Centre for Agricultural Strategy

# Food safety in the human food chain



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# 1 The human food chain and its relevance to food safety

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## INTRODUCTION

### The food chain

The UK food chain is massive and complex. It is summarised in Figure 1. Food is also a major component of domestic expenditure. In 1986 we spent £44 billion on food which represents 18.6% of total consumer expenditure (MAFF, 1987a). Even at the level of aggregation in the diagram it is clear that the food chain might be more aptly described as 'the food web' within which pathways merge and divide. Flows are determined, by our wishes, as we seek nourishment and pleasure within constraints of taste, belief and purse. We are looking increasingly for:

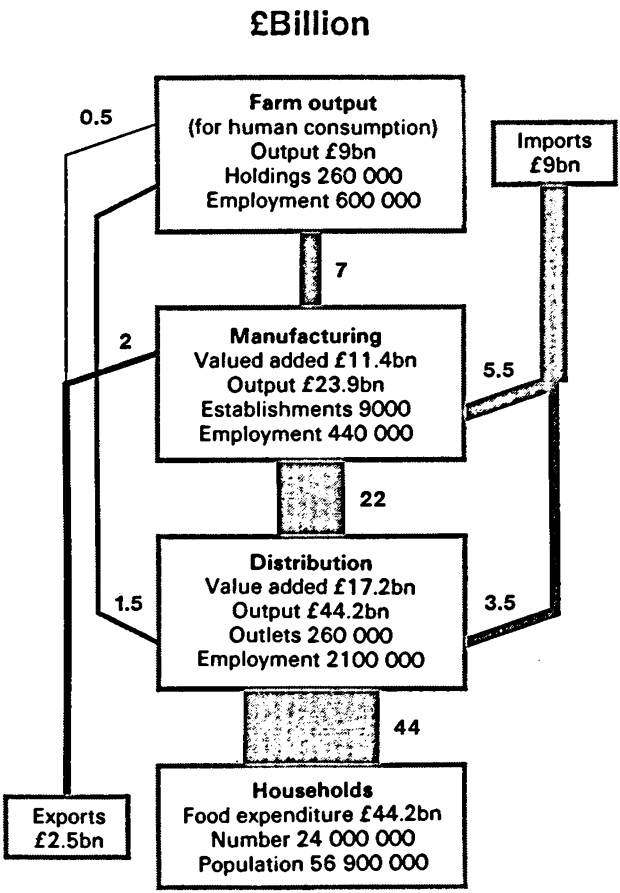
(i) quality;
(ii) variety;
(iii) convenience;
(iv) competitive prices;
(v) safety – confidence not worry.

To meet the needs of an increasingly demanding marketplace farmers, food manufacturers and distributors innovate.

New technologies and methods should not only be safe, but should not undermine what exists already to assure safety at other points in the chain. They should be underpinned by management which ensures that plans are delivered. The figure shows that about five-sixths of our farm output by value and nearly two-thirds of imported food are processed in some way before distribution. The chain for any individual food is at least as complex as the aggregation which we see in the figure. In pursuit of quality and efficiency:

(i) farmers and growers manage crops and animals using a range of feeds and fertilizers, agro-chemicals, and pharmaceuticals, often in

Figure 1
**The UK food chain 1986**




Source: Economics and Statistics (Food) Division, MAFF.

an extremely variable environment;
(ii) manufacturers separate, mix, treat and pack raw materials;
(iii) distributors handle and often re-pack foods;
(iv) storage frequently occurs before and after manufacture;
(v) householders and caterers handle, cook and store food.

Throughout the food chain considerable care is needed to avoid:
(i) contamination with materials from the environment;
(ii) conditions which favour the growth of micro-organisms or recontamination after foods have been treated to reduce these to an acceptable level.

*The strategic approach to food safety*

The complexity of the food chain requires a strategic approach to food safety which ensures that actions are not only taken at the most appropriate point to secure maximum effect and reliability for the least cost, but also avoid unwanted interactions. Implementation of strategies for food safety frequently depends crucially on human factors. More than 3 million people are employed in farming, food manufacture and distribution. In Figure 1, catering is included in 'distribution' and accounts for 24% of household expenditure on food (some 14% of civilian employment). Moreover foods must be handled safely in the home; the whole population except perhaps for the very young and very old thus has a part to play.

