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DEVELOPMENT OF HAZARD ANALYSIS BY CRITICAL CONTROL POINTS (HACCP) PROCEDURES TO CONTROL ORGANIC CHEMICAL HAZARDS IN THE AGRICULTURAL PRODUCTION OF RAW FOOD COMMODITIES.

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Abstract

Hazard Analysis by Critical Control Points (HACCP) is a systematic approach to the identification, assessment and control of hazards in the food chain. Effective HACCP requires the consideration of all possible hazards, i.e., chemical, microbiological and physical. However, current procedures focus primarily upon microbiological and physical hazards, and, to date, chemical aspects of HACCP have received relatively little attention. Consequently, this report discusses the application of HACCP to organic chemical contaminants and the particular problems that are likely to encounter within the agricultural sector. It also presents generic templates for the development of organic chemical contaminant HACCP procedures for selected raw food commodities, i.e., cereal crops, raw meats and milk.

Keywords

Hazard Analysis by Critical Control Points, HACCP, organic chemical hazards, raw foods, agricultural sector.

Introduction

Hazard Analysis by Critical Control Points (HACCP) is a widely accepted, rigorous and systematic method of identifying, assessing and controlling of hazards throughout the whole food chain (Mayes, 1992; ILSI, 1993; Mayes, 1994; Moy *et al.*, 1994; Reimers, 1994; Tompkin, 1994; Lee & Hathaway, 1998). HACCP principles have been incorporated into food safety legislation within most countries (e.g., see EU, 1992, 1993 for Europe, FDA, 1972; NAS, 1985; FDA, 1989; Taylor, 1993; US Federal Register, 1994, 1995 for the US, Agriculture Canada, 1993 for Canada or ANZFA, 1995, 1996 for Australia and New Zealand). Further to this point, HACCP has also been identified as a practical means of standardising international food quality control and assurance practices (Shank & Carson, 1994; Garrett *et al.*, 1998; Kvenberg, 1998).

As the primary source of raw ingredients for food production, the agricultural sector is a fundamental component of the most food product and supply chains (Figure 1). Consequently, the development of effective HACCP procedures for this sector is essential to the overall success of HACCP. This is particularly important for fruit and vegetables as they receive little processing before entering the domestic sector (Knight, 1998; Lee & Hathway, 1998). However, problems have been reported in the development of raw food HACCP procedures, most notably failures to identify food-specific microbiological hazards (Untermann, 1998, 1999), and to account for the inherent variability of raw food commodities (Lee & Hathaway, 1998; Mossel *et al.*, 1998). Other problems include the selection of inappropriate critical control points (CCPs), monitoring criteria and control measures. Although the cause of these problems undoubtedly varies upon as case-by-case basis, Lee and Hathaway (1998) identified “A lack of motivation within some segments of industry as to the relevance of detailed food safety controls for raw food commodities” as one of the factors involved. The development of generic HACCP templates (generalised HACCP procedures that can employed as the basis for the creation of site- and product-specific HACCP procedures) have been proposed as a practical means of addressing such problems (Tompkin, 1994; NZ MA, 1997).

HACCP was originally devised as an 'all-purpose' food safety assurance mechanism, and was intended for use with all types of hazards, i.e., chemical, microbiological and physical. However, current HACCP procedures developed and employed within the commercial sector focus predominately upon microbiological and physical food safety and, by comparison, chemical aspects of food safety typically receive little or no attention (Rhodehamel, 1992). This paper addresses this shortcoming by: (i) discussing the potential for the application of HACCP to chemical hazards within the agricultural sector, using organic chemical contaminants as examples, and (ii) providing a generic templates for the development of organic chemical contaminant HACCP procedures for raw food commodities. It should, however, be stressed that such procedures should always be incorporated into normal (i.e., total hazard) HACCP procedures as opposed to being used as 'stand alone' chemical hazard HACCP procedures.

Prerequisites for HACCP

Product Description

The products in question should be fully described prior to HACCP procedure development. Descriptions should include all ingredients, additives, production steps, handling procedures and intended end-point use of the product (CAC, 1993). For raw food commodities this would typically include available information on:

- Primary ingredients (e.g., plant crop, livestock),
- Pre-growth cycle activities (e.g., cereal grain treatments),
- Growth cycle (e.g., site, growth stages, associated operations, feeds used, chemicals applied),
- Harvesting or slaughter,
- Processing information (e.g., processing site, operations, additives),
- Other operations (e.g., transport, storage, miscellaneous handling),

- Intended use (e.g., direct consumption, consumption after domestic processing, secondary foodstuff ingredient).

This list emphasises a number of important factors regarding raw food commodities. Firstly, there are generally two discrete stages to raw food commodity manufacture: growth cycle (the rearing of livestock or growth of a food crop) and processing (the sorting, cleaning and conditioning of the product prior to sale). In some cases these stages are carried out by separate companies (e.g., beef cattle farmer and abattoir). Therefore, HACCP procedures may require co-operation between all parties involved. Secondly, production information should take into account growth cycles. Peters (1998) identified this as a key component of the effectiveness of the current Australian approach to HACCP. Certain activities are only permitted either prior to raw food commodity production (e.g., bio-solid application) or at specific stages during the growth cycle (e.g., pesticide use during cereal production). Thirdly, all production and processing sites should be identified and the ‘times of use’ should be recorded, as both of these factors can affect likelihood of hazards occurring and (when they do occur) the degree to which they occur. For example, fishing is commonly prohibited at certain times of year or in close proximity to sewage discharges (Ahmed, 1992). The product description is commonly used to construct a flow diagram of the overall production sequence (e.g., see Bryan, 1992; CAC, 1993; ILSI, 1993). Within the food-manufacturing sector this is normally relatively straightforward, because many operations are highly standardised, particularly in large food processing plants where high levels of quality assurance and automation are possible. By comparison, many operations within the agricultural sector can appear *ad hoc*. For example, a farmer may decide to add additional nutrients to feeds if cattle appear to require them, or decide not to apply a pesticide if a crop that appears to be growing well without it. Such inherent variability must be carefully considered when developing raw food commodity flow diagrams.

Other Prerequisites

Further prerequisites have been recommended for effective HACCP procedures for raw commodities (Peters, 1998; Lee & Hathaway, 1998) including:

- Workforce training programmes,
- Sanitary working environment (site, amenities, equipment),
- Standard operating procedures (SOPs) for all food production steps,
- Routine sanitation, maintenance and waste disposal procedures,
- Ingredient and site chemical inventories.

HACCP is a hazard management tool and these prerequisites form the infrastructure within which the HACCP procedure can be developed and implemented. Farmers and growers are likely to refer to government bodies, such as the Ministry of Agriculture Fisheries and Food (MAFF) in the UK or affiliated organisations, such as the National Farmers' Union (NFU), for guidelines for the development of these and other HACCP procedures. For pesticides, both legislation and recommendations already exist e.g.:

> *Control of Pesticides Regulations 1986.*
> Legislation regarding the supply, storage, sale, advertisement and use of pesticides.
>
> *Pesticide (Maximum Residue Levels in Crops, Foods and Feeding Stuffs) Regulations 1994.*
> Implementation of European Union and UK Directives regarding Maximum Residue Levels and monitoring programmes.
>
> *Plant Protection Products Regulations 1995.*
> Approved systems for agricultural pesticide use within the European Union.
>
> *Code of Practice for the Safe Use of Pesticides on Farms and Holdings 1998.*
> (Also referred to as the 'Green Code.') Practical guidelines for farmers and growers within the UK.

These documents and the associated idea of 'Good Agricultural Practices' for the control of pesticides in the food chain have been further developed by Knight (1998). Codes of Good Agricultural Practice for the Protection of Air 1992, Soil 1993, and Water 1991 have also been produced by MAFF, which provide practical guidelines for farmers regarding air, soil and water pollution. The development of similar documentation for priority contaminants or priority contaminant/food combinations would further benefit this type of approach. For example, sewage sludge application to agricultural land is regulated in the UK according to EU directive 86/278 and the UK Code of Practice for Agricultural Use of Sewage Sludge (last amended 1998). This identifies types of sewage sludge (untreated, treated, dewatered cake, thermally dried and lime-treated) suitable for use on agricultural lands and provides maximum application levels on the basis of total sludge weight, nitrogen content, metal content (molybdenum, selenium, arsenic and nominally zinc) and fluoride. In 1999, the development of the safe sludge matrix by ADAS Limited and others introduced further controls on the use of sewage sludges in agriculture to minimise the likelihood of problems associated with pathogenic organisms. These procedures may also prove to be an effective control of other contaminants in sewage sludges (e.g., persistent organic chemical contaminants). However, if they do not, the Code of Practice could be amended to incorporate control recommendations for other classes of contaminants.

Although these prerequisites are considered essential to the HACCP development process, there has been some recent criticism of food producers that instigate these prerequisites alone and describe this process as HACCP (Untermann, 1998). The establishment of these prerequisites prior to HACCP development allows the HACCP team to focus upon individual foodstuff- and production process-specific hazards, instead of repeatedly addressing basic food safety issues common to all processes.

The HACCP Procedure

European Union Directive 93/43/EEC regarding the hygiene of foodstuffs is implemented in the UK via the Food Safety (General Food Hygiene) Regulations 1995. This places the emphasis for food safety upon the identification of critical operation steps and means of controlling and monitoring these steps. The approach incorporates five principles, in accordance with HACCP.

1. Hazard analysis of given foodstuff,

2. Identification of all points or operation steps at which hazards may occur,
3. Identification of points critical to food safety (i.e., CCPs),
4. Implementation of control and monitoring procedures at CCPs,
5. Periodical review of food hazards, CCPs, control and monitoring to ensure continued effectiveness.

