FOOD SAFETY AND QUALITY ASSURANCE

C Knight
Campden & Chorleywood Food Research Association, Chipping Campden, UK

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Christopher Knight
Campden and Chorleywood Food Research Association, Chipping Campden, Gloucestershire, GL55 6TR, UK
Email: c.knight@campden.co.uk

ABSTRACT

The relationship between the agricultural and food sectors has changed significantly in recent years, and continues to do so. Historically, farmers produced food raw materials, most of which was for local consumption or sold-on through marketing organisations, with little thought of the end use of the material. Similarly, the food industry brought their raw materials from an intermediary and had little direct contact with primary production. For both of these sectors these trading patterns are long gone. Farmers now have to be much more aware of market demands and the needs of their customers in terms of food safety, legality, quality and functionality of their products. Likewise food businesses now have to consider their raw materials not just in terms of food safety and quality, but in terms of how it is produced. Today, therefore, the food chain is much more highly integrated. Through closer relationships along the food chain - and through systems such as specifications, traceability, codes of practice, and food safety management - the food production process is becoming less the work of a series of independent businesses and more a concerted approach to ensure food safety, legality and quality. The emphasis is increasingly on prevention of problems, through appropriate management systems. This paper outlines some of the main risk areas and the control systems adopted within the food supply chain in the UK and Europe.

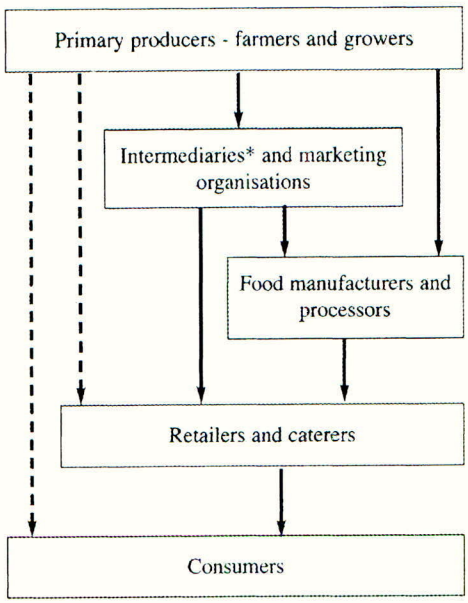
AGRICULTURE IN THE FOOD SUPPLY CHAIN

Most of the food we eat comes from crops and livestock that are farmed specifically for that purpose. A feature of this agricultural food production of the last ten years or so, and one that is still very much on-going, is its closer integration into the food supply chain. Increasingly farmers produce food and raw materials for specific purposes and with specific markets in mind – for example, supplying fruits and vegetables to a produce marketing organisation or growing crops under contract for a particular processor. This has had all kinds of implications for farming practices and farming businesses. Increasingly farmers are having to embrace concepts such as food safety management, quality assurance and traceability. At the same time it has enabled the farmer's customers to provide feedback on their needs and expectations and those of the consumer. Examples of this include greater emphasis on food safety issues and food quality aspects as well as environmental and social welfare issues and production philosophies such as integrated crop management and organic systems. Nor is the farmer alone in facing these influences, business supplying inputs used in agricultural production, such as the crop protection industry, are also having to embrace the same concepts and issues.

Material flows along the food supply chain, from the primary producer (i.e. farmer) to the consumer via various intermediaries including marketing organisations, processors and manufacturers and retailers (including food service outlets). This chain , which is illustrated in Figure 1, has and is becoming ever more complex, as it embraces the proliferation of product choice, new food technologies, modern transportation and the global trade in food materials. The food industry is now much more sensitive and responsive to the needs of the consumer, and as the food supply chain becomes more closely integrated this trend is as significant for the farmer as it is for the retailer.

Similarly, food safety legislation is having an increased influence on the agricultural sector, for example in respect of the requirements for general food hygiene and in prescribing maximum levels of food contaminates of agricultural origin, such as pesticide residues remaining in the food products. As a result primary producers must increasingly satisfy their customers that their products are safe to the consumer and produced to relevant standards (legal or customer requirements).

All sectors of the food chain, therefore, have to be aware of the main risk areas associated with their products and production operations, adopt appropriate controls and ensure proper operation of these controls. This paper gives an overview of some of the main risk areas, with special reference to crop production, and approaches to quality assurance being adopted in the agricultural sector to ensure food safety and quality is managed effectively.



