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Good practices for the feed sector

Implementing the Codex Alimentarius Code of Practice
on Good Animal Feeding

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Foreword

In the last decades, the rapidly growing world population, along with higher urbanization and changes in lifestyle and eating habits, have increased the consumption of food of animal origin. The trend has been particularly significant in many emerging economies, where increasing per capita income has led to higher consumption of animal proteins. The higher demand of livestock products has been met mainly through the intensification of production systems and a shift towards poultry and swine production. Both of which are associated with an increased use of animal feed and represent a daunting challenge in some production environments.

The challenge has not only been to meet the growing demand for feed, but also to ensure its safety. Feed safety is a key element in the sustainable production of food of animal origin: it is a prerequisite for food safety and human health, as well as a necessity for animal health and welfare; it is a component of access to trade, income generation and economic sustainability. In fact, feed is an integral part of the food chain and its safety has been recognized as a shared value and a shared responsibility.

FAO is committed to assist countries to comply with the Codex Alimentarius requirements, including those addressing feed safety, and assigns high priority to related good agricultural and production practices. Their application relies on the commitment and involvement of farmers, manufacturers and all other stakeholders in the feed sector. For this reason, close collaboration between private sector and intergovernmental organizations such as FAO in this endeavour is key for achieving the desired impact.

Especially in the current troubled times, collaboration at the international level with the private sector is more important than ever to ensure feed and food safety, food security and high-quality nutrition, and in so doing improving the general welfare of people around the world. Industry and intergovernmental organizations, such as FAO, must work together to ensure that both national markets and international trade continue to be fair, transparent, inclusive and reliable sources of food supply. In particular, together, we must combine our efforts to avoid food of animal origin value-chains being subject to disruptions by sanitary emergencies that link the animal and human sphere and that have profound consequences for global populations, such as the COVID-19 pandemic.



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The International Feed Industry Federation (IFIF) represents the global feed industry as an essential participant in the food chain that provides sustainable, safe, nutritious and affordable food for a growing world population. IFIF aims to stimulate the adoption and application of international standards to increase feed safety and believes that only by working together with all stakeholders in the feed and food chain we can safely and sustainably meet the demands of more and better food.

More specifically, the partnership between FAO and IFIF, which resulted in the production of the Manual of Good Practices for the Feed Industry, has been instrumental for achieving these objectives. The manual, since its first release in 2010, has been a very valuable tool to increase knowledge and improve feed safety at the production level, and is widely recognized and used in many countries around the world. The manual was initially supported by the Standards and Trade Development Facility of FAO, the World Organisation for Animal Health, the World Bank Group, the World Health Organization and the World Trade Organization. The undertaking was certainly no small task, but through the years it proved to be a worthy endeavour embraced and well supported by feed sector stakeholders.

This second publication is a fully revised, updated and expanded version of that manual and addresses recent developments in feed production and benefits from latest scientific and technical knowledge. While addressing feed and its safety, this revised manual supports the well-functioning of the livestock product value chains. In applying the One Health approach, it aims at contributing to ensure the production and availability of safe, nutritious and diversified food of animal origin for all, while respecting the environment and the welfare of the animals we care for. It especially addresses on-farm feed production at smaller and medium scales, to ensure that the expanding livestock sector can be of benefit for farmers more in need. The manual recognizes also some newer global concerns, such as the containment of antimicrobial resistance and shows the contribution of feed safety.

Both FAO and IFIF hope this manual will meet the expectation of a constantly evolving sector and will continue being an essential tool to support producers living up to their roles and responsibilities to ensure sustainable food production and feed a growing world population.