Organic Chemical Hazards

Chemical hazards can be classified as (i) applied chemicals, (ii) accidental chemicals, or (iii) background chemicals. (N.B.: This classification system is only intended for the purpose of discussion. Multiple exposure routes are possible for many chemicals and some may have be considered in terms of all three exposure classes, e.g., see Okeeffe and Kennedy, 1998 for further discussion).

Applied Chemicals

Applied chemicals are those intentionally added to foodstuffs or their ingredients. With the exception of malicious acts (e.g., the use of prohibited substances or sabotage) the use of these compounds is either regulated or the subject of recommendational Codes of Practice. Classes of applied chemicals commonly used in the agricultural sector are summarised in Table 1. Individual farmers and growers should ensure that they have adequate records for the compilation of accurate applied chemical lists. Furthermore, they should ensure that all applied chemicals are suitable for their intended uses, i.e.:

- All applied chemicals should be food or agricultural grade,
- All applied chemicals should be administered according to manufacturer’s instructions and within the guidelines of any existing governmental recommendations, and
- Where applied chemicals are regulated (as in the use of certain pesticide/crop combinations), only approved chemicals should be used.

Applied chemicals are often applied as large ‘point source’ doses so they have the potential for high contamination, if inappropriately used. Thus, attention is usually focused on these, and other classes of contaminants (i.e., accidental and background chemical) are rarely considered in current chemical HACCP procedures.

Accidental Chemicals

Accidental chemicals are either applied unintentionally to foodstuffs or generated unintentionally during rearing or production. The most common accidental chemicals are impurities in applied materials such as animal feeds, water supplies, composts and sewage sludges. However, both livestock and food crops can also be exposed to other site chemicals because of inappropriate use or accident (e.g., spillage or fire). Such site chemicals are likely to include cleaning materials, disinfectants, paints, fuels machine lubricants and preservatives (e.g., wood and metal treatment agents). Accidentally generated chemicals include those generated during food production, processing and storage. Since minimal food processing is carried out on raw food commodities, accidentally generated chemicals are most likely generated during growth cycles (e.g., rearing of livestock or growth of food crop) or storage. For raw food commodities, one class of accidentally generated chemicals requiring particular consideration is natural toxins. For example, Watson (1993) described mycotoxins as one of most significant hazards associated with cereal-based foodstuffs and Ahmed (1992) identified scombroid and paralytic natural toxins as significant hazards to consumers of sea foods.

Although some accidental chemicals can be readily identified (e.g., site chemicals), farmers and growers are unlikely to have the necessary knowledge and/or experience to identify and assess the significance of most accidental chemicals. Consequently, external advice will be needed if they are obliged to compile lists of accidental chemicals. Possible sources of such information include MAFF, commercial food research associations and the NFU.

Background Chemicals

Background chemicals are ubiquitous environmental contaminants that may enter food chains at almost any stage of raw food commodity production. Initially, much research focused on polycyclic aromatic hydrocarbons, polychlorinated biphenyls, polychlorinated dibenzo-*p*-dioxins and dibenzofurans, but other classes of chemicals including volatile aromatics, chlorinated solvents, benzenes, naphthalenes and diphenoquinones, polychlorinated diphenyl ethers, polybrominated dioxins, biphenyls and diphenyl ethers, and synthetic musks are now receiving being to receive similar attention.

Environmental contaminants are of particular concern if they are persistent, bioaccumulative and toxic. Therefore, simple methods have been developed to identify priority chemicals upon the basis of these factors (e.g., see Wearne *et al*, 1996). Background environmental contamination is a complex process as numerous exposure routes may be involved. Furthermore, the relative significance of individual exposure routes will vary both contaminant and foodstuff (e.g., see Figure 2). Some researchers have attempted to predict environmental contaminant behaviour using physico-chemical parameter screening models (Wild & Jones, 1992; Wild *et al.*, 1995). However, as with accidental chemicals, farmers and growers will rarely have the knowledge and experience required to unambiguously employ such screening models. Therefore, identification of priority background chemicals is likely to become the responsibility of outside agencies.

Hazard Analysis

Once potential chemical Contaminants have been selected for investigation, some form of hazard analysis is required. Usually, quantitative risk assessment would be used for this purpose, e.g.:

$$HI = \left(\frac{[Food]_{\text{Contaminant}}}{MRL_{\text{Contaminant}}} \right)$$

Where HI is the hazard index, $[Food]_{\text{Contaminant}}$ is the contaminant concentration in the investigated food, and $MRL_{\text{Contaminant}}$ is the maximum residue level for the contaminant in the investigated food.

Although widely used by chemical waste management industries (e.g. see Barron *et al,* 1994; Fries, 1996; Kloepper-Sams *et al,* 1996; Valberg *et al,* 1996) this approach is unlikely to be suitable for many contaminant/food combinations as much of the information required is unlikely to be available. For example, the types of information that a farmer or grower would typically require to conduct such procedures include:

- Contaminant levels in primary ingredients (e.g., seeds, livestock), feeds, applied chemicals, and environmental media,
- Assessment of the relative significance of different exposure routes,
- Food surveillance data for consumption levels (probably requiring additional consideration for 'at risk' consumers; the young, elderly, pregnant women, the sick, over-eaters, consumers with atypical diets), and
- Dose-response assessments for individual contaminants.

Such approaches have, therefore, been described as a burden to HACCP unless sufficient reliable data is available and the risk assessment methods are kept practical, easy-to-interpret and cost-effective (Mayes, 1998). Quantitative risk assessment can, however be applied during the development of agricultural food contaminant strategies and recommended practices documentation (e.g., Good Agricultural Practices, Codes of Practice). Mathematical methods such as predictive risk assessment have been identified as potential tools for microbiological hazard analysis (Untermann, 1998). However, our limited understanding of the food chain means that predictive chemical contaminant risk assessment is unlikely to be an effective means of evaluating food safety within most agricultural practices. Nevertheless, it still likely to provide a useful framework for improving our understanding of chemical contaminants within food systems and could play an important role in developing and testing novel food safety strategies. A less rigorous approach, such as semi-quantitative or qualitative hazard assessment, is more practical within routine raw food commodities HACCP. This type of approach has been described previously by Lee and Hathaway (1998) and Untermann (1999) and an example of the use of a combination of procedures is presented here as Figure 3. The key advantage of this type of approach is that it is flexible in that hazard assessment can be tailored to the availability of information investigation and the experience of the HACCP team (Mayes, 1992, 1998). Regardless of the sophistication of the procedures developed, training programmes, hazard analysis guidelines, specialist computer software and external auditing should all be used wherever possible.

Identification of CCPs

Any stage of food production can have an influence upon the properties of a finished foodstuff. Within HACCP, activities or operations that affect food safety are defined as control points (CPs) and a control action is an activity or operation that can either eliminate or reduce an existing hazards (or hazards) or prevent the subsequent development of an introduced hazard (or hazards). A CP that is critical to food safety is a critical control point (CCP). Accurate assignment of CCPs is crucial to efficient and economical deployment of monitoring, control and corrective resources (Havelaar, 1994; Bovee *et al*, 1997). However, this is both a complex and demanding procedure (Sperber, 1992; Tompkin, 1994), and misassignment of CCPs has been identified as a major cause of ineffective HACCP (Untermann, 1999). To simplify the procedure, CCP assignment decision trees are often used (e.g. see Mayes, 1992; CAC, 1993; ILSI, 1993; Figure 4).

The International Commission on Microbiological Specifications for Foods (ICMFS) has proposed that CCPs be further classified as either CCP1s, (CCPs at which control is assured) or CCP2s, (CCPs at which hazards can only be minimised and control can not be completely assured) (ICMFS, 1988). Although this approach is widely used (e.g., see Bryan, 1992; Cordier, 1994; Tompkin, 1994), it has been criticised for giving the impression that CCP1s were absolute assurances of safety (Buchanan, 1990; Untermann, 1998). Lee and Hathaway (1998) classified chemicals hazards as C1 (identified chemical hazards), and C2 (unidentified chemical hazards) types. Conventional HACCP focuses upon C1 type hazards. CCPs can also be assigned for unidentified hazards but the nature of the hazard has to be defined. For example, contamination of foodstuffs by unidentified organic chemicals in production water can be minimised by ensuring the quality of water supply, instigating pre-processing clean-up procedures and/or minimising the volumes used in food production. However, it should be noted that C2 type CCPs are unlikely to be true CCPs according to the classical definition, because the effectiveness of monitoring procedures and corrective actions would be unknown.

Organic Contaminant Control

Five general types of control actions should be considered within the agricultural sector: inspection, assurance of site quality, assurance of ingredient and packaging quality, adherence to safe production practices, process optimisation, and maintenance of production equipment.

Inspection

Inspection steps are obvious stages of food production to exert control but contemporary analytical monitoring procedures for organic chemical contaminants in foodstuffs are often expensive, sophisticated and time-consuming (Gilbert, 1994). Therefore, economic factors are likely to limit the routine use of analytical inspection to large organisations rather than small- and medium-scale agricultural units such as freehold farms and specialist food producers (Jouve, 1994). Most data available for this sector is likely to be inferred from external surveillance exercises or model systems. Therefore, the emphasis of organic chemical HACCP procedures will likely be placed on other types of control action. Development of more rapid, robust, economical and 'user-friendly' analytical methods is essential if analytical inspection is to play a significant role in future organic chemical HACCP procedures for the agricultural sector.

Assurance of Site Quality

For each production operation, the local environment is a potential source of organic chemical contamination. In agriculture practices, most operations are carried out in the open, therefore, site hazard analysis is probably the most practical means of identifying associated chemical hazards. Soil, vegetation, rain water, river water and air should all be considered in turn and all available evidence evaluated, including:

- Specific data for the local environment (e.g., contaminant 'hot spots'),
- General contamination problems within the UK (e.g., UK priority pollutant sources), and
- Hazards associated with external local activities (e.g., potential contamination from local industry).