* includes abattoirs, produce marketing organisations, grain merchants, brokers and wholesalers

Figure 1. Relationships and the flow of materials in the food supply chain

FOOD SAFETY ISSUES

What are food safety hazards?

Broadly, a food safety hazard is a biological, chemical or physical agent that can cause an adverse health reaction in the consumer. Both biological (particularly microbiological) and chemical hazards can occur naturally in primary products and all three types can potentially gain access during agricultural production, including post-harvest handling of primary products, e.g. storage, transportation. Examples of typical food safety hazards in crop products are shown in Table 1.

The actual hazards associated with a particular agricultural situation will depend on the specific circumstances including, location, production system and intended market. There are numerous theoretical safety hazards in primary products, but only a few will be significant in any particular situation. In deciding the significance of a hazard, the risk associated with the hazard will have to be taken into account, that is the likelihood of the hazard causing an adverse health reaction, taking into account the likely severity of that effect. For food safety hazards associated with primary products this may be difficult to judge and factors such as whether there are legal standards or customer requirements may need to be taken into account.

Table 1. Typical food safety hazards in crop products

Biological hazards	Chemical hazards	Physical hazards
Food poisoning organisms: e.g. pathogenic bacteria, protozoa, viruses	Residues of pesticides	Foreign bodies: e.g. glass metal, wood, stones
Disease causing organisms: e.g. Cholera, Hepatitis	Naturally occurring contaminants: e.g. heavy metals, nitrates, mycotoxins	
Parasites: e.g. tapeworms	Other agricultural contaminants: e.g. mineral oils, cleaning chemical residues	
Allergenic components	Natural toxicants: e.g. glycoalkaloids	

Routes of contamination

Awareness and understanding of the possible causes of food safety hazards in crop production is important for all those involved in crop production, as this will help determine the most appropriate control measures. In addition, the identification of the cause of the hazard may help determine the risk associated with the hazard in a particular agricultural situation. For example, the use of surface water to irrigate crops may pose a greater risk than ground water.

The majority of food safety hazards on crop products are probably introduced during production and post-harvest handling operations, for example:

- inputs in husbandry practices (e.g. manure, sewage sludge, irrigation water); or
- activities associated with people, use of equipment or from the environment, e.g. personal hygiene, wild and farm animals.

In some instances, contamination may be a result of changes in a pre-existing condition or hazard. For example, certain conditions of storage of cereals may lead to the production of fungal toxins (mycotoxins). In these instances what was not a problem may become one as a consequence of changes induced by the actual production practices.

Preventing contamination

From a food hygiene point of view, food safety in agriculture is mainly about preventing contamination and preventing the development of hazards. In general there are few, if any, opportunities in most crop production operations to eliminate or reduce a hazard once it has arisen. In general, Good Agricultural Practice (GAP) is about minimising the likelihood of a food safety hazard arising. The measures to control hazards in agriculture production can be broadly divided into two types.

- Actions associated with the product: An action as a control measure is the process of doing something specific in the production process which acts on the product. Typical examples are drying of grain, controlled storage conditions and sorting/inspection.
- Activities associated with the production process: An activity as a control measure is a policy, procedure, work instruction associated with the production operation. Typical examples are training of staff, pest control procedures, cleaning schedules and personal hygiene.

Microbiological hazards of concern

There is a wide range of food poisoning and disease organisms that can potentially contaminate crop products, including bacterial pathogens, protozoa and viruses. The vast majority of outbreaks of food related illnesses are due to these pathogenic microorganisms rather than chemical and physical contaminants. These are of particular concern on products that will be eaten raw but also on food raw materials for further processing. Pathogenic bacteria, for example, can multiply profusely in foods without necessarily altering the food in appearance, taste or smell. This means that something on the raw material that is not necessarily a problem to start with, may become a problem, some time later, in the food product made from it. Examples of key groups of pathogens relevant to produce (fruits and vegetables) are shown in Table 2.

Examples of the causes of contamination of microbiological hazards (food poisoning organisms) in crops and typical control measures are shown in Table 4a.