The framework for food safety has 3 main components:
(i) judgement to define safety;
(ii) management to secure safety;
(iii) surveillance to confirm safety.

I shall illustrate these three components of food safety by reference to specific chemical and microbiological risks which are best controlled in the early stages of the food chain since others today will deal with risk assessment and management in the later stages of food manufacture and distribution.

## JUDGEMENT OF SAFETY

### Pesticide evaluation

Evaluation of pesticide safety provides a good example of the way in which judgement in several fields of science must be combined in order to judge risk and thus to reach conclusions on the overall safety of specific applications of specific products.

*Maximum residue levels (MRLs)*

The benefits of pesticide use in food production and storage must of course be weighed against risks from residues and metabolites of the pesticide

remaining in the product at the time of consumption. We should bear in mind for example that as well as contributing to the efficiency of the food chain, pesticides can contribute directly to safety by reducing diseases or controlling vectors. In determining what residue should be allowed in food, the main principle to be observed is that the amount should not be higher than that which results from 'good agricultural practice' provided that the final amount of residue in the daily food is not greater than the amount accepted as safe for long term consumption. This principle provides the foundation for a precautionary approach to pesticide control which has been adopted in many countries and which is fundamental to the UK Control of Pesticides Regulations (1986). The precautionary approach means that no more pesticide should be used than is needed to realise the intended benefit and that such pesticide usage is only acceptable if the Maximum Residue Level (MRL) which results is below a safety ceiling.

As in other measures intended to minimise this food contamination, information is needed in 2 main areas to establish MRL's:

(i) the probable human exposure;
(ii) the toxicity of the material.

The extent of human exposure depends on two factors:

(i) the amount of residue or metabolite in a food as consumed;
(ii) the amount of food consumed.

To provide information on the first point, applicants for registration of a new pesticide are required to measure the residues found in crop trials which emphasise circumstances where residue levels are likely to be highest. The data enable regulators to determine the probable maximum level of residue in a crop or product under the proposed conditions of use and to establish the rate and route of its decline. Regulators can then decide whether proposed rates of use at particular stages of growth or storage and intervals between application and consumption are reasonable. Trials also allow the Maximum Residue Level (MRL), ie the residue level which is likely to occur under conditions of good agricultural practice, to be established.

*Determination of probable levels of residue consumption*

Special surveys may be required to provide data on consumption of foods which are likely to contain residues. In many cases, food consumption in Great Britain may be inferred from the results of the National Food Survey which is based on food purchases by a nationally representative sample of 7000 households each year. Using these data an estimate of a high consumption rate for individual foods may be obtained. These high rates will be exceeded on occasions by a small number of consumers but are unlikely to be exceeded regularly by all but a very few individuals.

Having established high consumption rates for foods on which the pesticide may be used, the next step is to establish extreme intake for the pesticide. To do this it is assumed that:

(i) all foods which may contain the pesticide do contain a pesticide;
(ii) each food contains the pesticide at the MRL;
(iii) an individual has a high consumption rate for all foods on which the pesticide may be used.

In arriving at an estimate for some pesticides of course it may be necessary to take into consideration exposure other than through the food chain.

*Determination of pesticide toxicity*

Ideally the toxicity of the pesticide would be established on the basis of human epidemiology, ie historic description of the effects of known exposure on human health. Such epidemiological information is rarely available so that toxicity has to be evaluated instead by extrapolation from animal trials, including target organ toxicity, carcinogenicity, mutagenicity, teratogenicity and reproductive toxicity.

*Establishment of 'no-observed effect level' (NOEL)*

Information is also required on the metabolic fate and behaviour of compounds including bio-transformations and possible biochemical, haematological and pharmacological effects. Trials are conducted at a number of dose levels and often in more than one animal species to establish the maximum dose at which no specific treatment related effects are apparent. This dose is known as the 'no-observed effect level' (NOEL). It is not possible here to discuss in detail the factors which should be taken into account when extrapolating from the lowest NOEL obtained in animal trials to the acceptable daily intake (ADI), the amount of material expressed on a body weight basis which can be consumed daily over a whole lifetime in the practical certainty that no harm will result. Extensive discussion at national and international level over several decades has, however, led to frequent adoption of a safety factor of 100 for conversion of NOEL to ADI. Other values may be considered more appropriate, however, depending on the nature of the problem. In particular if a substance is shown to act as a carcinogen or mutagen by mechanisms which are likely to occur in humans, then their use is normally restricted so as to prevent the occurrence of detectable residues in food.