As previously discussed, this type of approach will require some degree of external input (i.e., training, guidelines, software or auditing). A stratified approach, similar to the Dutch ABC system for contaminated land bio-remediation, could be developed for the classification of potential food production sites, e.g.:

A.	No food production	(strong evidence that use of site would result in production of hazardous foodstuffs),
B.	Permission required	(evidence that one or more inputs to the site is a potential hazard to food production: *Default classification*),
C.	No restrictions	(all available evidence indicated that site is safe for food production. Only adherence to normal recommended food production practices required).

Designating 'B' as the default position means that all new sites automatically require external assessment before they can be used for food production. Furthermore, the classification of most food production sites as 'B' would make routine auditing and assessment compulsory activities for the majority of sites.

The ‘B’ category could be further stratified according to any restriction placed upon food production:

B1. Site unsuitable for food production and no food production is allowed. This status is analogous to ‘A’ and site should be so designated such until contrary evidence is provided.

B2. Site suitable for food production although monitoring and special practices may be required in addition to normal recommended food production practices,

B3. Site suitable for food production although monitoring may be required in addition to normal recommended food production practices,

B4. Site suitable for food production although special practices may be required in addition to normal recommended food production practices,

B5. Site suitable for food production with only adherence to recommended food production practices. This status is analogous to ‘C’ and site should be designated such until contrary evidence is provided.

This approach could be interpreted as HACCP, e.g. production site has been identified as a potential CCP (Sperber, 1992). Contamination can result from a number of agricultural practices. For example, long-term use of sewage sludge in agricultural practices has resulted in increased levels of organic chemicals in soils (Korentajer, 1991). Compliance with relevant Codes of Practice is likely to be the most practical method of controlling such potential sources of contamination. However, chemical contamination can also result from activities beyond the control of individual farmers or growers. For example, a cereal farmer could do very little to control airborne contamination of crops by polychlorinated dibenzo-p-dioxins and dibenzofurans as a result of inappropriate incineration practices at manufacturing sites not directly adjacent to the production site. In such cases, control actions, such as the regulation of significant external contamination sources, would have to be the responsibility of a government body able to implement corrective actions, i.e., set and enforce regulatory limits. One of the identified strengths of HACCP is that it places the responsibility for ensuring control of a given production operation upon the individual (or individuals) carrying out that operation. This is widely believed to provide an incentive for safer production practices as well as an increased understanding of safety issues (WHO, 1993; Mayes, 1994; Moy *et al.*, 1994; Tompkin, 1994). Furthermore, it is unlikely that corrective actives could be implemented effectively, i.e., in time to save existing food commodities. Consequently, this type of control probably can not be considered HACCP according to the strictest definitions. However, it should not be ignored, as it would be an important component of an integrated chemical contamination management plan. Practically, such an approach would probably have to be managed by a single body (e.g., the proposed Food Standards Agency) and incorporate:

- General agricultural production protocols (e.g., GAPs),
- Product- and process-specific protocols (e.g., HACCP), and
- Environmental management (e.g., regulatory control of external contamination sources).

Assurance of Ingredient and Packaging Quality

A wide range of ingredients are used in the production of raw food commodities, e.g., see Table 1. Other materials that are technically not ingredients are also likely to come into contact with foodstuffs within the agricultural sector, e.g., water or packaging materials. Farmers and growers should take all reasonable steps to ensure that these are suitable for their intended purpose and only purchased from reputable suppliers. Similarly, all agricultural ingredients and material suppliers should ensure that all materials sold for use in food production are suitable for their intended purposes and supplied with supplier assurance documentation and correct usage instructions. Knight (1998) identified two main categories of supplier assurance: supplier approval and supplier specifications. Under supplier approval, the supplier is required to demonstrate that (i) they are reputable, (ii) raw materials and processes used in the production of the supplied goods are in accordance with their intended uses, and (iii) quality assurance procedures are effective. Various criteria have been proposed for approved supplier status, including:

- Previous trading history,
- Membership of a recognised trade association,

- Accreditation within an accepted quality assurance scheme (e.g., ISO 9000, EN29000, SQF 2000, Assured Combinable Crops Scheme), or
- Food grade or agricultural grade classification of supplied goods.

Under supplier specification, the supplier guarantees that all supplied goods will meet all specifications defined in the purchase contract. In some cases these specifications can be very specific (e.g., supplied ingredients for specialist foodstuffs). More frequently, these specifications tend to be based on general industry standards, such as the United Kingdom Agricultural Supply Trade Association (UKASTA) Grain Contract or the Campden & Chorleywood Food Research Association Food Quality Specifications for the fruit and vegetable processing industries. Wherever available, supplier specification of maximum acceptable residue levels for identified contaminants within supplied goods would be the most effective means of chemical HACCP ingredient quality assurance.

Adherence to Safe Production Practices

A prerequisite of HACCP is the development of SOPs in accordance with current understanding of safe production practices which generally address non-specific food safety issues. However, specific recommendations may be made regarding the safe use of certain ingredients, processing operations or ingredient/processing operation combinations or safe production of certain foodstuffs. It is these safe production practices which should be addressed within the HACCP procedure. A number of key factors have been identified for the effective use of adherence to safe production practices as a control action with HACCP:

- Production Practices need to be defined according to current understanding of safe production practices. Information sources are likely to include relevant GAPs, Codes of Practice, Assured Practices Protocols, government recommendations and legal requirements, recognised trade association guidelines and supplied ingredients handling instructions.

These should be used to develop product-specific SOPs for the safe production of the individual foodstuff under consideration.

- All workers involved in the defined procedure need to be adequately trained to carry out their individual responsibilities. A number of publications have discussed this area in detail, and education has been identified as a significant factor in effective HACCP (WHO, 1993; Mayes, 1994; Moy et al., 1994; Tompkin, 1994; Khandke & Mayes, 1998).
- Documentation and validation procedures need to be developed that can be used to demonstrate that the handling procedures have been carried out as defined (Sperber, 1996). External accreditation is normally incorporated into this type of approach as a means of increasing consumer confidence and demonstrating 'due diligence' (ILSI, 1993). Quality accreditation systems, such as EN 29000, ISO 9000 or SQF 2000, are commonly recommended for this purpose.

Process Optimisation

For microbiological hazards, processing practices such as heat treatment or pasteurisation are often used to control or eliminate hazards that have previously developed in a given foodstuff. However, raw food commodities are unlikely to undergo any more than basic processing, e.g:

For fruit:	Cleaning, washing, sorting, packaging.
For vegetables:	Cleaning, washing, sorting, packaging.
For cereals:	Deinfesting, sorting, dehusking or shelling, conditioning, dehydrating, rolling, milling, packaging.
For milk:	Chilling, homogenising, pasteurising, bottling or packaging.
For raw meat:	Skinning, boning, eviscerating, cleaning, size reduction, chilling, packaging.
For raw fish:	Cleaning, descaling, filleting, chilling, packaging.

Furthermore, although current research indicates that these types of processes can reduce residue levels of some chemical contaminants, the observed decreases are typically small (i.e., less than 50%) or even insignificant (e.g., see Dejonckheere *et al.*, 1996). Therefore, processing alone should not be relied upon to eliminate or significantly reduce hazards associated with chemical contamination and process optimisation is, at best, likely to provide only CCP2 type control (hazard minimisation but control not assured) as part of a raw food commodity organic chemical contaminant HACCP procedure.

Maintenance of Production Equipment

Poorly maintained equipment is a potential source of contamination. For example, incorrectly calibrated spraying equipment or leaking fuel tanks on farm vehicles could both cause chemical hazards to food production. Consequently, all relevant site equipment should be in good working order. Two types of maintenance procedures are normally recommended: routine preventative servicing and fault repairs. All personnel responsible for such activities should have appropiate training and qualifications. Wherever contract services are used to maintain site equipment, both the employer and contract service management should take all reasonable steps to ensure that all personnel involved are suitably trained and qualified. One example of this type of approach is the voluntary sprayer test scheme run by the Agricultural Engineers Association (AEA), which involves routine testing and repair of spraying equipment by AEA-affiliated companies and certifications of property maintained spraying equipment.

Chain of Responsibility

No single action is likely to ensure food safety. For example, analytical inspection only guarantees product assurance at the inspection point. Similarly, most safe production practices are only designed to ensure that a given production step does not become a significant hazard. Therefore, it is usually important to use control methods in combination to establish an assured supply chain. Knight (1998) recommended that

"All raw materials should be identified in such a manner to enable them to be identified at all steps up to use; all in-process products should be identified in such a manner to maintain product identification, and finished products should be identified in such a manner to allow a defined production run to be identified." The purpose of an assured supply chain is to provide a traceable record of the production process that requires a chain of responsibility within which each individual is responsible for their part in the food production process. One example of this type of approach is the UKASTA scheme for the assured supply, distribution and intermediate storage of cereals and other combinable crops and the manufacture and distribution of animal feedstuff products. When a crop is grown, harvested, processed and packaged at a single site the supply chain can be readily (and unambiguously) identified. However, raw food commodities are often sent to secondary sites for processing (e.g., meat abattoirs, cereal mills, packaging plants) and many of these sites deal with multiple suppliers or even wholesalers. In such cases, some degree of product mixing (e.g., overlap of product batches or batch blending) is likely to occur. Therefore, it may not always be possible to trace finished products back to individual harvests. However, even in cases where ingredient batches were mixed, the combination of an assured supply chain and an effective HACCP procedure provides evidence that "all reasonable precautions" were taken and that "due diligence" was exercised during the production of a foodstuff (see ILSI, 1993 for further discussion).

