SESSION 6B

PESTICIDE RESIDUES IN FOOD

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Papers: 6B-1 to 6B-4

Pesticide residues – better early than never?

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ABSTRACT

Some supermarkets are leading the drive for zero-tolerance of pesticide residues in food, acknowledging the concerns of the average consumer. The Food Standards Agency recently instituted a review of literature in the public domain concerning pesticide residues and the potential for their minimisation. A review of UK research initiatives indicated that the concern to reduce environmental impact has outweighed the main - and often conflicting - demands of the consumer for food that is both cheap and "chemical"-free. Any attempt to reduce residues in food must inevitably focus on late season and storage practices rather than earlier prophylactic treatments that may have more environmental impact. Procedures can be cited that do or could promote additional pesticide near to or after harvest. These include the long-term storage of fruit and potatoes, the use of strobilurin fungicides, and the introduction of crops with herbicide insensitivity.

INTRODUCTION

The Food Standards Agency recently instituted a review on the crop protection of UK food commodities, particularly fresh fruit and vegetables, as a preliminary to developing a strategy on the minimisation of pesticide residues. This arose from clear evidence that the public do not favour any "chemical" residues occurring in food and from the zero-tolerance response of some supermarket chains. This zero option may have environmental consequences.

THE DOMINANCE OF PESTICIDES

Pesticides are used in food production to control the effects of fungal diseases and pests on crop development, to reduce competition with the crop by other plants, and to protect harvested food from pest and disease attack, and to control development of stored products. Pesticides may not provide the only means of crop protection but their effectiveness and simplicity of use have made them the method of choice for global agriculture. The use of pesticides became the norm after the Second World War, with more than 800 active ingredients in use across the European Union by the 1990s. Agricultural systems have developed in response to the availability of pesticides to prevent most previously intractable problems. Concern about pesticide use has been voiced since shortly after their inception, with counter arguments based on the need to combat crop losses, put conservatively at 35% of potential crop production, with a further 20% loss post-harvest. Holm (1976) showed that yield reductions ranged from zero to 90% due to weed competition, with means in the range

17-51%. Pimentel (1992) estimated that pesticides, with sales of 2.5 million tons per annum, had saved about 10% of the world's food supply, but contended that the damage caused by pesticides exceeded their benefits. Pretty *et al.* (2000) expanded this contention, reckoning that the total external costs of UK pesticide-based production was £2.3 billion per year, or £208 per hectare, of which the presence of pesticides in drinking water required £120 million treatment per annum.

Public concern

This dominance of pesticides has led to concern over pesticide residues in food, and this has repeatedly been endorsed in surveys of public concern. *The Guardian* published 81 articles on pesticide residues in 1999-2002. Recent press coverage is based on pesticides being an ever present contaminant of food, with the word chemical frequently being substituted. It would be difficult to find a report from the public media that endorsed the use of pesticides, unless it was perhaps associated with an issue of immediate concern for public health. Thus, whilst the first reality is our dependence on pesticides the second has come to be the control exerted over the public consciousness by media and pressure groups such that pesticide residues in food are unacceptable, and the belief that they are to be found only in conventionally produced food.

Sources of residues data

The principal sources of data within the UK are the surveillance reports of the Pesticide Residues Committee (PRC), established in 2000 to replace the Working Party on Pesticide Residues (PRC 2002). PRC oversees the monitoring of the UK's food and drink in a three part programme of checks:- that no unexpected residues occur; that residues do not exceed *Codex Alimentarius* Maximum Residue Levels (MRL); and that human dietary intakes are within acceptable levels. MRL are usually measured in mg/kg or parts per million, but in some cases are based on current Limits of Detection (LOD, hence LOD-MRL). PRC's reports are directed at an informed public, and use every opportunity to explain that MRL are not safety limits, i.e. they can be exceeded without implying a risk to health, and that their role is to demonstrate pursuit of Good Agricultural Practice (GAP), thus facilitating international trade. Nevertheless the very nature of the expression *maximum residue level* gives the wrong steer to even an informed public, and brings us back to the second reality, the fact that the public's perception of pesticides is utterly negative. The third of PRC's checks, the acceptable levels, derive from exposures primarily established in short and longer term studies of pesticides in mammals, generating the Acceptable Daily Intake (ADI), the Acute Reference Dose (ARfD), and the Acceptable Operator Exposure Level (AOEL). In addition to PRC's monitoring the Pesticides Safety Directorate operates an enforcement programme, dedicated for example to winter lettuce in 2001; its results are included in PRC publications. Other sources of data on products in the UK are generated by the food industry and consumers' associations, with some results being published, or at least the subject of some publicity. The European Commission publishes an annual compilation including UK data.

Residue results

The third reality concerns the actual levels of contamination observed in foodstuffs. For example, 29% of the 4,003 samples tested by PRC in 2001 were free from pesticide residue (Table 1). PRC (2002), in reporting these results, noted that "desirable safety margins" had been eroded by 0.25% for the 0.7% of samples exceeding MRL. Figures for nine supermarket chains, as measured on behalf of Friends of the Earth (2002), were 29 to 63% of fruit and vegetables with pesticide residues.

Table 1. Pesticide Residues in UK Food Samples (source: Pesticide Residues Committee)

	Year		
	1999	2000	2001
No of Samples Analysed	2,300	2,304	4,003
% with measurable residues	27	28	29
% with residues exceeding MRL	1.6	1	0.7
% of samples of with measurable residues			
Bread	6	44*	38
Milk	0	0	2
Potato	51	48	33

* Residues of chlormequat assessed for first time and found in 41% of samples.