A particular use of a particular pesticide is acceptable only if the MRL is such that total intake from all sources is below ADI. Since many pesticides leave no detectable residue and in many other cases the margin between MRL and ADI is very large, interactions between different uses of the same material rarely give rise to problems.

*Importance of independent guidance*

The effectiveness of safety assurance systems of the type I have outlined depends upon the validity of the assumptions made at each stage and the

quality of the underlying science. Independent expert guidance on criteria methodology, the interpretation of data and the adequacy of quality assurance arrangements in all organisations providing such data are vital, not least as a basis for public confidence. In the UK this independent expert input is arranged through the Advisory Committee on Pesticides and various specialist committees of the Department of Health.

*Interpretation of data*

I have dwelt at some length on the complexity of the arrangements required to reach a valid judgement on what is safe or acceptable at any particular time. It is tempting to quantify the overall judgement as a single risk factor, but such figures must be treated with caution. The uncertainty of the overall judgement is the product of the uncertainties of all the subsidiary judgements. Accordingly, there can be very big differences between optimistic and pessimistic interpretations of the same data. For enforcement purposes regulators have to choose a discrete level of threshold of contamination but it should be appreciated that this is a point which is to some extent arbitrary on the curve which relates risk to exposure. Moreover there is a good deal of scatter in the data which contribute to that curve. The general approach adopted for pesticides, that of estimating maximum intake and evaluating toxicity can be adapted for use in relation to other chemical contaminants in order to set priorities for action to reduce exposure.

Expert judgement as to what is safe must be coupled with management of the food chain in a way which ensures that acceptable levels are not exceeded. These arrangements frequently provide subjects for whole conferences in their own right and I should merely like to remind participants that in the UK there is a statutory requirement for training those who apply pesticides so that they can use materials in accordance with approved recommendations and for record keeping to show that they do. The aim is to ensure that good agricultural practice is observed so that MRL's are not breached.

Any weaknesses in pesticide approval and management should be revealed by food surveillance. I shall return to this subject in general later, but for the moment, remind participants that a large government programme focused on areas where residues are likely to be present, planned and interpreted in the light of independent advice, is backed by extensive work carried out by food manufacturers and distributors for quality control purposes.

## FOOD CHAIN MANAGEMENT

### Microbiological food safety

Contamination of food by micro-organisms poses slightly different problems

from contamination by chemicals. Exponential growth in micro-organisms means that under appropriate circumstances the transition from a tolerable population of pathogens to one which is well above the Minimum Infectious Dose (MID) can be very rapid. Under appropriate conditions relatively low populations of micro-organisms can show high metabolic activity yielding significant amounts of toxins which can then survive processing. Traditionally therefore, the approach in microbiological food safety has been one of extreme caution, relying on short distribution chains for vulnerable foods, severe but effective methods of preservation and thorough cooking prior to consumption. Food safety is achieved, but frequently at the expense of some sacrifice of eating quality and choice. Any relaxation of traditional practice, must be accompanied by improved standards of management and monitoring of conditions at critical points in the food chain to identify lapses which could lead to the proliferation of pathogens. End product monitoring is not usually an effective strategy.

Control of pathogens in food requires food chain management in 3 main areas:

(i) prevention of primary contamination or its elimination when unavoidable;
(ii) packaging to preclude re-contamination;
(iii) storage and distribution under conditions which arrest microbial growth and metabolism.

There are obvious benefits to applying these principles as early in the food chain as possible but costs can be considerable as recent UK experience with *Salmonella* has shown.