Periodical Review of HACCP Procedure

Once developed, HACCP procedures should be implemented quickly with minimum disruption to food production. The management and periodical review of the procedure is the key to its continued success (Khandke & Mayes, 1998; Sperber, 1998). Under normal conditions (i.e., when production is under control) reviews of production practices and associated documents act as an assurance that the HACCP procedure has been correctly adhered to. In the event of corrective actions being taken, reviews of the conditions that resulted in their implementation and their effectiveness can be used to evaluate the effectiveness of the implemented HACCP procedure (ILSI, 1993). The occurrence of regular or preventable control losses indicates a need for the reassessment of the HACCP procedure, reformulation of product or even redesign of the production process (Stevenson & Humm, 1992; Sperber, 1992). This type of constant "feedback" allows a HACCP procedure to evolve with changes in the production environment and remain effective under conditions where other more structured assessment protocols would fail (Savage, 1995).

Discussion

The Pillsbury Company developed HACCP in the 1960s, to ensure the safety of foodstuffs consumed during space flights (APHA, 1972; Pillsbury Company, 1973) to overcome limitations of end-point testing. For example, within end-point testing:

- Large proportions of a food have to be taken for analysis to ensure the samples are representative of the foodstuff in question,
- Food safety is only ensured for tested hazards at the point of testing,
- Tests are often expensive, time-consuming, difficult to interpret and destructive,
- Control of hazards is reactive as opposed to proactive, and
- Responsibility for food safety is focused upon a relatively small component of the workforce, quality assurance and control personnel.

For microbiological hazard control, HACCP has been shown to be more effective, reliable, economical and practical than conventional end-point testing (Mayes, 1992; ILSI, 1993; Mayes, 1994; Moy *et al.*, 1994; Tompkin, 1994). All aspects of food production, distribution, retail and domestic use are considered as part of the development of the HACCP procedure (Reimers, 1994). Furthermore, the approach is flexible, which means that it can be readily adapted to incorporate existing hazard control procedures or be incorporated into larger integrated quality management programmes (Moy *et al.*, 1994; Savage, 1995; Peters, 1998). Application of HACCP to organic chemical contamination in foodstuffs would likely result in similar advantages as it is probably the most effective hazard control procedure currently available. However, if HACCP is to become a more effective means of controlling organic chemical contaminants in raw food commodities some issues must be addressed. These include problems related directly to the agricultural sector and some directly to the development of chemical HACCP procedures.

Many agricultural operations can be *ad hoc* and even subjective. For example, a farmer may decide to alter a routine practice if a crop is not developing as expected. The alteration employed is likely to have been developed as the result of years of experience of the agricultural site and/or food crop. Such practices could therefore vary significantly and this variability is likely to be unavoidable as purchasers (and consumers) are likely to expect consistent products (i.e., similar yield, appearance, texture and flavour) form a product environment that is itself inherently variable. In terms of food safety, the most obvious consequence of this type of approach is a potential variability in the levels of hazards associated with the raw food commodities produced, which has to be recognised when assessing hazards and developing food safety strategies. However, other components of HACCP would be affected. For example, care would be required when developing flow diagrams, SOPs and processing documentation to prevent the introduction of impractical working practices.

Both analytical monitoring and process optimisation are effective and economical components of microbiological HACCP. However, their limited use within the agricultural sector with respect to chemical hazard control means that they are unlikely to become significant components of current chemical HACCP procedures. Consequently, current procedures are likely to focus upon raw ingredient sourcing (supplier approval and certification) and the adherence to safe production practices within an assured supply chain. One less obvious consequence of this approach is that control is likely to rely upon a series of CCP2s. Therefore, chemical HACCP is unlikely to be as efficient as microbiological HACCP, within which safety can usually be ensured using a limited number of carefully selected CCP1s. Thus, there is a need for continued development of both process optimisation and analytical techniques if they are to become more significant components of future raw food commodity chemical HACCP procedures.

Individual farmers and growers are unlikely to have the necessary experience and/or knowledge to identify chemical hazards and develop effective control strategies and will need to rely on external advice when developing HACCP procedures. Possible sources of such information include government bodies such as MAFF, commercial organisations, such as Campden & Chorleywood Food Research Association and Leatherhead Food Research Association, and affiliated organisations, such as the National Farmers Union. These organisations should therefore ensure that all relevant information is easily accessible and regularly updated.

Some chemical hazard control strategies have already been (or are in the process of being) developed, e.g., pesticide handling, agricultural sewage sludge application and packaging material assurance schemes. Wherever such schemes exist they should be incorporated into the HACCP procedure as completely as possible to avoid any unnecessary repetition.

Generic Organic Chemical Contaminant HACCP

Generic organic chemical contaminant HACCP procedure templates are presented below for three classes of raw food commodities (i.e., food crops, raw meats, and milk). These templates were designed to be used in the production of specific foodstuff flow diagrams and HACCP procedures. For example, the cereal production template could be used to develop a specific flow diagram and HACCP procedure for organic chemical contaminants during the production of wheat. Consequently, these templates should only be used as guidelines for the development of HACCP procedures.

Food Crops

A number of publications have recognised the potential benefits of developing HACCP or HACCP-type approaches for the production of cereal crops (van der Veen, 1994; Knight, 1998; Peters, 1998). Peters (1998), for example, described two predominant Australian approaches to HACCP for fruit and vegetables: the SQF 2000

Quality Code and the Woolworths Vendor Quality Management Standard (WVQMS). The fact that both systems are voluntary and third party certified is believed to be a significant factor in their widespread acceptance. Knight (1998) published a detailed and highly practical guide to the implementation of a HACCP-based system for pesticide use with food crops. Nickelsen and Jakobsen (1996) described the use of hazard identification, exposure assessment, dose-response assessment and risk characterisation for raw materials used in the production of a fermented maize foodstuff, ‘kenkey,’ and recommended the use of HACCP-based framework for this approach.

A typical generic procedure for the production of crop plants is presented in Flow Diagram G1 and associated hazard control methods are identified in Table G1. Flow Diagram G1 depicts crop growth and processing steps commonly associated with cereal production. However, with minor modifications this procedure could also be applied to other crops, such as fruit and vegetables. Before beginning crop production, the growing site, water supplies and all associated equipment should be assessed with regards to all chemical contaminants under consideration and their suitabilities for all intended use determined (Table G1, controls A, E, F and G, respectively). Similarly, all previous practices carried out upon the site should also be reviewed and should be demonstrated to be non-detrimental to crop production. Further to this point, any actions that have been undertaken to minimise hazards resulting from previous site activities should be fully documented (Table G1, control C). All reasonable measures should be taken to ensure that seed stock are free of contamination. There are two likely sources of seed stock: previous harvested and purchase. Seed stock produced in previous harvests are likely to have been stored over winter and may have been treated prevent either spoilage or infestation. Consequently, a number of potential control measures should be considered for such seed stocks (Table G1, storage site controls A, B, D, G and H, respectively). All other seed stocks should be purchased from a reputable supplier (Table G1, control B) and relevant analytical monitoring data should be requested if available (Table G1, control K). During their growth cycles crop typically develop through a number of distinct stages. In the case of cereal production five discrete steps have been identified in Figure G1, i.e., sowing, crop establishment (early vegetative growth), stem elongation (late vegetative growth), ear emergence (reproductive growth) and ear development (grain ripening). The number and nature of growing steps should be modified to reflect the crop under consideration. Each of these steps should be considered individually because the activities in each are likely to vary considerably. For example, certain pesticides can only be used during certain stages of crop development. Typical controls include Table G1, controls C, D, E, F and G. Similar consideration should be given to harvesting. Processing is likely to take place at a different site. Consequently additional site and equipment assessments will be required (Table G1, controls A, E, F and G, respectively). All subsequent processing, storage and associated activities (i.e., site and equipment maintenance and cleaning) should be carried out according to good working practices, using chemicals and materials suitable for their intended purposes (Table G1, controls D, G, H, I and J). For cereals, conditioning is a drying process designed to inhibit microbial activity that may also reduce levels of volatile and semi-volatile organic contaminants. Furthermore, at typical operating temperatures, 60 to 80°C, it is unlikely to result in the generation of hazardous pyrolysis products. Therefore, conditioning (time and temperature) is a potentially promising CCP. However, such extreme conditioning is not always practical for more perishable plant crops such as fruit and vegetables. Multiple batches of crops are likely to be combined for wholesale as manufacturers and retailers commonly purchase such commodities in bulk. Where such activities occur, all component batches should be accredited (e.g., produced according to HACCP) and traceable. Analytical monitoring may also be carried out at this stage, e.g., at the request by a potential bulk buyer (Table G1, control K).

Raw Meats

The International Commission on Microbiological Specifications for Foods (ICMSF, 1988) identified HACCP as the most effective means currently available for the control of microbiological hazards in raw red meat, poultry and fermented sausages. ICMSF (1988) also recommended the widespread use of HACCP within the meat and poultry industries and identified specific CCPs for the control of *salmonella*. Franco *et al* (1990) identified a number of potential CCPs associated with the slaughter of cattle, swine and sheep, including pre-slaughter transport, slaughter and evisceration.

Hathaway and McKenzie (1991) recommended the routine inspection of carcasses and offals as a means of minimising both microbiological and chemical contamination. Tompkin (1990) discussed the application of HACCP to both raw and processed meat products and later produced generic HACCP procedures for meat products (Tompkin, 1994). Tompkin (1994) also suggested that the effectiveness and efficiency of HACCP justified its use by the meat industry, regardless of legal status. The New Zealand Ministry of Agricultural identified a number of limitations to existing raw meat HACCP procedures and addressed these problems by developing a generic template for raw meat HACCP (NZ MA, 1997; Lee & Hathaway, 1998).