Table 2. Pesticide residues detected in a selection of vegetables and fruit 1991-2002 (source: Pesticide Residues Committee)

Crop	No. samples tested	% with residues	% > MRL	No. pesticides found
Carrot	369	64	0.8	12
Celery	276	66	4.0	30
Lettuce	803	58	3.7	37
Mushroom	255	11	0.8	5
Onion	146	48	0	1
Potato	1,722	37	0.3	15
Tomato	359	23	0.3	26
Apple	396	44	0	25
Banana	181	65	2.8	7
Grapes	382	44	2.1	46
Orange	303	95	2.0	30
Strawberry	383	67	0.3	12

Residue occurrence is generally in fruit and vegetables among products sold in the UK (Table 2), with rather lower levels of occurrence in potatoes offset by the importance of this crop to the national diet. The residues detected are primarily fungicides, but sprout suppressants dominated the residues found in potato, as again in 2002, when chlorpropham was found in 23 out of 138 samples. Chlorpropham does not have an MRL set, but the highest level found was 6.6 mg/kg (PRC 2003).

The origins and potential impact of the result

PRC (2002) note that the outcome of MRL exceedance in 2001, on worst case scenario, would be a few upset stomachs. The calculation of ADI, expressed in mg active ingredient per kg body weight, is based on a complex model of risk factors coupled to the "no observed adverse effect level" in animal experiments, but multiplied up by an uncertainty factor, usually one hundredfold. It is not clear the extent to which ADI as a risk assessment takes into account residue losses during processing, and residue gains associated with, for example, the use of spices and the treatment of food premises (Singh & Singh, 1990). It is relevant to note that the passage of the Food Quality Protection Act in the USA in 1996 resulted in a major, US-wide risk assessment of human exposure to organophosphorous (OP) insecticides as a whole (Miller, 2002). Its main finding was that exposure was largely associated with the use of dichlorvos (DDVP) for domestic pest control rather than with dietary exposure. Dichlorvos was withdrawn from the UK domestic market in 2002 (Department for Environment, Food and Rural Affairs, 2002). However, the assumption is still that the main source of pesticide residues overall is by consumption of treated crops or through the consumption of milk and meat products from animals fed on crops containing residues. The herbicides 2,4-D, 2,4,5-T and MCPA regularly occur in milk. The residues derived from persistent organochlorine pesticides are easily absorbed into fats, resulting in animals constantly recycling them and causing contamination of milk and meat. It is possible to derive a signature from the degradation products of DDT to indicate exposure to recent use, historical use, or metabolism via animals or micro-organisms (Working Party on Pesticide Residues, 2000).

There may be misconceptions about the importance of conventional production relative to other systems. Baker *et al.* (2002) compared pesticide residues in fruit and vegetables originating from conventional and organic production systems, and from crops subject to integrated pesticide management (IPM). They found that 23% of organically produced samples contained one or more residues, compared to 73% of conventional samples and 47% of IPM-derived samples. Forty per cent of the residues in organic samples were derived from persistent organochlorine pesticides banned in western Europe.

A consideration of the routes of pesticide residues to the plate must take into account the relative importance of products derived from the UK and those coming from abroad. PRC reports differentiate, where possible, between UK-derived products and those from abroad. The level of pesticide detection and MRL exceedance are higher for imported products than for those of UK origin (PRC, 2002). The level of pesticides in foodstuffs must normally decline from the moment of their use through continued crop growth, harvest, storage, to the cleaning and cooking of the food. Exotic raw spices and dried food or preserves may add pesticide residues to the plate, to which must be added those from animal products and finally non-dietary exposures at work or in domestic pest control. The human body immediately takes on the task of excreting or degrading any ingested residues.

Data that track the passage of pesticides from application to human excretion are limited. The only accurate and copious figures are those at the shop counter. Figures are also available for pesticide sales, their actual usage and levels on crops when the pesticide is undergoing evaluation. The actual point of consumption of residues, i.e. the meal as a whole, is only analysed for foods eaten whole – bread, some fruit and prepared foods such as preserves and instant meals, and for ADI and ArfD, usually in the event of concern about a particular residue finding. There are few studies of the movement within the human body of modern pesticides; those that have been done concerning breast milk, blood and urine typically concern residues of the largely banned persistent organochlorine insecticides. Thus our knowledge of the "life-cycle analysis" of a pesticide within the food chain is incomplete, with possibly more information available about its leaving that system, i.e. entering the environment.

The market response

Attempts to explain that exceedance of maximum residue levels does not constitute a health risk have failed. Attempts to explain that even lower levels of residue are of no concern have failed. Telling the public that everything they eat is a chemical have failed to convince them. Stating that some naturally occurring chemicals are more toxic pesticides than those applied to the crop probably adds to the confusion. It is unlikely that the hormetic benefits of such exposure (Calabrese & Baldwin, 2002) will be accepted by the general public.

The reality has become that the public require food to be free from any trace of pesticides. The toxicology of the residue is largely irrelevant. The argument for dominance of an alternative reality, that consumers require cheap and blemish-free food, is being eroded by systems less dependent on pesticides, i.e. organic production, and pesticide-free food, i.e. infant food products. The supermarkets respond by setting requirements well below MRL, and most are developing sales policies based on zero tolerance. It is pertinent to assess the impacts of this policy, given that we are still working with production systems that evolved in response to the availability of synthetic pesticides.

The negative impact of zero tolerance

The benefit of zero tolerance must foremost be the satisfaction of the consumer. A longer term benefit might be a realisation by consumers and their advisors that there is more to health than avoidance of xenobiotics.

Some high-yielding modern cultivars can survive only if protected from pests and pathogens to which they are susceptible either by the use of pesticides or by intensified breeding to introduce resistance factors. A classic example would be the potato cv Maris Piper, resistant to some cyst nematodes, but susceptible to aphids, the viruses they transmit, and to slugs. Taking this to extremes some crop species cannot survive unless protected, e.g. potato affected by late blight, *Phytophthora infestans*.

The "better the devil you know" syndrome applies here, whereby well established pesticides are associated with well established methods of detecting their residues. The substitution of an easily detected existing pesticide by a seemingly residue-free pesticide may prove unsustainable as analytical technology catches up.

