food manufacturing industries and clearly points the way ahead for this important area of food safety.

Of course not all food as it appears in the market place has undergone a process of manufacture. Many microbiological problems arise from the direct contamination of raw foods followed by preparation treatments which are inadequate to kill the micro-organisms present. Some of such contaminations can be prevented but many cannot in the present state of our knowledge and the present structure of the food industry. Here the need is primarily for education in the rules of hygiene. It has to be admitted that the standards of hygiene in some retail outlets and catering establishments still

leave much to be desired whilst the lack of understanding of even some of the basic rules of hygiene on the part of many consumers is disturbing. It is still unhappily true that the vast majority of food poisoning incidents arise as a result of inappropriate handling of foods in the home kitchen.

The extensive use both in the food processing industry and in the kitchen of refrigeration, freezing and microwave cooking opens up opportunities to control the spread and proliferation of hazardous micro-organisms and also, through their misuse or abuse, present dangers. Such changes in technology are of course also a feature of the changing scene with regard to food safety. Somewhat in the future, but probably of very great ultimate importance, will be the application of food irradiation. Food irradiation is capable of eliminating micro-organisms from food materials with complete safety. At the present time it offers the only feasible opportunity to break the *Salmonella* cycle in the UK poultry industry. The technique is not without its problems, of course; not all foods can be irradiated effectively whilst retaining their eating quality and there are certainly some instances of decreased nutritional value associated, for instance, with the partial destruction of some vitamins. The most important problem, however, is the obvious suspicion on the part of the consumer following the Chernobyl incident although it should be emphasised that we are dealing with a quite different type of irradiation and that irradiated food presents no more radiation hazard than does a precooked, cooled, food product present a scalding or burning hazard. Here the most important need is the development of an adequate test which will demonstrate that a food has been irradiated for monitoring purposes. The opportunity for an unscrupulous operator to recycle microbiologically unacceptable food by irradiating it is an obvious one and effective monitoring methods are clearly needed.

SUMMARY

The whole question of food safety is, naturally, one of major concern to the population in the UK. The British consumer has available a wide, sometimes bewilderingly wide, range of natural food and manufactured food products which are attractive in taste and appearance and which survive on the market simply because the consumer likes them and buys them. The modern food industry, however, is large, complex and sophisticated and the consumer is understandably confused and suspicious of an industry whose processing units must at times seem more like a chemical manufacturing plant than a kitchen. The industry is in a rapid state of change and this is reflected in changed concepts of, and approaches to, the issues of food safety.

There is a clear problem of microbiological food poisoning in the United Kingdom and it is also evident that there are a significant number of individuals in the population who exhibit intolerance to some food components. These may be natural components of foods such as shellfish, strawberries or milk or they may be food additives such as tartrazine or quinine. This is a notoriously difficult area in which to do research and it is often impossible to confirm that a particular food intolerance is, in fact, real. The problem, however, is a very real one and it is an area into which further research into mechanisms is badly needed.

There are many natural materials present in the raw foods entering our food supply which are known to have toxic effects when consumed in substantial amounts. We know very little of the significance of these materials when they are consumed at low levels as part of our normal diet. Traditionally they have been accorded nothing like the attention devoted to those additives which are used in food manufacture but there is a significant body of opinion that they may well play a significant role in relation to the safety of our food supply and that they merit more serious attention. Certainly changes in the nature of the food supply need careful monitoring in relation to possible increases in the consumption of such natural toxicants.

The additives which are used in the production of manufactured food products are subjected to extensive testing and there is no medical evidence that approved additives represent any kind of general public hazard.

The food industry is in a constant progressive state of change and this is reflected by evolving concepts of food safety. At the present time the main features of this change are the development of control procedures aimed at preventing the development of microbiological hazards to replace the product monitoring which has been a feature of microbiological testing to date, the careful monitoring of changes in the UK diet and of new materials entering the food supply for possible safety problems, the development of improved tests for use in evaluating the safety of food components and the development of more effective models for the interpretation of test data.

In the background to these more immediate changes lie a requirement for better understanding of the relationship between diet and disease, a need for continued surveillance of the intakes of foods and food components, a need to better understand the microbial ecology of foods, a need to better understand the mechanisms involved in food intolerance and a need to understand much more fully the features of a molecule which make it hazardous when consumed as part of our diet.