A typical generic procedure for raw beef production is presented in Flow Diagram G2 and associated hazard control methods are identified in Table G2. In this case some of the identified steps are specific to raw beef production (e.g., the post-slaughter processing procedure). Consequently this procedure should be modified before application to other meats (e.g., pork, lamb or poultry). Before beginning beef cattle production, the rearing site, water supplies and all associated equipment should be assessed with regards to all chemical contaminants under consideration and their suitabilities for all intended use determined (Table G2, controls A, F and J). All previous practices carried out upon the site should also be reviewed and should be demonstrated to be non-detrimental to livestock. Further to this point, any actions that have been undertaken to minimise hazards resulting from previous site activities should be fully documented (Table G2, control J). All reasonable measures should be taken to ensure that cattle selected for rearing are free of contamination. A number of controls should be considered for cattle born on-site: background contamination from the site, site practices and site chemicals (Table G2, controls A, G, H, I and J). In addition, a significant proportion of the maternal parents body burden of organic chemical residues can be transferred to the offspring. Therefore, the maternal parent is a potential CCP both at birth and during weaning (Table G2, control B). All other cattle should be purchased from a reputable supplier (Table G2, control C). The flow diagram used in this example divides the latter stages of rearing into post-weaning calf and adult beef cattle. This division was made because calves and adult beef cattle are likely to be treated differently (e.g., different feeding practices, different degrees of medical attention, different locations). Furthermore, calves are likely to be more susceptible to chemical contaminants. Consequently, hazards may have to be assessed differently depending upon the age of the animal under consideration. Additionally, cattle can be moved around significantly during rearing for grazing or medical treatment, or housed in barns during wintering or bad weather. Therefore, a wide range of controls (e.g., Table G2, controls A, D, E, F, G, H, I and J) must be considered separately for each discrete activity identified (e.g., field grazing and enclosed rearing). Selection for slaughter is the final stage at which livestock can be assessed. Thus, this is a practical point to review the HACCP procedure and any additional evidence for chemical hazards (Table G2, control K). All subsequent processing, storage and associated activities (i.e., site and equipment maintenance and cleaning) should be carried out according to good working practices, using applied chemicals, materials and site chemicals suitable for their intended purposes (Table G2, controls G, H, L and M). Skinning and evisceration have both previously been identified as potential CCPs for chemical residues (Lee & Hathaway, 1998). However, it is currently unclear how effective they are. Separate batches of meats are only likely to be combined after processing (e.g., during wholesale or retail). Where all component batches should be accredited (e.g., produced according to HACCP) and traceable. Although uncommon, analytical monitoring may be carried out at this stage, e.g., at the request by a potential bulk buyer (Table G2, control N).

Milk

HACCP principles have been widely discussed and accepted within the dairy industry. HACCP has been recommended as a quality assurance system for cultured dairy produce, pasteurised milk, non-fat dried milk, cheese and yoghurt (Bigalke, 1981; Christian, 1987; van Schothorst & Kleiss, 1994). Christian (1987), for example, concluded that HACCP approaches offered significant advantages over traditional quality assurance methods. Gravani and Bandler (1987) recommended the incorporation of existing quality assurance methods within HACCP and described HACCP procedures for microbiological and physical hazards in natural cheese plants. Van Schothorst & Kleiss (1994) discussed the application of HACCP to chemical, microbiological and physical hazards and concluded that HACCP was applicable to all forms of dairy food processing. Henson *et al* (1999) carried out an extensive study of HACCP within the UK dairy sector, and concluded that HACCP provided both significant financial and practical advantages over traditional safety assurance methods.

A typical generic procedure for milk production is presented here as Flow Diagram G3 and associated hazard control methods are listed in Table G3. The early stages of milk production (i.e., the rearing of the calf) are similar to those previously described for beef production. The rearing site, water supplies and all associated equipment should be assessed with regards to all chemical contaminants under consideration and their suitabilities for all intended use determined (Table G3, controls A, F and J). All previous practices carried out upon the site should also be reviewed and should be demonstrated to be non-detrimental to livestock. Further to this point, any actions that have been undertaken to minimise hazards resulting from previous site activities should be fully documented (Table G3, control J). All reasonable measures should be taken to ensure that cattle selected for rearing are free of contamination. A number of controls have to be considered for cattle born on-site: background contamination from the site, site practices and site chemicals (Table G3, controls A, G, H, I and J) and the maternal parent both at birth and during weaning (Table G3, control B). All other cattle should be purchased from a reputable supplier (Table G3, control C). In this example subsequent rearing is divided into two steps: post-weaning calf and adult dairy cattle. As with beef cattle, dairy cattle can be moved around significantly during rearing. Consequently, these steps are further divided into sub-groups to reflect this behaviour (e.g., enclosed rearing, field grazing and calving). Each of these activities should be assessed separately and a number of controls may have to be considered (e.g., Table G3, controls A, D, E, F, G, H, I and J). Calving is, in effect, the first step of the milking process, and it should be assessed during the HACCP procedure (e.g., Table G3, controls A, D, E, F, G, H, I, J and K). The potential transfer of contaminants from dairy cattle to milk during milking should also be considered (Table Z, control L) along with any activities associated with milking (e.g., Table G3, controls A, F, G, H, I and J). All subsequent processing, storage and associated activities (i.e., site and equipment maintenance and cleaning) should be carried out according to good working practices, using applied chemicals, materials and site chemicals suitable for their intended purposes (Table G3, controls G, H, M and N). Separate batches of milk are likely to be combined either on-site or after production by a wholesaler or retailer. Where such activities occur, all component batches should be accredited (e.g., produced according to HACCP) and traceable. Analytical monitoring may be carried out at this stage, e.g., at the request by a potential bulk buyer (Table G3, control O).

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Table 1: Classes of applied chemicals commonly used in the agricultural sector.

Raw Food Commodity	**Applied Chemicals**
Vegetables	Herbicides, insecticides, fertilisers, nutrients, disinfectants*, detergents*, fumigants*
Fruit	Herbicides, insecticides, fertilisers, nutrients, disinfectants*, detergents*, fumigants*
Cereals	Herbicides, insecticides, fertilisers, nutrients, growth regulators, disinfectants*, detergents*, antioxidants*, fumigants*,
Milk	Antibiotics, other veterinary drugs, mineral supplements, vitamin supplements, protein supplements, growth factors, digestion enhancers, antioxidants*, disinfectants*, detergents*,
Raw meat	Antibiotics, other veterinary drugs, mineral supplements, vitamin supplements, protein supplements, growth factors, digestion enhancers, preservatives*, antioxidants*, disinfectants*, detergents*,
Raw fish	Antibiotics[+], disinfectants*, detergents*,

* Normally associated with post-harvest or post-slaughter activities.

[+] Normally only associated with farmed fish.

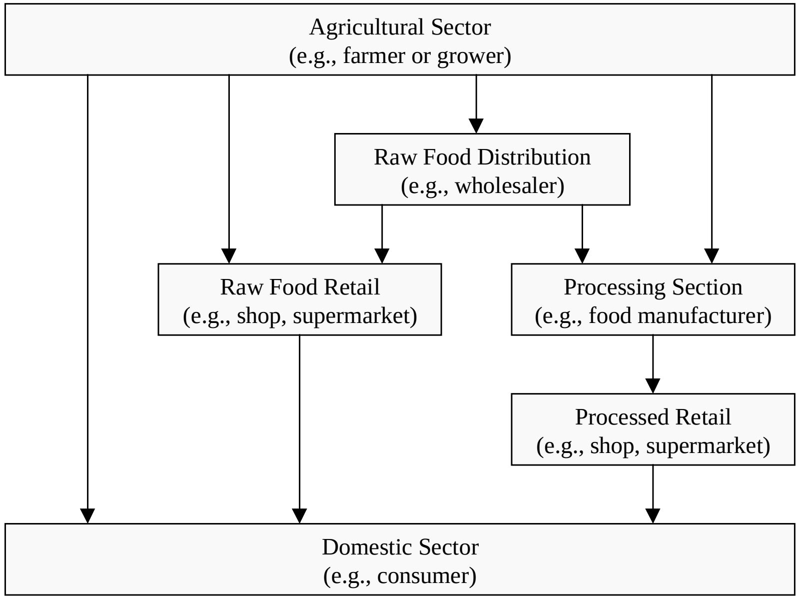


Figure 1: Some Examples of Typical Food Supply Chains.