And then there is the problem of minimising pesticide use around harvest time. Earlier concerns about insecticides were largely associated with their persistence or their direct effect on the human nervous system. The replacement of these materials by synthetic pyrethroids shifted the focus towards the pesticides on which we are more heavily dependent, the fungicides and herbicides. The more recent concern about pesticide residues *per se* has highlighted the use of growth regulators. The emphasis now is surely on those pesticides that generate residues at harvest or in store irrespective of the hazards associated with them – and these are largely fungicides, desiccants and growth regulators.

Knock-on effects of treatments

If late season treatments are more likely to generate residues than those applied earlier, a solution to one crop problem that requires a further treatment for another must also give cause for concern. There are a number of examples, actual and potential, of this knock-on effect.

1. Mushrooms. PRC (2001) reported seven samples of mushrooms containing chlormequat in 2000. These residues probably arose from use of straw-based growing media from treated cereal crops.

2. Fruit storage rots and maturation control. The amount of rotting during storage of apples is mainly determined by the growing conditions. Different varieties also have greater susceptibility and each has its own storage requirements in terms of temperature, carbon dioxide and oxygen concentration. Thus a risk assessment on a crop as it arrives at store may restrict the need to apply a fungicide drench. Post harvest fungicides are not essential – they are banned in some EU countries – but rotting levels may be doubled by failure to treat. A fast turnaround at harvest is rarely possible, owing to the need to obtain the best market price for the produce, and so it is the market that largely dictates the need for post-harvest treatment. Harvest damage of pears is responsible for post-harvest infection by *Botrytis*. This is largely because the fruit stalks do not absciss naturally, as in apples, leading to sharp-ended stalks ("snags") that inflict damage on other fruit when moved into store. Pears are stored at sub-zero temperatures, and then ripened over 6-8 days once out of store, again in contrast to the slow maturation process of apples. Iprodione has an off-label approved usage for this problem, and its residues are frequently detected on pears.

One major food outlet has experienced difficulty in meeting its zero tolerance declaration with lemons. Citrus fruits are generally picked green and then 'degreened' prior to marketing using ethylene at high humidities. The raised humidity increases the risk of infection with *Penicillium* and *Botrytis*, requiring late pre-storage treatments with fungicides. The public are not aware that skin colour in citrus is not an indicator of ripeness, green produce being wholesome but nevertheless unacceptable. Incidentally, waxing of fruits, in particular citrus, is essentially cosmetic but is claimed to have added value in terms of reduced water loss and some protectant action against fungal infections, but not enough to guarantee freedom from risk. Thus the withholding of products to maximise their economic impact on the market results in additional fungicide use because of increased risk of attack.

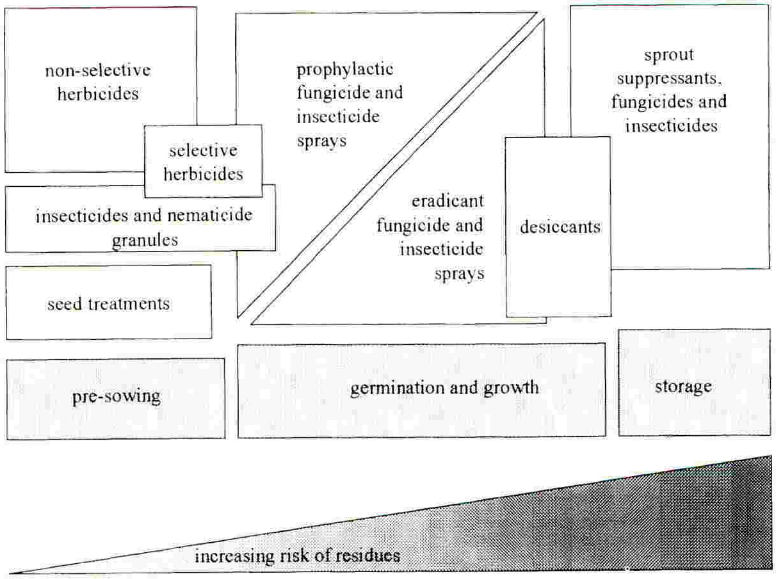
3. The need for desiccants following effective fungicide action. The introduction of strobilurin fungicides to a range of crops can reduce senescence of aerial parts such that desiccants may be required at the end of the season. This may explain the occurrence of glyphosate residues in 7% of bread samples analysed on behalf of the Pesticide Residues Committee in 2000 (PRC 2001).

4. Crops genetically modified to facilitate the use of selective herbicides. Irrespective of the outcome of current trials concerning the environmental impacts of herbicide-tolerant crops, the delay in application of pesticides associated with herbicide-insensitive crops may be expected to increase the risk of residues at the end of the season.

Environmental consequences of zero tolerance

The greatest threat of adopting a zero tolerance policy in association with the continued use of pesticides will be to push back treatments as far as possible within the growth season. Integrated pest management depends on accurate scouting of the crop to minimise unnecessary treatments and to validate those that are undertaken. The latter is an expectation under the Pesticide Voluntary Initiative. Thus there should be more reliance on "intervention" treatments based on eradicant fungicides and fast-acting, selective and non-persistent insecticides to address detected problems rather than prophylactic treatments such as seed coatings, nematicidal granules applied at planting and protectant fungicides. The widespread and indiscriminate protection conferred by the latter types of treatment has caused environmental concern, but their deployment at the beginning of the growing season rather than near its end minimises their potential to generate residues (Figure 1). Thus a demand for zero tolerance may result in increased use of less targeted, broad spectrum pesticides likely to have a greater environmental effect than treatments pinpointing problems.

Figure 1.The pesticide timetable in relation to crop growth, emphasising the increasing likelihood of residues with age of the crop.