Table 2. Examples of pathogens relevant to produce

Pathogen Group	Examples	Diseases
Bacteria	Camphylobacter jejuni	Gastoroenteritis
	E. coli	Gastoroenteritis
	Salmonella sp	Gastoroenteritis
	Shigella sp	Bacillary dysentery
	S. typhi	Typhoid fever
	V. cholerae	Cholera
Protozoa	Giardia lambilia	Gastoroenteritis
	Cryptosporidium sp	Gastoroenteritis
Viruses	Hepatitis virus	Infectious hepatitis
	Norwalk virus	Gastoroenteritis
	Rotavirus	Gastoroenteritis

Adapted from Chilled Food Association, 2002

Chemical hazards of concern

Food chemical hazards in crop products may be either 'natural' or extraneous. Naturally occurring chemical hazards, while highly undesirable, may be natural components of the product. Some are of microbiological origin (e.g. mycotoxins). Extraneous contaminants include chemicals used in the production process (e.g. pesticides used to control pests and disease) or are potential contaminants used in agricultural situations (e.g. mineral oils) or from the general environment (e.g. heavy metals, dioxins). Brief details of some of the more important chemical hazards are given in Table 3.

Current interests in applied chemicals focus on the residue remaining in the product after application in crop production and after harvest during storage periods. Other chemicals are adventitious contaminants arising from the environment (e.g. pollutants in the soil, air and water) (see Table 4). Legally prescribed Maximum Residue Levels (MRLs) for many of these chemicals are now in force in the European Union. Examples of the causes of contamination by pesticides residues (e.g. above prescribed MRLs) and typical controls are shown in Table 4b.

Table 3. Examples of chemical hazards in crop products

'Natural' toxicants	Extraneous contaminants
Nitrates † (e.g. in lettuce)	Pesticide residues †
Mycotoxins † (e.g. in cereals)	Heavy metals † (e.g. lead and cadmium)
Aflotoxins † (e.g. in nuts)	Cleaning chemical residues
Glycoalkaloids (e.g. in potatoes)	Mineral oils (e.g. diesel, lubricants, hydraulic oil)
	Environmental pollutants † (e.g. dioxins, PCBs)

† MRL legislation applies for some crops/commodities in the EU.

Table 4a. Example causes and typical control measures - Food poisoning organisms (pathogens) especially *E. coli* and *Salmonella* sp,

Possible cause of contamination	Typical control measures
Introduction of pathogens from incorrect use of organic manure including sewage sludge	Use of organic manure is based on recognised codes of practice/GAP (e.g. Safe Sludge Matrix in the UK)
Introduction of pathogens from irrigation water applied to crop	Water used for irrigation is evaluated (source and routes of contamination) Application method and timing appropriate to the crop
Introduction of pathogens from animal contact with crops and land	Measures to prevent animals and livestock from accessing crop fields
Introduction of pathogens from people handling the crop commodity	Personal hygiene standards Staff receive training in hygiene
Introduction of pathogenic bacteria from pests, particularly during storage	Pest control procedures to deter/eradicate infestations Premises designed and maintained to exclude pests
Introduction of pathogens from plant and equipment	Hygiene and housekeeping procedures for commodity contact equipment and plant Use of dedicated equipment

Table 4b. Example causes and typical control measures - Pesticide residues exceeding prescribed MRLs

Possible cause of contamination	Typical control measures
Introduction of pesticide residues due to incorrect decisions on use	Use approved pesticides in the approved manner – follow pesticide product label recommendations Personnel making decisions are suitably qualified/competent
Introduction of pesticide residues due to inaccurate application	Accurate application equipment – periodic maintenance and calibration Personnel applying pesticides are suitably trained and qualified to use the equipment required
Introduction of pesticide residues due to due to incorrect harvest interval	Follow pesticide product label recommendations Procedures to identify crops for harvest

Physical hazards of concern

The variety of foreign bodies that have been found in food is considerable, though the majority constitute food quality issues rather than safety issues. Typical physical food safety issues in food raw materials are glass, metal, wood, stones and toxic berries, all of which can potentially gain access during crop production and post-harvest handling, particularly storage. Some are materials widely used in agricultural situations (e.g. glass lights, metal in machinery and wooden handling containers). Others are more likely to come in with the product as a result of operations, such as harvesting. These are often associated with crops as components of the growing environment (e.g. stones, soil or weeds).

Glass is perhaps the most emotive of foreign body contaminants. Slivers of glass in food can be highly dangerous. Fragments of glass are very difficult to detect, and accordingly strict procedures need to be in place to prevent contamination in place. In simple terms, this means prohibiting glass wherever possible, protecting it where it has to be used (e.g. covering lights) and avoiding areas where glass is likely to be present.