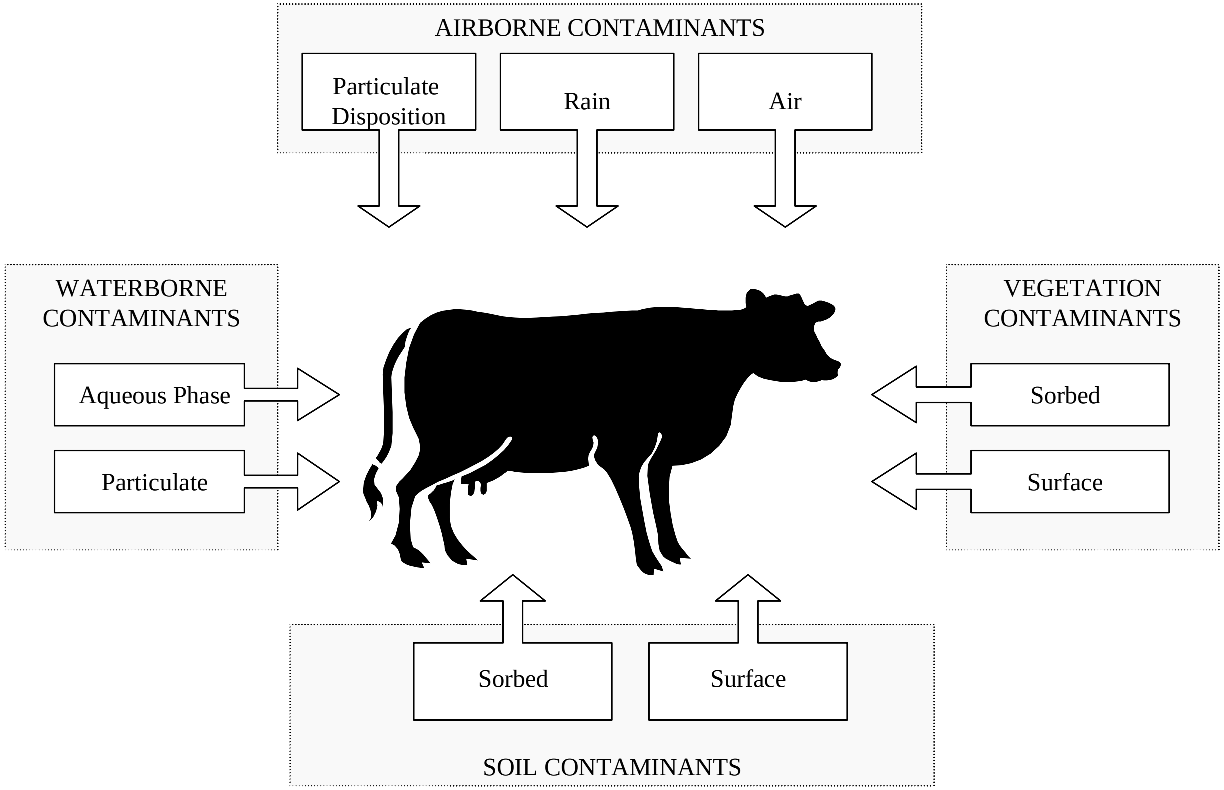


Figure 2: Schematic Representation of Potential Exposure Routes for the Contamination of Beef Cattle by Ubiquitous Environmental (Background) Chemicals.

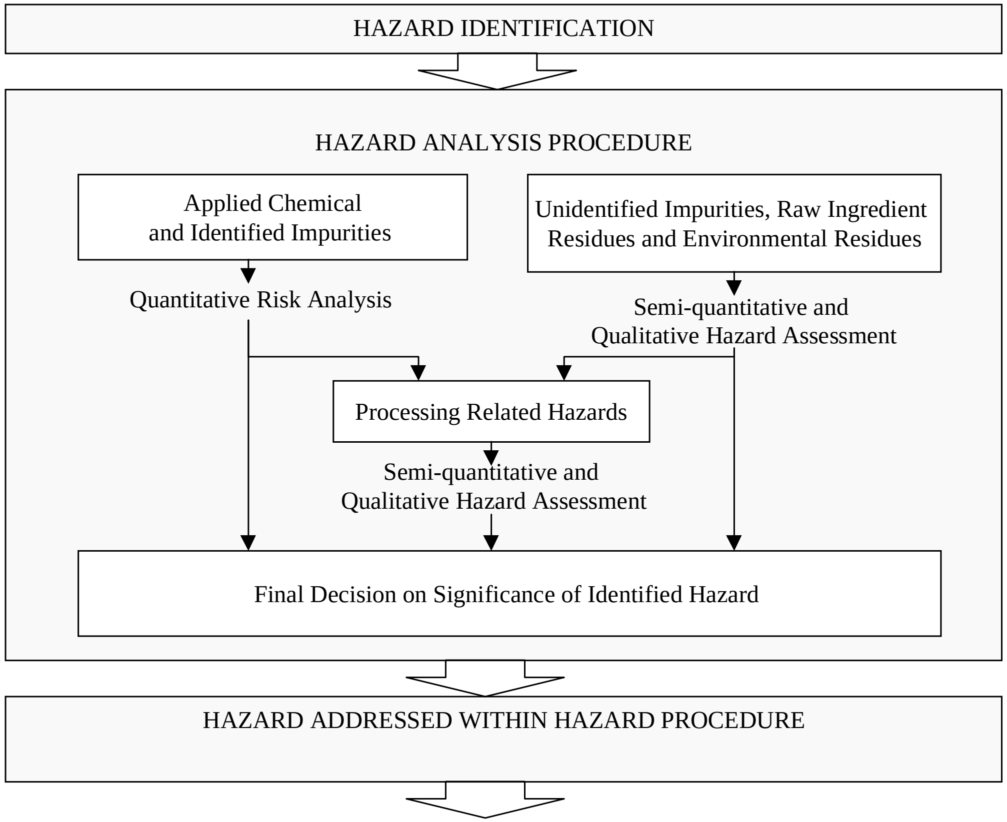


Figure 3: Example of the Combined Use of Quantitative, Semi-Quantitative and Qualitative Approaches with Hazard Analysis.

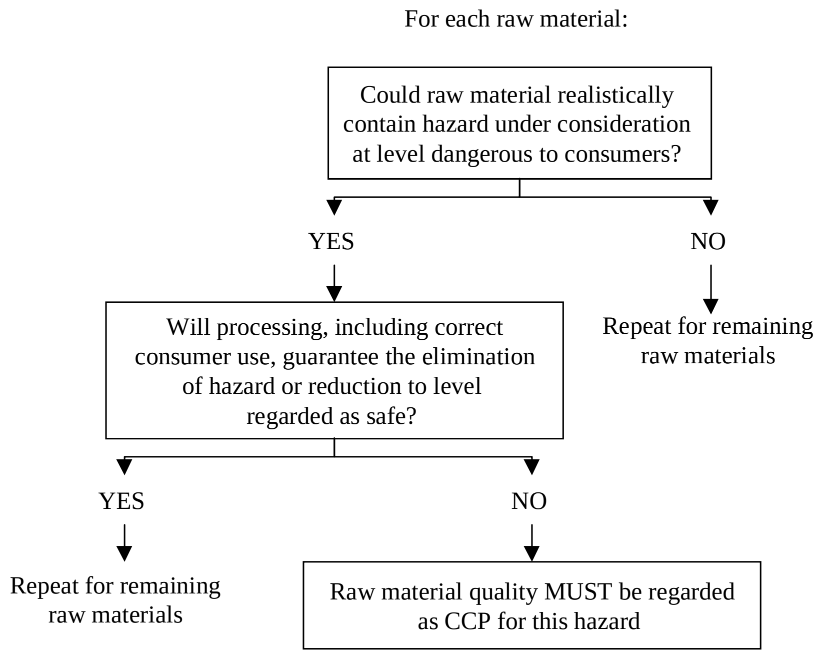


Figure 4a: CCP Decision Tree for Raw Materials as Developed by Mayes, 1992.

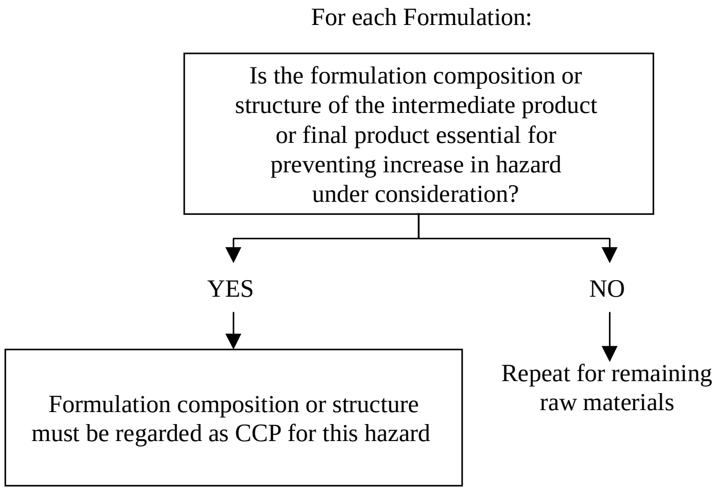


Figure 4b: CCP Decision Tree for Formulation as Developed by Mayes, 1992.