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Removing hazardous products from the food chain

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ABSTRACT

A survey of consumers in 2000 identified widespread public concern over the potential health and environmental impact of pesticides and also a general distrust of the framework surrounding food safety issues. To restore consumer confidence the Co-op developed controls that avoid or restrict the use of certain pesticides by suppliers worldwide. Pesticides are selected on the basis of comparative assessments for efficacy, environmental impact and known health issues. The Co-op promotes a three step approach to the control of pests by encouraging the use of preventative measures, cultural and biological control rather than relying on pesticide use. During the past few years the Co-op has banned and restricted the use of 50 pesticides and is continuing it's work to develop it's policy and position. The Co-op take a proactive stance with growers and issues data sheets allowing growers to compare the relative hazards and benefits of products. It is necessary to continue to develop alternative strategies that reduce the reliance on pesticides and promote the use of more benign alternatives. Quality assured food schemes have the potential to help with this. Regulation is essential to maintain the safety of registered products but the addition of a comparative assessment of risk when evaluating new products would be welcomed. Co-operation between all parties in the food industry is essential to reduce residues, improve food safety and restore consumer trust.

INTRODUCTION

Providing safe, wholesome food was one of the founding principles of the Co-op movement some 150 years ago. Company policy-makers and managers believe that new work on pesticides simply brings those principles into practice.

A survey of Co-op customers, described in their recent report (2001), reveals that, whilst they are generally happy with the product choice and quality they now see on supermarket shelves, they are increasingly concerned about health scares, environmental concerns and animal welfare outrages which have created an atmosphere of mistrust, not just of the retail industry, but of the whole framework that surrounds food safety and quality. The survey also showed that after BSE and genetic modification, pesticides were an important area of concern, ahead of emotive subjects such as battery chickens and animal welfare. There is a general belief that pesticides are a risk to health, and that they permeate the food chain as residues. Consumers have very little ability to control their exposure to pesticides, other than through choosing to buy organic food, which may not be available to everybody. They have concerns about the effect of pesticides on health, the environment, and occupational health. Overall, two thirds of consumers gave pesticides a thumbs down, with 'concerned' and 'very concerned' responses accounting for over two thirds in the survey.

The Co-op reflected this level of concern, tempered with a pragmatic approach, in a new programme of work on pesticides that they have developed over a number of years. The Co-operative Group in the UK, through Farmcare, is the largest farmer in the UK, and has a strong ethos of integrated crop management, using many techniques derived from organic farming. In conjunction with Farmcare they have developed controls that involve avoiding certain pesticides and restricting others, applied to all their growers worldwide.

MANAGING PESICIDE RISK

The starting point for the Co-op was a risk assessment of a number of pesticides, taking into account all the available information, although they observe that this was in some cases minimal. Working in partnership with Farmcare, they considered the toxicology of each substance, its bioaccumulation and persistency within the environment. A resulting list of banned pesticides was instituted (Anon, 2001).

Co-op restricted pesticides can only be used by specific agreement with the Co-op, and where a supplier or grower requests approval for use they have to provide supporting evidence that other alternatives are not viable. The Co-op then encourages the grower first to consider other control measures including cultural or biological controls, or more benign chemical alternatives, before approval is granted. Because of the work done with Farmcare, and developing knowledge, the Co-op have been able to suggest to other suppliers viable alternatives, confident that they would perform at an economic as well as at a control level. Farmcare has shown over a number of years that an integrated crop management approach can deliver improved overall results with less reliance on chemical intervention, and thus a reduction in the overall pesticide costs.

These controls form part of a Code of Practice, which the Co-op developed for all suppliers almost three years ago and which is applied to the worldwide production of all fresh produce, and produce for frozen, dried and canned goods. Where problems are identified, for example the use of a pesticide without approval, then steps can and have been taken to stop supplies from a particular grower until matters are resolved to the Co-op's satisfaction. This involves working with growers to find alternatives, and information is provided to assist this process.

Pro-active approaches

The Co-op publicises all of their pesticide results on their website (www.co-op.co.uk) so that all consumers, including their members can access the data. The Co-op was the first retailer to do this and believes that this transparency is vital to reinstating consumer trust. The Co-op would welcome initiatives from other retailers to follow suit: this would provide opportunities to share data more broadly, and allow collaborations on research into alternatives, and how to make practical improvements.

The Co-op believes that it is extremely important that they do not just apply more restrictions to the agricultural industry, but that they help to provide solutions. This applies equally to large and smaller growers worldwide: those in other countries have an equal, if not greater, need for information and assistance. Obtaining unbiased advisory information from agrochemical companies is not easy, especially in developing countries, and the Co-op believe it is fundamental in allowing growers to make informed decisions on crop management. The industry has produced Environmental Information Sheets, but these have a UK focus, do not yet cover all pesticides, and do not offer comparative information, so this is not accessible unless a whole collection of Environmental Information Sheets is available.

As an alternative and to provide improved support for growers, the Co-op has produced a series of Product Advisory Sheets. These aim to share information with growers on the possible control methods for pests in the particular crop so they can make an informed decision on the controls best suited to their needs. They include details of preventative measures, and cultural and biological controls. Information on the approved pesticides includes details on their potential environmental and health effects, potentially enabling a comparative risk assessment to be made, and the more benign products to be selected, if used at all. The Co-op has produced Product Advisory Sheets for a growing range of crops, including carrots, potatoes, avocadoes and pineapples, demonstrating their equal commitment to growers in the UK and further afield. They have been very well received by growers, and remove reliance on agrochemical sales sources for information on products.

The role of quality assured schemes

The Co-op has begun to progress this idea with the Assured Produce Scheme. Unfortunately due to the disparate nature of the scheme progress, to date, has been slow. The Co-op believes schemes such as the Assured Produce Scheme (APS) and the Euro-Retailer Produce Working Group (EUREP) can help to deliver small steps in improvements and practices, both in terms of effectiveness and efficiency of control, whilst supporting a change in how people think about farming and growing controls. However, such development is not inherent within the APS and rarely exhibited by EUREP Good Agricultural Practice (GAP). It is clear that the long term aim should be to support a more sustainable scheme.