FOOD QUALITY CONCEPTS

Quality can vary and in terms of product attributes it can determine whether the product is suitable for a particular market. The most widely used concept of quality in terms of food raw material is "fitness for purpose" - that is that the material possesses the required physical, chemical and sensory properties to satisfy a given need or requirement. For the food industry this is an essential element of the way in which primary agricultural products are utilised.

Nowadays, however, quality in the widest sense of the term extends beyond the traditional concept based on the properties of the material, to embrace the issue of the so-called "extended product" based on the way in which the material is produced, i.e. production related issues. These "extended product" issues take into account the more general attributes that affect a product's market placement - such as Integrated Crop Management (ICM), organic, environmental considerations, ethical trading and so on. Many of these clearly have an agricultural dimension.

Quality assurance of food raw materials

As has been described in the previous sections, there are many safety issues that the food and agricultural industries have to address. In recent years there has been a marked shift in emphasis towards preventative quality assurance systems, the underlying principles of which are the identification of the main risk areas and adopting appropriate controls.

Quality assurance is a long standing feature of food industry best practice and the increasing integration and sophistication of the food supply chain has led to the emergence of various quality assurance systems in the primary agricultural production sector, including, for example:

- specifications defining quality of raw materials and products;
- codes and standards defining good practice;
- food safety systems based on Hazard Analysis and Critical Control Point (HACCP) principles; and
- product identification and traceability systems.

In this way all sectors of the food supply chain can work together to meet the demands and expectations of their customers as well as fulfilling their own legal obligations.

Specifications

Product quality can be defined in great detail, for example in a specification, which is agreed between supplier and customer. Raw material quality can be assessed against many criteria

depending on the requirements of the buyer. The individual characteristics can be numerous and their relative importance will differ with the product and intended use. Freedom from defects is often of importance, including for example presence of foreign bodies such as stones and toxic berries (food safety issues) and insects, extraneous vegetable matter, blemished and damaged product and taints (quality issues). The specification may also refer to relevant safety and legal requirements such as for pesticide controls and appropriate production standards to be adopted, e.g. organic or ICM production systems.

Production standards

Regulation in agriculture is a combination of statutory regulation and industry self-regulation. Self-regulation usually involves the adoption of specific regimes and protocols, developed by the industry, or recognised quality management systems developed by national and international standards bodies. The adoption of the schemes by businesses is voluntary but may also be a condition of supply for some customers.

In addition to general management philosophies, as exemplified by the ISO 9000 standard, there are specific regimes and protocols that define good practice. These regimes are now widely adopted in agriculture, particularly in the UK. A specific regime or quality assurance systems is generally comprised of two elements.

- A best practice protocol, which is a 'how-best-to-do-it' instruction or guideline.
- A mechanism for constant surveillance, internally and/or by third parties inspections.

There are many examples of these specific regimes, including quality assurance schemes (Knight et al, 2002). The scope is often specific to a particular sector (e.g. crop type) or production issues (e.g. organic, non-genetically modified). The majority are national but some are becoming internationally accepted. Some examples of specific regimes in the UK agri-food sector are given in Table 5.

Table 5. Examples of specific regimes for crop products in the UK

Sector	Specific regime
Cereals, oilseeds and pulses	Assured Combinable Crops Scheme (ACCS)
Fruit, vegetables and salads	Assured Produce (AP)
Organic production	UKROFS Standards for Organic Production Soil Association Standards for Organic farming
Animal feed	UKASTA Feed Assurance Scheme
Integrated Farm Management	Linking Environment and Farming (LEAF)
Genetically Modified Organisms	BRC/FDF technical standard for the supply of identity preserved non-genetically modified food ingredients and products

The Assured Produce scheme is typical of assurance schemes in the UK and is applied to fruits, vegetables, salads and potatoes produced in the UK. There is a protocol for each crop governing crop husbandry, operational controls and environment management. The protocols are guidelines for best agricultural practice based on ICM principles. The surveillance procedures involve an annual self-assessment questionnaire and periodic inspections by external independent verifiers. The scheme is backed by the National Farmers Union, representing the producers, major retailers and other organisations representing the food industry.

Whilst the UK industry has been at the forefront of the development of assurance schemes, similar developments are now taking place internationally. The Euro-Retailers Produce Working Group (EUREP) was formed to develop a European good agricultural practice protocol for fruits and vegetables. The current EUREPGAP Fruits and Vegetables Protocol (EUREP, 2001) has been developed with input from all sectors of the fresh produce industry including producer organisations outside the EU.