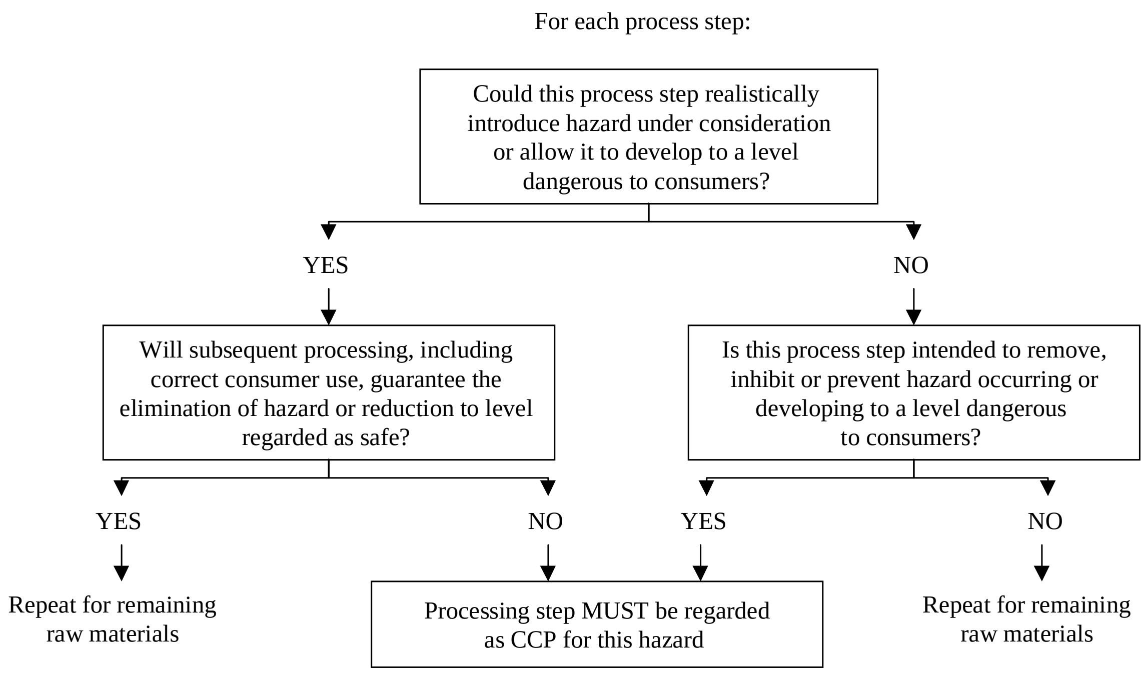
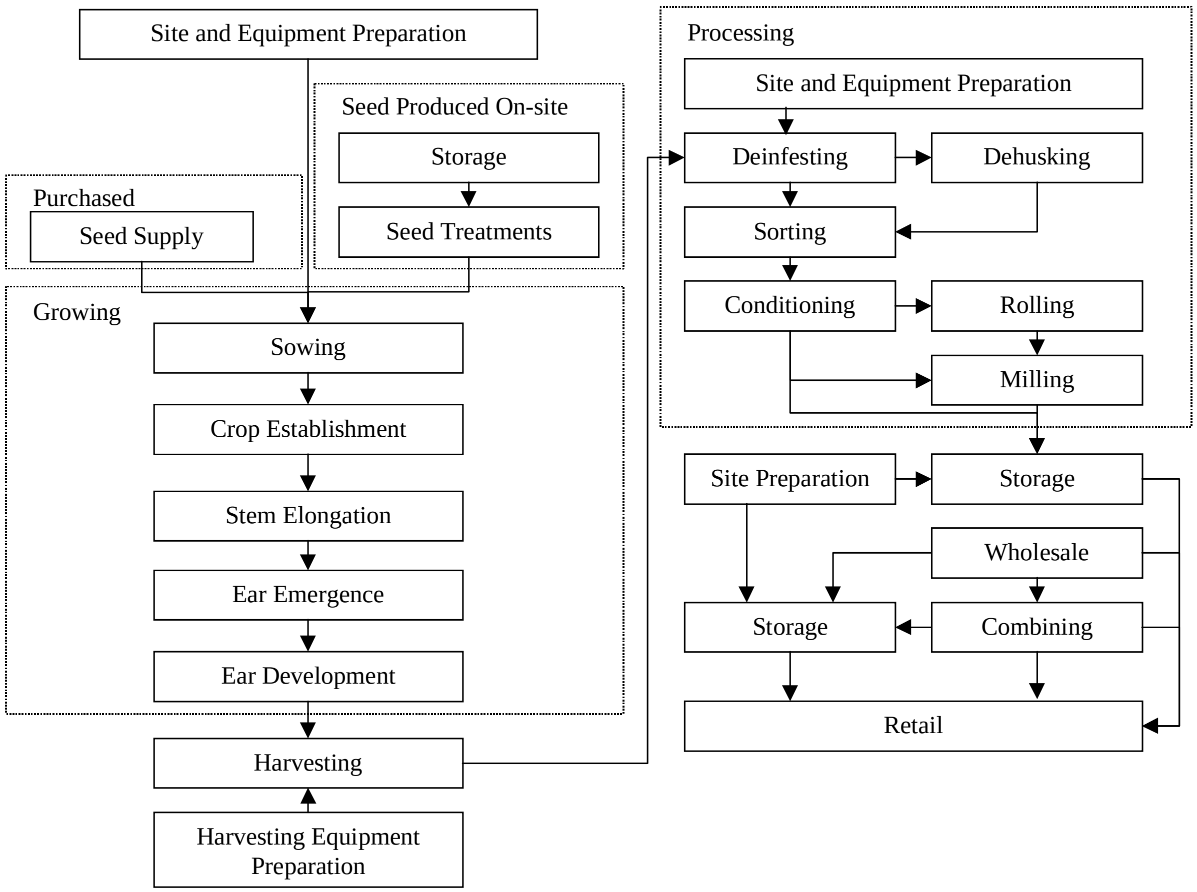


Figure 4c: CCP Decision Tree for Processing as Developed by Mayes, 1992.



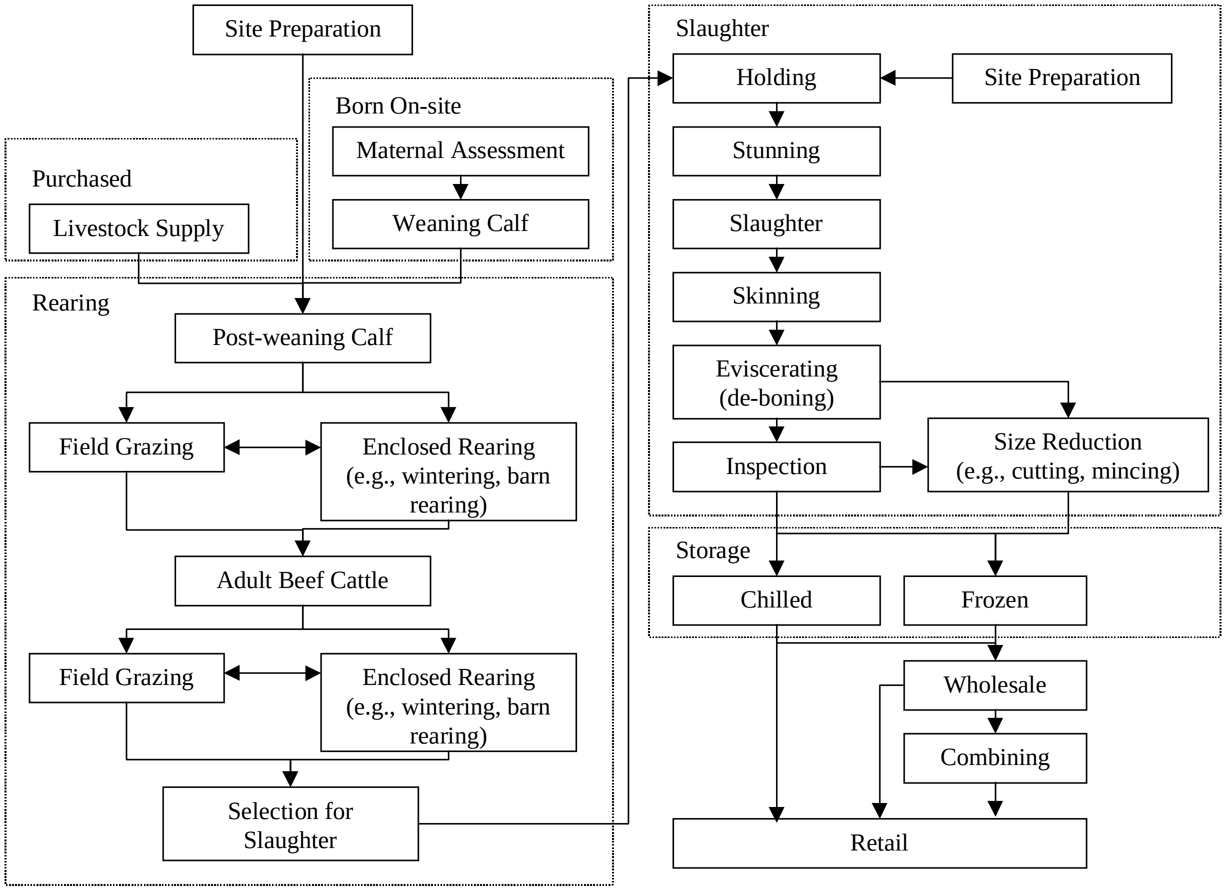
Flow Diagram G1: ‘Generic’ Flow Diagram for Crop Plant Production.

Table G1: Typical Hazard Controls for Crop Plant Production.

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
A	Contamination from background environment	Site assessment as part of assured scheme	Site classification as suitable for intended practice	Regulator approval, Routine reassessment	Review site classification Reassess site designation Document actions taken
B	Previous contaminant of seed stock	Seed produced according to accepted practices	Documentation (e.g., HACCP)	Site Documentation	Reassess herd husbandry Document actions taken
		Seed purchased from reputable suppler	Supplier approval, Seed certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
C	Contamination from field practices (e.g., sewage sludge application)	All field practices according to good working practices and all materials used suitable for their intended purpose	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Material certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
D	Excess residues of applied chemicals (also contamination by impurities in applied chemicals)	All applied chemicals purchased from reputable suppliers and applied according to good working practices	Supplier approval, Chemical certification	Supplier documentation	Review supplier status Review alternative chemicals Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
E	Field applications produced on-site previously contaminated (e.g., composts)	All field applications produced on-site according to accepted safe practices, using assured ingredients	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, ingredients certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken

Table G1: Continued…

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
F	Contamination from water supply	Assure water supply	Use assured water supply (Domestic and river water supplies)	Local Water Authorities and/or Environment Agency documentation	Review supplier status Review alternative water supplies Document actions taken
G	Contamination from site equipment	Ensure all equipment properly maintained	Maintenance programme, GAP, SOPs	Maintenance records	Review maintenance procedures Review workforce training Review alternative procedures Document action taken
H	Excess residues from site chemicals (e.g., sanitisers, detergents, disinfectants)	All site chemicals purchased from reputable suppliers and applied according to instructions	Supplier approval, Chemical certification	Supplier documentation	Review supplier status Review alternative chemicals Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
I	Contamination risk associated with processing step	All processing practices according to good working practices and all ingredients, applied chemicals, process chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Material certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
J	Contamination risk associated with packaging	All packaging materials and practices according to good working practices and all ingredients, applied chemicals, process chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Material certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
K	Contamination of ingredient, intermediate or finished product.	Analytical monitoring	Maximum acceptable residue level or ‘zero tolerance’	Analytical report	Review procedures Review relevant supplier status Review relevant alternative suppliers Document actions taken



Flow Diagram G2: 'Generic' Flow Diagram for Raw Beef Production.

Table G2: Typical Hazard Controls for Raw Beef Production.