The role of the regulator

The Co-op would like to see the Pesticides Safety Directorate (PSD) supporting comparative data as part of the approvals process. It will prove valuable when the first pesticides are removed from the market by the European Union this year, and more information on alternatives is needed.

For the Co-op, working with growers has identified difficulties for UK producers, particularly in relatively small crop and usage areas, for example, in apple growing. UK approvals are not being sought by manufacturers for actives that would be advantageous for UK growers and are already approved on the continent. There are also products approved for limited applications in the UK that have, in some cases, wider approval on the continent. They may offer more effective and yet more benign control. Such restrictions create a disadvantage for UK growers and potentially increasing dependence on older chemistry. The Co-op would like to see improved ways of looking at the way 'mutual recognition' is applied by PSD.

They would also like the Advisory Committee on Pesticides (ACP) to consider methods for the registration of alternative forms of pest control, with an appropriate regulatory hurdle. However the Co-op are in no way advocating deregulation of the approvals process, which is still critical in maintaining safety.

Developing the Co-op pesticide control programme

As the Co-op continue to develop their programme of control over pesticides, they regard the way they regulate the selection of pesticides as the most important aspect. They have developed a new advisory panel of eminent scientists (including two who also sit on the ACP), chaired by Christopher Stopes, a consultant in food and farming, who also sits on the ACP. The panel reviews the pesticides against a hazard framework based closely on the work of the ACP. It does not supersede the regulatory approach but provides a parallel model for development.

Currently the Co-op are reviewing their list of restricted pesticides, focusing on, for example the most commonly found residues, and those actives with potential for endocrine disruption. This may lead to more restrictions, and the development of alternatives. For example, there is an urgent need for an alternative to carbendazim. It is the most common residue found in Co-op testing programmes, though always below the Maximum Residue Limit (MRL). There is also a need for more research into alternatives, led perhaps by government and industry.

Specific research work is required within the pesticide area to investigate the efficacy at lower rates and degradation curves for all pesticides, with the overall aim of reducing residues within products. In addition there is a need to further examine the impact of chemical mixtures (cocktail effect) on human health.

In developing countries there is a need help find alternatives to pesticides where the MRL has been reduced to the limit of detection. Food production is a global process and, as such, the Co-op believes that the needs of growers must be considered. There is scope for collaboration between government departments, potentially including The Department for International Development (DfID), to generate sustainable solutions, and access to the market for small growers abroad.

CONCLUSIONS

With customers continuing to raise concerns regarding the use of pesticides and residues within products, it remains necessary to continue with the work to develop alternative strategies that reduce the reliance on pesticides and promote the use of more benign or non-chemical alternatives. In achieving these aims, the Co-op urges all parties, both directly and indirectly connected to the food industry, to work closely together.

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The growers' perspective on strategies for the minimisation of pesticide residues in food

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ABSTRACT

Current crop protection is largely based on the use of pesticides. Although the scale of use results in the occurrence of measurable residues in about a third of food products, only a very small proportion of residues detected exceed maximum residue levels (MRL) and there is no substantive evidence that current residues represent a health issue. On the other hand there are significant health risks in insufficient consumption of roughage, fruit and vegetables. At the present time, in both the EU and the UK, the application of pesticides in agriculture is decreasing. Growers' maintain that pesticide residues should not be seen in isolation within the debate about food quality, and minimising pesticide residues through reduced use or alternative practices must be seen in the context of consumer demands for products with high visual impact, and the need for available and affordable produce. The balance of perspective for consumers regarding relative risks must be maintained.

INTRODUCTION

There is now overwhelming evidence that the lack of fruit and vegetables in our diet is a major factor in the ill health issues facing the developed world. Many informed commentators submit that pesticide residues, provided they are strictly within maximum residue levels (MRLs) industry guidelines, are not a risk of any consequence in comparison to faulty diet, i.e. excessive consumption of fats, sugar, salt and over manufactured food and insufficient consumption of roughage, fruit and vegetables. Nevertheless, at a recent Food Standards Agency (FSA) stakeholders' meeting (30/04/02) Prof. David Coggon, Chair of Advisory Committee on Pesticides, stated "In advising ministers, we must base our advice on scientific advice but also the need to reflect public concerns over pesticide residues". Growers' appreciate the pressures on the FSA to compromise on this issue but urge very careful consideration of any advice to Government on changes, which are not fully justified, and to evaluate the likely repercussions such a compromise would send in several directions. To keep matters in perspective it should be remembered that any synthetic pesticide residues are only a tiny fraction of total ingested pesticide. Prof. Bruce Ames, Director of the National Institute of Environmental Health Sciences Centre, UC Berkeley has calculated that naturally occurring pesticides in food constitute 99.99% of ingested pesticides. He estimates we ingest more carcinogens in one cup of coffee than we get from the residues of synthetic pesticides on all the fruits and vegetables we eat in a year (Ames, 1997).

FARMERS' AND GROWERS' INITIAL PERCEPTIONS

Every pesticide application cost is straight off the grower's potential profit margin. The pressure to minimise pesticide application is already heavy, but a producer also has to meet consumer and buyer expectations and failure to do so can be catastrophic with margins at their current level. One occasional aphid per sprout is just acceptable but two aphids means the probable rejection of the entire crop. Rejection by the market results in major investment loss. The risk always resides with the producer and can easily result in total financial failure. Often the decision of whether or not to spray is akin to walking a tight rope with customer demands of appearance and cleanliness on the one side and demands of minimal residue on the other, not to mention the invidious Governmental policy to 'name and shame' retailers with supplier problems.

To reduce MRLs purely as a concession and not on a sound scientific basis will send a host of messages. What message will it send to embattled producers and their evaluation of risk? What message will it also send to the host of pressure groups who may seize on any such 'concession' as positive proof that MRLs were not safe in the first place and renew pressure for further reductions? What message will it send to those supermarkets who recognise the scientifically based safety margins built into MRLs are so amply extensive and have had the courage to stand by this line?