The EUREPGAP document sets out a framework for GAP based on best practice for the production of horticultural crops. It defines the minimum standards acceptable to the leading retail groups in Europe. GAP is defined as the means of incorporating Integrated Pest Management (IPM) and ICM practices within the framework of commercial agricultural practice. Producers can now seek EUREPGAP approval through independent verification from an independent verification body approved by EUREP.

Food safety systems

The internationally recognised philosophy for assuring food safety is HACCP (Hazard Analysis and Critical Control Point). The HACCP system is used throughout the food industry to identify hazards and their controls, focusing on prevention of hazards. The use of HACCP is of increasing importance in primary production. Although there is currently no legal requirement for farmers to use a HACCP approach, in the UK, it is increasingly seen to be of benefit in the supply of primary agricultural products, particularly produce. Codex also recommends a HACCP-based approach throughout the food chain as a means to enhance food safety (Codex, 2001).

The HACCP system is based on seven principles, and when conducting a HACCP study in agriculture the seven principles of HACCP may be applied as twelve stages as shown in Table 6 (Knight and Stanley, 2000). These include both essential preparation stages (the 'planning' stages 1 to 4 described here) and the principles of HACCP (the 'application' stages 5 to 12).

Traceability

Requirements for traceability have been a long-standing feature of industry self-regulation. Explicit legal demands have been more limited. Current legislation associated with traceability for agricultural products in the EU relates to specific issues e.g. beef labelling. In future, however, food companies in the EU may be obliged to ensure traceability under new food hygiene legislation.

Table 6. Stages in a HACCP study in agriculture

Stage	Description
Stage 1	Define the terms of reference
Stage 2	Select the HACCP team
Stage 3	Describe the essential product characteristics
Stage 4	Describe the production process
Stage 5	List all potential hazards associated with each process step, conduct a hazard analysis and consider any measures to control identified hazards (HACCP Principle 1)
Stage 6	Determine Critical Control Points (HACCP Principle 2)
Stage 7	Establish critical limits for each CCP (HACCP Principle 3)
Stage 8	Establish a monitoring system for each CCP (HACCP Principle 4)
Stage 9	Establish a corrective action plan (HACCP Principle 5)
Stage 10	Establish verification procedures (HACCP Principle 6)
Stage 11	Establish documentation and record keeping (HACCP Principle 7)
Stage 12	Review the HACCP plan

In general, requirements for traceability are not prescriptive, that is they just define overall objectives without specifying the level of traceability that is to be achieved or the system to be used. There is good reason for this in crop products in particular. The type and level of traceability achievable is dependent on various factors, which relate to the nature of the product and the production operations undertaken. That is, there is no single universally applicable system of traceability; it will depend on the scope of the system and what is practical for a given product and production operation. The system in place should be the most appropriate for the specific circumstance, and should be sufficient to trace the identity and history of the product and its components throughout the supply chain.

Traceability features the establishment of the identity, history and source of a product and needs to be established at all stages of the food supply chain, including primary production. This means that at each stage operators should be able to identify the nature and source of any materials supplied to them, trace the product through there production system, and identify to whom the product has been supplied.

In agriculture, direct traceability of primary products is feasible for some production systems but not for others.

For products handled as discrete units, such as where the product is a single item or in a container such as a box or sack, these units can be identified and traced back to a defined source. Direct traceability is possible in this situation, that is the unit can be identified and its history and source determined. For example, in the case of lettuce, which can be harvested and packed in the field, the individual lettuce heads can be traced to a defined harvest and crop. This means that information about inputs used such as pesticides and irrigation can be made available.

At the other extreme, materials handled in bulk or mixed direct traceability is not possible. Identification of the source lots is, however, feasible and the different crops that make up the mix, and hence their history and source can be identified. Taking a seed crop, such as maize or wheat, as an example bulking or mixing is routine after harvest during storage and distribution. Traceability of the individual product is not therefore feasible, but identification of the particular lots (e.g. from field, farm, storage unit) that make up a given batch of grain may be possible (Figure 2).

Somewhere between these extremes lie crops like potatoes, where the level of traceability achievable depends on the method of post-harvest handling. For boxed stored crops, it is possible to trace individual boxes back to a defined crop harvest, i.e. a situation analogous to lettuce. For bulk stored crops the situation is more akin to wheat, where direct traceability is not possible but identification of the lots that make up the bulk is feasible (Figure 2).