*Salmonella*

*Salmonella enteritidis* PT4 has emerged as the most common single type of *Salmonella* identified as a cause of human food poisoning in England and Wales. There has also been an increasing association of egg and egg products with outbreaks of human food poisoning caused by this bacterium and measures to control *Salmonella* in commercial egg-laying flocks based on the following principles have been adopted as a consequence:

(i) supply of uninfected stock;
(ii) continuous bacteriological monitoring;
(iii) removal of infected stock;
(iv) prevention of the introduction of infection with particular reference to feed.

There is not time to go into the detail of these measures or the way in which they are being enforced, but it should be recognised that they represent simultaneous and continuous action at critical control points in the *Salmonella* cycle in poultry laying flocks.

## FOOD SURVEILLANCE

Food surveillance, ie the collection and analysis of samples from appropriate points in the food chain followed by evaluation of the significance of results for human health, provides a check on the adequacy of arrangements for ensuring food safety, an indication of the nutritional value of the national diet, and early warning of problems.

### Steering Group on Food Surveillance

In Great Britain surveillance of chemicals in the diet is overseen by a MAFF Committee, the Steering Group on Food Surveillance (SGFS). SGFS brings together medical and scientific experts from Government, the academic community and industry. It supervises a comprehensive programme of food sampling and analysis which provides an up-to-date picture of the nutrients, food additives and contaminants in a diet. SGFS is supported by 10 specialist Working Groups covering:

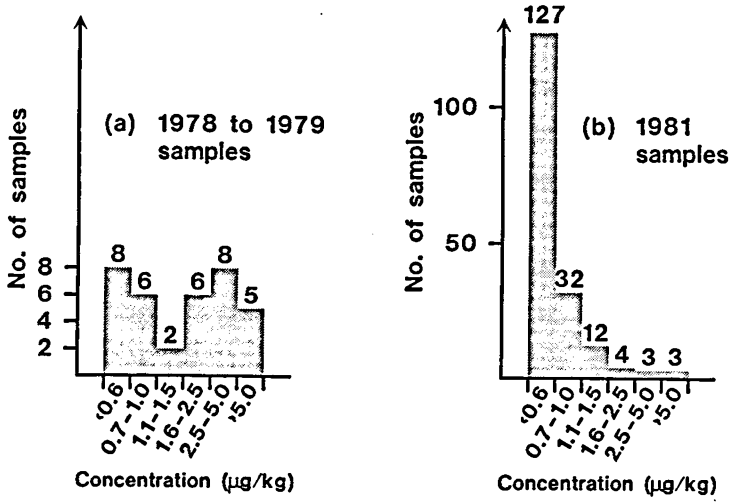
(i) chemical contaminants from packaging and other materials which might come into contact with food;
(ii) food additives;
(iii) metals and other inorganic contaminants;
(iv) naturally occurring toxicants;
(v) nitrates and related compounds;
(vi) nutrients;
(vii) organic environmental contaminants;
(viii) pesticide residues;
(ix) veterinary drug residues;
(x) radioactive contaminants.

Each working group keeps under review possibilities for contamination or inadequacy of the diet by commissioning surveys and research into key areas and by critical evaluation of information available from other sources. A key role of SGFS and its Working Parties is to confirm the quality of the underlying science. Particular attention is given to finding out whether there are groups within the population who are at special risk because of abnormal eating habits and other factors. Where problems are detected SGFS investigates their origin and recommends remedial action.

### Nitrosamines

For example because of technical advances in malting, food surveillance detected minute quantities of potentially toxic nitrosamines, notably *N*-nitrosodimethylamine, in beer in the late 1970's (see Figure 2). Research in collaboration with maltsters and brewing engineers, commissioned by SGFS, enabled the problem to be evaluated and provided a basis for remedial action. As Figure 2 shows the problem had been eliminated by 1981. Monitoring followed by collaboration with industry rapidly provided a high level of consumer protection.