If Government is not prepared to use scientific evidence as the basis of risk assessment and scientific evidence alone, public and parliamentary confidence will be shaken. When so much evidence from organisations like the Food Research Institute and National Centre for Policy Analysis is so uncompromisingly positive about the benefits to health from the inclusion of fruit and vegetables in the national diet, why is it that an entire nation's common sense seems to have been 'high jacked' by a movement which started out with such laudable objectives.

So why is fresh produce consumption so unfashionable? Three reasons come to mind:

1. The attractiveness and convenience of manufactured snacks and fast food. The whole basis of this industry is for the product to be desirable with little or no concern that excessive consumption will eventually harm the consumer. Fast food is now an integral part of our society's culture but the cost to the National Health Services has yet to be fully revealed. Perhaps the UK and EU governments should be considering a tax on fats and sugars rather than pesticides!

2. The association of fruit and vegetables with pesticide residues. We need to recognise the benefit the media have derived from this issue, it has 'sold a lot of copy' and entrenched consumers perception that all fruit and vegetables must be potentially harmful; this line is also regrettably promoted by scientists anxious for research funding.

3. The cost of fruit and vegetables. Actually the fact is that strictly controlled use of herbicides, fungicides and insecticides all makes fruit and vegetables remarkably freely available and affordable to the consumer. Losses of essential chemicals or reductions of MRLs for political expediency could deprive many, and in particular those of lower income, of their choice of a healthy diet with a subsequent deleterious effect on general health of considerable magnitude.

ARE THERE VIABLE OPPORTUNITIES AT FIELD LEVEL?

Nevertheless, farmers and growers are responsive to their markets and they constantly review the number of options not related to current pesticide application practices and technologies, which could influence the quantity of residues or the frequency with which such residues are found. Both biotechnology enhanced production systems and organic farming have as part of their basic rationale the reduction of pesticide use to low or no levels. Both approaches individually and as part of a whole UK strategy have a potential role to play in reducing residues in food.

Organic farming has been successful in reducing the frequency and levels of pesticide residues in produce from this sector (Baker *et al*., 2002). In many cases this means of production results in a yield penalty. It is a fallacy to present organic production as the panacea. Already, the evidence in several EU Member States, notably France and the UK, indicates that organic production is increasingly unprofitable (up to 40% of UK organically produced milk is currently sold in the mainstream commodity market). Moreover, organic producers may use a number of pesticides authorised under the framework of Directive 91/414 as well as certain traditional elemental substances such as copper and sulphur, which are known to have a negative environmental impact. The producers of minor crops who will suffer profoundly under the 91/414 revocations are very concerned over the lack of research into, and promotion of, alternative pest control strategies, which will soon be key to the continuation of any production within the EU of certain fresh produce.

However, many of the crop protection practices developed for organic farming seem likely to have value to conventional agriculture, especially integrated crop management (ICM) systems. Introducing appropriate methods from this sector may therefore reduce both pesticide use and recovery as residues e.g. selection of varieties, timing of operations, but some organic techniques adopted by conventional production e.g. use of fleece to deter insect pests, bring higher costs and there are waste disposal issues. There needs to be joined-up thinking from Government - alternative technologies can sometimes fall foul of other regulations.

The use of genetically modified (GM) crops in crop production in USA has resulted in some reductions in pesticide use. Total reductions seem less than had been anticipated. Varieties engineered to be resistant to insect pests, *Bacillus thuringiensis* (Bt) varieties, have reduced the use of insecticides but currently, no commercial GM varieties seem to have been rendered resistant to fungal infection. Conventional plant breeding can reduce the need for fungicides and insecticides but is likely to have little impact on herbicide use.

The adoption of alternative pest control methods and a reduction of farmers' dependence on pesticides is desirable but the sustainable use of pesticides can only be delivered by ensuring better training of the people who use pesticides. This has been recognised within the industry and considerable progress made in training, record keeping and crop assurance scheme uptake. Enforcement, by monitoring for MRLs or measures of environmental impact, is flawed as some pesticides leave little or no detectable residues. In addition some active substances occur naturally and traces may not result from agriculture.

Mandatory EU requirements would be impractical and unworkable because they would be unenforceable. The use of EUREP (a produce assurance scheme in Europe), which involves the whole food chain from producer to consumer, is more likely to result in positive action because commercial expediency drives up production standards. The adoption of the Assured Produce Scheme in the UK, which is funded by the producers, has raised standards of management and awareness throughout the food chain in a remarkably short time. Since there are no agreed or comparable protocols of ICM/IPM/IFM across member states, how can compliance be linked to subsidy without introducing the real risk of distorting production costs for produce grown in more than one member state? At the moment adherence to good agricultural practice (GAP) is the only criteria that could be used but the mechanisms for demonstrating compliance vary markedly between member states. It seems logical to standardise inspection mechanisms before lifting standards.

CONCLUSION

No decision should be taken without proper evaluation of possible side effects. Vegetable producers know at first hand the enormous pressures that have been placed on production to conform to an avalanche of legislation, withdrawal of many established pesticides, costly directives and margin reductions from supermarkets and now an erosion of confidence from their bankers after some spectacular business failures. Confidence is low, even amongst the most efficient in the UK production, but the current strength of sterling ensures the retailers' shelves are full. But one would indeed be foolish in the extreme to say they will always be full. Governments need to weigh up most carefully the effect of a message that reducing the permitted levels of pesticide residues to almost an unsustainable degree will have on the confidence of growers and particularly if there is no scientific or statistical basis for such changes. Fruit and vegetables are, without question, essential to the national diet and the nations health. A solid core of domestic production is essential as a basic national insurance (witness this year's drought in central, southern and eastern Europe), but if production becomes uneconomic because 'the hurdles are set too high', for whatever reason, many producers will reduce their commercial exposure and simply exit production.