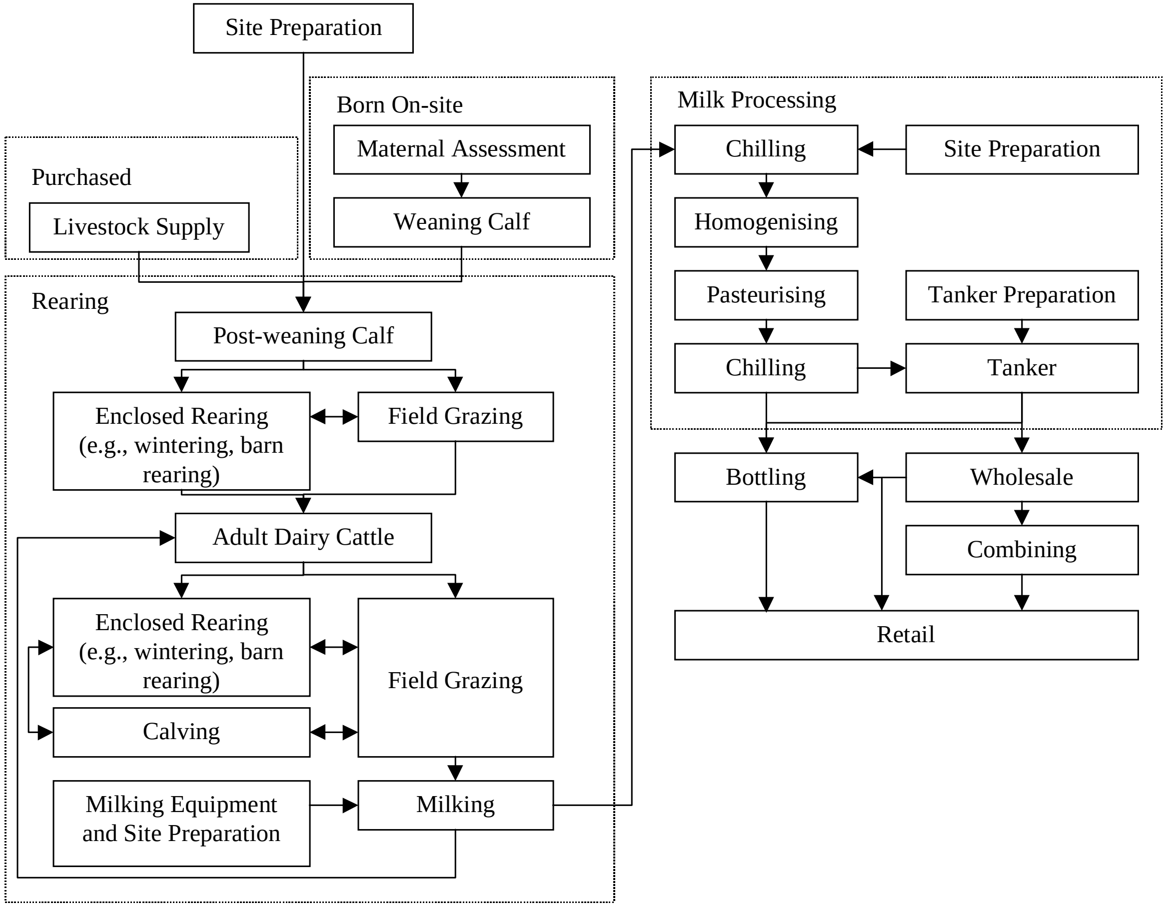
Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
A	Contamination from background environment	Site assessment as part of assured scheme	Site classification as suitable for intended practice	Regulator approval, Routine reassessment	Review site classification Reassess site designation Document actions taken
B	Transfer of contaminant body burden from (maternal) parent	Parents bred according to accepted practices	Documentation (e.g., HACCP)	Site Documentation	Reassess herd husbandry Document actions taken
		Parents purchased from reputable suppler	Supplier approval, Livestock certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
C	Purchased livestock previously contaminated	Livestock purchased from reputable suppler	Livestock produced according to assured practice	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
			Supplier approval, Livestock certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
D	Purchased Feedstuffs previously contaminated	All purchased feedstuffs purchased from reputable suppliers and used according to instructions	Supplier approval, Feedstuffs certification	Supplier documentation	Review supplier status Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review workforce training Document actions taken
E	Feedstuffs produced on-site previously contaminated (e.g., silage, grain)	All feedstuffs produced on-site according to accepted safe practices, using assured ingredients	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, ingredients certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
F	Contamination from water supply	Assure water supply	Use assured water supply (Domestic and river water supplies)	Local Water Authorities and/or Environment Agency documentation	Review supplier status Review alternative water supplies Document actions taken

Table G2: Continued…

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
G	Excess residues of applied chemicals (also contamination by impurities in applied chemicals)	All applied chemicals purchased from reputable suppliers and applied according to good working practices	Supplier approval, Chemical certification	Supplier documentation	Review supplier status Review alternative chemicals Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
H	Contamination from site equipment	Ensure all equipment properly maintained	Maintenance programme, GAP, SOPs	Maintenance records	Review maintenance procedures Review workforce training Review alternative maintenance procedures Document action taken
I	Excess residues from site chemicals (e.g., sanitisers, detergents, disinfectants)	All site chemicals purchased from reputable suppliers and applied according to instructions	Supplier approval, Chemical certification	Supplier documentation	Review supplier status Review alternative chemicals Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
J	Contamination from field practices (e.g., sewage sludge application)	All field practices according to good working practices and all materials used suitable for their intended purpose	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Material certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
K	Contamination of animal selected for slaughter	Any evidence (outside standard HACCP procedure) that animal selected for slaughter may not be suitable for intended purpose	Animal (or herd) classification as suitable for slaughter	Regulator approval, Routine reassessment	Review site classification Reassess site designation Document actions taken

Table G2: Continued….

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
L	Contamination risk associated with processing step	All processing practices according to good working practices and all ingredients, applied chemicals, process chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs Supplier approval, Material certifications	Site documentation Supplier documentation	Review procedures Review workforce training Document actions taken Review supplier status Review alternative suppliers Document actions taken
M	Contamination risk associated with packaging	All packaging materials and practices according to good working practices and all ingredients, applied chemicals, process chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs Supplier approval, Material certification	Site documentation Supplier documentation	Review procedures Review workforce training Document actions taken Review supplier status Review alternative suppliers Document actions taken
N	Contamination of ingredient, intermediate or finished product.	Analytical monitoring	Maximum acceptable residue level or 'zero tolerance'	Analytical report	Review procedures Review relevant supplier status Review relevant alternative suppliers Document actions taken



Flow Diagram G3: 'Generic' Flow Diagram for Milk Production.

Table G3: Typical Hazard Controls for Milk Production.

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
A	Contamination from background environment	Site assessment as part of assured scheme	Site classification as suitable for intended practice	Regulator approval, Routine reassessment	Review site classification Reassess site designation Document actions taken
B	Transfer of contaminant body burden from (maternal) parent	Parents bred according to accepted practices	Documentation (e.g., HACCP)	Site Documentation	Reassess herd husbandry Document actions taken
		Parents purchased from reputable suppler	Supplier approval, Livestock certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
C	Purchased livestock previously contaminated	Livestock purchased from reputable suppler	Livestock produced according to assured practice	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
			Supplier approval, Livestock certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
D	Purchased feedstuffs previously contaminated	All purchased feedstuffs purchased from reputable suppliers and used according to instructions	Supplier approval, Feedstuffs certification	Supplier documentation	Review supplier status Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review workforce training Document actions taken
E	Feedstuffs produced on-site previously contaminated (e.g., silage, grain)	All feedstuffs produced on-site according to accepted safe practices, using assured ingredients	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, ingredients certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
F	Contamination from water supply	Assure water supply	Use assured water supply (Domestic and river water supplies)	Local Water Authorities and/or Environment Agency documentation	Review supplier status Review alternative water supplies Document actions taken

Table G3: Continued….

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
G	Excess residues of applied chemicals (also contamination by impurities in applied chemicals)	All applied chemicals purchased from reputable suppliers and applied according to good working practices	Supplier approval, Chemical certification	Supplier documentation	Review supplier status Review alternative chemicals Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
H	Contamination from site equipment	Ensure all equipment properly maintained	Maintenance programme, GAP, SOPs	Maintenance records	Review maintenance procedures Review workforce training Review alternative maintenance procedures Document action taken
I	Excess residues from site chemicals (e.g., sanitisers, detergents, disinfectants)	All site chemicals purchased from reputable suppliers and applied according to instructions	Supplier approval, Chemical certification	Supplier documentation	Review supplier status Review alternative chemicals Review alternative suppliers
			Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
J	Contamination from field practices (e.g., sewage sludge application)	All field practices according to good working practices and all chemicals and materials used suitable for their intended purpose	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Relevant certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
K	Contamination risk associated with calving (also potential contamination reduction step via transfer to offspring)	All calving practices according to good working practices and all feedstuffs, applied chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Relevant certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken

Table G3: Continued….

Control	Hazard	Control Measure(s)	Critical Limit(s)	Monitoring	Corrective Action(s)
L	Transfer of contaminant body burden to milk	All milking practices according to good working practices and all chemicals and materials used suitable for their intended purpose	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Relevant certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
M	Contamination risk associated with processing step	All processing practices according to good working practices and all ingredients, applied chemicals, process chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Relevant certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
N	Contamination risk associated with packaging	All packaging materials and practices according to good working practices and all ingredients, applied chemicals, process chemicals and materials used suitable for their intended purposes.	Adherence to GAP, SOPs	Site documentation	Review procedures Review workforce training Document actions taken
			Supplier approval, Material certification	Supplier documentation	Review supplier status Review alternative suppliers Document actions taken
O	Contamination of ingredient, intermediate or finished product.	Analytical monitoring	Maximum acceptable residue level or 'zero tolerance'	Analytical report	Review procedures Review relevant supplier status Review relevant alternative suppliers Document actions taken