Figure 2
**NDMA (*N*-nitrosodimethylamine) levels in ale, lager and stout, UK retail samples**




Source: MAFF 1987 (b)

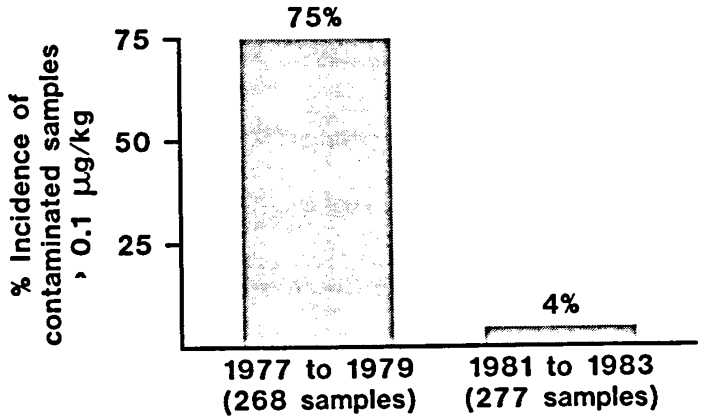
### Mycotoxins

Food surveillance also showed that small quantities of potentially carcinogenic mycotoxins were being transferred from animal feedstuffs to cows' milk. Research carried out in collaboration with animal feed manufacturers provided a basis for control which was enforced by new regulations. As a result the proportion of milk samples showing contamination at a level of more than 0.1 µg/l fell from 75% to 4% between 1979 and 1981 (see Figure 3). Again food surveillance coupled with collaborative research provided a high level of consumer protection.

### Medical significance of findings

The medical significance of food surveillance findings is evaluated by specialist DoH (Department of Health) committees on toxicity, carcinogenicity and mutagenicity. Given the multitude of chemicals in our food, surveillance could provide an open ended requirement for scientific resources. Effectiveness depends on sound judgement of priorities. SGFS attempts to concentrate resources on areas where problems are most likely to be found whilst leaving the programme sufficiently comprehensive to

Figure 3
**The decrease in aflatoxin $M_1$ contamination of UK Milk**




Source: MAFF 1987(b)

detect the unexpected and to have the capacity to respond quickly to change. For example surveillance of radioactive contaminants in food was expanded many fold in the days following the Chernobyl nuclear accident. Effective food surveillance can do much to raise consumer confidence in food so that publication of results is important. A compromise has to be set however between speed of reporting and the value of comprehensive reports which evaluate thoroughly analytical information drawn from a wide area.

**Microbiological food surveillance**

Microbiological food surveillance is carried out by 52 regional and area laboratories of the Public Health Laboratory Service (PHLS) to provide a microbiological service to Environmental Health Departments of local authorities. Milk, cream, ice cream and increasingly other foods are examined together with imported food sampled at points of entry or distribution centres. Raw foods, particularly meat and poultry and animal feeds known to spread agents of food poisoning, are monitored to trace the origin and route of transmission of these organisms. The necessary research into the survival and multiplication of food poisoning bacteria is carried out and preventative measures are initiated when required. The Communicable Diseases Surveillance Centre provides a focus for collection and evaluation of data from PHLS and other sources.

## CONCLUSION

At the outset I suggested the framework for food safety has 3 main components:

(i) judgement of what is acceptable;
(ii) management of the food web to achieve acceptability;
(iii) surveillance to confirm achievement or identify the need for change.

Although we probably now have access to the safest food supply in history, there is no room for complacency, not least because, in our pursuit of variety, convenience and competitive prices, we are demanding even more skilled management from farmers, food manufacturers and distributors. There are opportunities to improve the scientific basis for judgement on acceptability, to tighten the management of the food chain and to improve surveillance. Unfortunately many of these opportunities carry a significant cost so that we face a problem of choice. We must view food safety as a whole, and seek balance in our marginal investments in it. We should seek balance, not only within food safety, so that greatest effort is devoted to the greatest real risks, but we should balance between investment in food safety and investment in the development of other aspects of society. This balance is possible only if we can achieve greater public awareness of the whole gamut of food safety and food choice issues which underlie that well-worn term 'a healthy diet'. Without awareness there will be gaps between perception and reality.

This broad message is much more difficult to communicate than simple stories of the performance of this or that chemical in an arbitrary test on the other side of the world. We must, however, try, and I therefore very much welcome the effort and initiative of the organisers today in trying to put safety in its food-chain or food-web context. I hope that the very general principles which I have outlined today and which will be familiar to many of you will help to provide a framework for our discussion.

## ACKNOWLEDGEMENT

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