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The role of biotechnology in the management of pesticide residues

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ABSTRACT

Despite the fact that 70% of food eaten in the UK in 2000 had no detectable pesticide residue, this subject, whether it has a real or perceived risk, is on the consumer agenda. The issue must therefore be managed in a responsible manner if the industry is to gain support. If we are to learn from the GM debate, it is clear that we must all recognise that there is no such thing as one solution to the needs of agriculture and so by default recognise that choice is necessary. However, as industry, we must be bold enough to say that this choice applies in all directions. The current generation of GM crops with herbicide tolerance or insect resistance are, in reality, unlikely to significantly affect the levels of pesticide residues in food. In the future, genetic fungal resistance has the capacity to have a more fundamental effect, but again, genetic resistance will not obviate the need for chemical protection. As such therefore, GM crops may be able to play a role, and indeed can help in sensible pesticide residue management strategies, but they are not a silver bullet. They are, and should be seen as, part of a range of modern R&D based solutions. However, if they are to play a role, then we must continue to ensure that sound science in both research and development and regulation, and not populist reaction, is the foundation stone on which to build. We must also demonstrate and ensure that this foundation is enhanced with quality stewardship of our products to ensure they are used in a responsible manner and offer consumer and grower choice – no matter where in the world they are used. This is where global companies, such as those represented by the Agricultural Biotechnology Council, have a major, significant and possibly unique role to play

INTRODUCTION

During the 'GM Nation?' debate, I remember talking to one lady who said she was concerned about GM and food safety. There have been no tests at all she insisted. I took the time to explain in great detail the safety of the PAT protein and the feeding studies and toxicological tests we had carried out, which lead to us being able to define the No Observable Effect Level. I then ended by saying that, for the average human (70kg), this means that you could eat the equivalent of 24,000 tonnes of oilseed rape seed (a heap the size of a row of terraced houses), every day of your life for the rest of your life and there would not be any effect due to the ingestion of the PAT protein. She thought about this for a little while, then said in all seriousness, what would happen if I ate 25,000 tonnes a day?

I use this not to make fun but as an example of those who, having suddenly realised that they did not really know where their food came from, feel disenfranchised, worried or both. Pressure groups and a media hungry for a "scare" story, have added to and perpetuated this feeling by undermining and questioning everything. The result is that in the absence of "acceptable" answers, people yearn for a utopian era where all food was "good for us". Such an era of course has never existed, but in reality if it did we are probably closer to it now than was ever the case in this never-defined bygone time.

The lady at the meeting was not given comfort by the fact that we could quantify the food safety levels of this crop, she just felt that it was "wrong". Of course she should have the right to choose, but it was also clear that she was unable to assess the risk to herself as an individual in any real or helpful way. The mere fact that we had measured it at all meant that she assumed the worst. Her reaction of "I just want to go back to the good old days," may of course have been a desire to go back to a time when worries and concerns were not constantly in the headlines, regulators were trusted, and she did not have to try and weigh up the risks and benefits for herself.

Pesticide residues create exactly the same dilemma. Industry and regulators alike have to try to get risk into perspective whilst accepting that moral or ethical considerations will play a part in consumer choice.

The challenge for politicians is perhaps more acute. They should rise above the "knee-jerk" populist reaction to tabloid headlines that are constantly calling for this or that to be banned or for him or her to resign. They must also weigh up the needs of the many against the demands of the few or the noisy. The question with GM crops as with pesticide residues is will they?

Whatever the outcome of their deliberations, industry will have to comply with the regulatory requirements. Clearance of, and adherence to, these regulatory requirements is of course not the same as trying to convince others of our product's benefits. If we are to learn anything from the GM debate, it is clear that all must recognise that there is no such thing as one solution to the needs of agriculture and so must recognise that choice is necessary. However, we must be bold enough to say that this choice applies in all directions. We must base our messages on sound science, and try to communicate in clearly understandable terms. Finally we must be honest and open and not fall into the trap of selling "jam tomorrow", but tell it like it is.

That is what I hope I will be able to do in this paper on the role of biotechnology in pesticide residue management.

Pesticide Residues

Despite the fact that 70% of food eaten in the UK in 2000 had no detectable pesticide residue (Pesticide Residues Committee, 2001), this subject, whether it has a real or perceived risk is on the consumer agenda (though not at the high levels that some pressure groups would have us believe). The issue must therefore be managed in a responsible manner if the industry is to gain support.

Foods most likely to contain pesticide residues are typically those that have had a crop protection product applied later on in the growth stage of the crop or indeed during storage. The persistence or systemic nature of the product also defines residue levels and so they tend to be insecticides or fungicide rather than herbicides. Finally there is a tendency that food produced in countries with high pest pressures (e.g. warmer climates), have a higher potential for pesticide residues due to the nature of the spray programme needed e.g. in exotic fruits.

The role of GM crops in pesticide residue management

Since their commercial introduction in the mid 1990s, GM crops are being chosen by more and more farmers each year and grown on more and more acres (Table 1). They are now grown in 16 countries by nearly 6 million growers, three quarters of which are resource-poor farmers (James, 2002). The main crops grown remain the commodity crops of soya, maize, cotton and canola and of course the main traits are herbicide tolerance and insect resistance (Table 2).