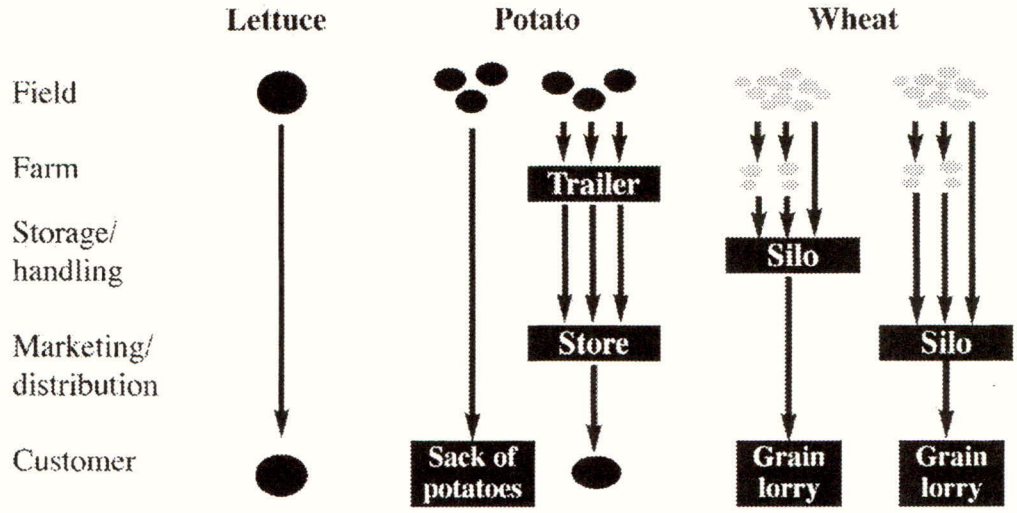


Figure 2. Examples of traceability of crop products

Traceability does not by itself control anything in terms of food safety hazards, that is it does not prevent or eliminate a hazard or reduce it to an acceptable level However, if there is a problem with a product, tracing the source of the material can help to deal with the non-conforming product (isolate and/or recall) the affected products, to identify the cause of the problem and to prevent a recurrence.

INTERNATIONAL PERSPECTIVE

Agricultural food production is a global activity and many products are traded across and between nations and continents. The food supply chain, as depicted in Figure 1, may span many parts of the globe. A retailer, for example in the UK, will typically sell branded and own-label products produced or formulated from ingredients that are sourced from mainland Europe, Asia and the Americas. A single primary product or ingredient might pass through several hands between the farmer as primary producer and the food manufacturer in its journey from farm to fork. This is no less so in the modern food supply chain for perishable products, such as fruit and vegetables, than durable products such as cereals and oilseeds. Maize or soya for example will be harvested by the farmer, transported, stored, mixed with other crops, brought by brokers, sold on to suppliers and then processed or fractionated. The different products or fractions may in turn be sold separately before further processing by ingredient or food manufacturers. While some of these products are traded on the open market others may be produced under contract, where a farmer and/or supplier in different parts of the world is contracted to a food manufacturer.

Either way, whether sourcing raw materials direct or on the open market, the farmers' customer will almost certainly exercise a degree of control over the material being supplied. This includes specifications, product identity and traceability, adopting good agricultural and manufacturing practices (GAP and GMP) and food safety management. Food raw materials and products that are traded internationally, therefore, have to comply with regulations not just in the country of production but also in the country of marketing, including any legislative and industry self regulatory aspects. In this respect the UK and European principles and systems, that have been discussed in this paper, have a direct impact on crop protection practices world-wide

FOOD SAFETY MANAGEMENT IN AGRICULTURE

Food safety management is an increasingly important aspect of primary production as customers and consumers seek greater assurance of food safety. This involves being aware of the main hazards, adopting appropriate controls and ensuring proper operation of these controls. The emphasis is on prevention – through appropriate management systems. Quality assurance systems for ensuring that primary products are safe, of the desired quality and meet the demands and expectations of the customer, include specifications, quality assurance and risk assessment schemes and their attendant protocols. Traceability can complement these by enabling the source of materials to be identified so as to establish that controls have been applied and verify they are effective. If there is a problem, corrective actions can be taken to re-establish control and deal with any non-conforming product.

In general, these procedures have become an integral part of the way in which the many partners in food production chain work together to develop and supply products that meet the needs and expectations of the consumer. As farming operations become more closely integrated into the chain, the expectation is that they will have to operate at similar levels of food safety management and develop systems compatible with those the in latter stages of the chain.

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