Table 1: Global area of GM crops in 2002 (James, 2002)

Year	Hectares (millions)
1996	1.7
1997	11.0
1998	27.8
1999	39.9
2000	44.2
2001	52.6
2002	58.7

Table 2: Dominant GM crops in 2002 (James, 2002)

Crop	Hectares (millions)	% GM Area
Herbicide tolerant soyabean	36.5	62
Bt Maize	7.7	13
Herbicide tolerant canola	3.0	5
Herbicide tolerant maize	2.5	4
Bt Cotton	2.4	4
Herbicide tolerant cotton	2.2	4
Bt / Herbicide tolerant cotton	2.2	4
Bt/Herbicide tolerant maize	2.2	4
Total	58.7	100

It is clear from 20 years of research and commercial experience that herbicide tolerant (HT) crops enable farmers to produce high yielding, high quality crops. In addition, according to the Prime Minister's Strategy Unit's assessment of the costs and benefits of GM crops, they offer convenience and cost savings. It is also clear that with appropriate stewardship and management guidelines that all of these benefits can be achieved in a way that is environmentally benign or even beneficial compared to some farming techniques.

Recent research carried out at Brooms Barn in Suffolk, UK (May, 2003) for example, demonstrated that different application timings and application methods meant that the weeds within a crop of GM sugar beet could be managed in various ways which could be tailored to different wildlife needs. Thus the crop could be managed to be more skylark or stone curlew friendly.

Research at Scottish Agricultural Colleges (Booth *et al.*, 2002, Walker *et al.*, 2003) has shown that the introduction of GM herbicide tolerant oilseed rape could facilitate uptake of minimal cultivation techniques in the UK. With GM, it is possible to produce high quality crops without the concomitant reductions in yield that often currently occur. The switch from current establishment and husbandry techniques, to one based on GM HT and minimal cultivation, could save over 16 million litres of fuel per annum. Such a decrease in fuel use would not only reduce the amount of greenhouse gas emissions by 57,000 tonnes per annum, but increase the "fuel out to fuel in" efficiency ratio from 12:1 to 19:1. This in turn could provide the much needed stimulus for the bio-diesel market (Agricultural Biotechnology Council, 2003).

As with any crop protection product, the companion herbicides to GM HT crops follow the usual regulatory assessments, which include safety and likely residue levels. Good stewardship ensures that the rates of application and timings, defined by the regulatory process, are adhered to, and also balance need, due to weed incidence and efficacy, with cost efficiency.

There is some debate about whether the use of GM HT crops reduces herbicide application (usually due to definition of a.i.). In reality, however, because of the nature of the products and the growth stage of the crop at application, the net effect of GM HT crops on pesticide residues in food will be minimal / neutral.

It is well documented that the introduction of insect tolerant (IT) crops, particularly cotton has resulted in a big decrease in the amount of insecticide needed to be applied. The often-quoted example is that less insecticide is used in Alabama now than at any time since the 1940s. James (2002) estimates that Bt cotton could reduce the use of insecticides by 33,000 tonnes. The technology can clearly also improve the yields (by up to 80% (Qaim and Zilberman, 2003)) and quality of crops. In addition, the use of insect resistant maize for example can reduce secondary infection levels with a consequent reduction in mycotoxins such as aflatoxin and so lead to a general increase in food quality and or safety (Miller, 1999).

Whilst GM IT crops have reduced the need for insecticides, they have not negated them. Depending on the incidence of pest levels and the need to ensure a sensible pest resistance management scheme, insecticides are applied at various application rates. Once again application of these insecticides to the current commercial crops is made at a growth stage of the crop where residues do not generally become an issue. Thus with the use of GM IT, even though there has been a documented reduction in the use of chemical control methods, it is unlikely to have a major effect on pesticide residues in food.

Future potentials

At the risk of selling jam tomorrow, future traits such as disease resistance (potato blight, *Phytophthora infestans,* for example) could have a more significant effect on pesticide residues in food. Clearly in such examples, where products are applied at a growth stage where residues are more likely to appear in the harvested product, then the use of genetic resistance rather than chemical control can play a more significant role in residue management. In this example however, it should be stressed that absolute control is probably unlikely and this coupled to the need for a resistance management strategy is likely to require some chemical control. In addition of course the blight fungicide is only one of the crop protection products applied; thus the genetic fungal resistance would have no effect on the residues that may appear from application of storage products for example.

Other future GM crops such as increased protein wheat, increased vitamin rice or enhanced starch potatoes are not necessarily going to have any effect on pesticide residue management as they may need to be treated exactly the same as non-GM crops. If they are introduced to the market with stacked genes for pest and disease management then this may have an effect. However, as for all of the other examples, this will always be dependent on pest incidence and resistance management strategies, which will define the levels and timing of pesticide applications. It is this in turn therefore, that may have the greater effect on pesticide residues.

Finally within this section, one of the biggest contributors to the pesticide residue register is exotic fruit. Given the nature of the returns from these crops and the current low level of commercial GM developments in these crops, it is unlikely that we will see widespread growing of GM disease or pest resistant pineapples in the foreseeable future.

CONCLUSIONS

The goal of today's food industry is to balance the consumer needs of, quality, safety, continuity of supply and convenience with those of animal welfare, environmental issues and of course the biggest driver, price.

As part of that industry, the goal of today's research and development based crop production companies must be to help farmers around the world to supply these foods efficiently and in a way that has as little negative environmental impact as possible. Clearly we must also take pesticide residue management into account.

This remit holds true whether we are producing products for sale in the developed or developing world countries. However, we must remain cognisant of consumer and grower choice, and adopt sensible pragmatic and responsible approaches to the needs of agriculture and food supply, and not try to impose prescriptive solutions. Without such an approach, the long-term benefits of which we are convinced may not be achieved.

Within this overall goal, GM crops have the potential to play a significant role by producing high quality, safe, affordable foods in a way that is sympathetic to the environment. They may also be able to play a role, and indeed can help in pesticide residue management strategies, but in all of this, they are not a silver bullet.

Europe), then we must continue to ensure that sound science not populist reaction continues to be the foundation stone on which to build.

We must then demonstrate and ensure that this foundation is enhanced with quality stewardship of our products to ensure they are used in a responsible manner and offer consumer and grower choice – no matter where in the world they are used. This is where global companies such as those represented by the Agricultural Biotechnology Council, (contrary to pressure group spin), have a major, significant and possibly unique role to play.

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