Daniel Bercovici
Chairman (2018–2021)

International Feed Industry Federation (IFIF)

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Abbreviations and acronyms

aw	Water activity	PCBs	Polychlorinated biphenyls
AMR	Antimicrobial resistance	dl-PCBs	Dioxin-like polychlorinated biphenyls
BSE	Bovine spongiform encephalopathy	OIE	World Organisation for Animal Health
DDGS	Distiller's dried grains with solubles	PA	Pyrrolizidine alkaloids
DON	Deoxynivalenol	PAH	Polycyclic aromatic hydrocarbons
EHEC	Enterohemorrhagic <i>Escherichia coli</i>	PCDDs	Polychlorinated dibenzo-p-dioxins
FAO	Food and Agriculture Organization of the United Nations	PCDFs	Polychlorinated dibenzofurans
GAP	Good agricultural practices	PEDV	Porcine epidemic diarrhoea
GHP	Good hygienic practices	POPs	Persistent organic pollutants
GHbP	Good husbandry practices	SOPs	Standard operational procedures
GMP	Good manufacturing practices	SRM	Specific risk material
GVP	Good veterinary practices	STEC	Shiga-toxin producing <i>Escherichia coli</i>
HACCP	Hazard analysis and critical control point	TSE	Transmissible spongiform encephalopathy
IARC	International Agency for Research on Cancer	WDG	Wet distiller's grain
ICP	Inductively coupled plasma	WGS	Whole genome sequencing
ISO	International Standardization Organization	WHO	World Health Organization
OC	Organochlorines	ZEN	Zearalenone

Glossary

Acceptable level

A level of hazard in a food at or below which the food is considered to be safe according to its intended use.

Ambient temperature

The temperature of fluid or gas (usually air) that surrounds objects on all sides.

Antimicrobial agent

Any substance of natural, semi-synthetic, or synthetic origin that at in vivo concentrations kills or inhibits the growth of microorganisms by interacting with a specific target (FAO, WHO, 2011a).

Antimicrobial resistance (AMR)

The ability of a microorganism to multiply or persist in the presence of an increased level of an antimicrobial agent relative to the susceptible counterpart of the same species (FAO, WHO, 2011a).

Antioxidant

Substance prolonging the storage life of feed and feed ingredients by protecting them against deterioration caused by oxidation (ISO, 2019a).

Applicant

A producer or processor seeking certification against a standard for the production and supply of feed ingredients intended for feeding to farm or companion animals.

Aspirate (to)

To remove chaff, dust, or other light materials by use of air.

Attrition

Reduction of particle size by friction, rubbing, or wearing away.

Baffle

Any type of plate or sheet used to direct the flow of product or air within a process system.

Balanced

A term describing a feed, diet, or ration that contains all known required nutrients in proper amounts and proportions based upon recommendations of recognized authorities in animal nutrition for a given set of physiological requirements and environmental conditions.

Base mix

Similar to a supplement but containing only part of the animal's protein requirements, so must be used with high protein ingredients and grain.

Biscuit

A hard or crisp, dry, baked product.

Blend (to)

To mingle or combine two or more ingredients or feed, but not necessarily to achieve uniform dispersion (ISO, 2019a).

Block (to)

To agglomerate individual ingredients or mixtures into a large mass; the product of this process: agglomerated feed compressed or chemically hardened into a solid mass cohesive enough to hold its form and weighing over one kilo (approximately two pounds) and may weigh from 7kg to 240kg (15 to 500lbs).

Bran

Milling fraction obtained from the removal of the outer layer of cereals (ISO, 2019a).

Brick

Agglomerated feed compressed into a solid mass cohesive enough to hold its form and weighing less than one kilo (approximately two pounds).

Buffer

Substance used in feed to help resist changes in the acidity of the digestive tract (ISO, 2019a).

By-product

A secondary product produced in addition to the principal product (also see co-product).

Cake

A mass resulting from the pressing of seeds, meat, or fish to remove oils, fats, or other liquids, accumulation of dust on a filter or other equipment.

Calibration

The demonstration that a particular instrument or device produces results within specified limits by comparison with those produced by a reference or traceable standard over an appropriate range of measurements.

Can (to)

To process, package, seal, and sterilize a feed for preservation in cans or similar containers.

Carrier

An edible material to which feed ingredients are added (absorbed, impregnated, or coated) to facilitate their uniform distribution in feed.

Carryover

Contamination of a material or product with another material or product that originates from previous use of equipment.

Chaf

Hulls or other seed coverings, together with other plant parts separated from seeds during threshing or processing.

Check (to)

Monitoring and measuring of processes and products against policies, objectives and requirements for the product, with the reporting of results.

Chelated mineral

Organic mineral complex formed between an organic molecule and a mineral (ISO, 2019a).

Chip (to)

To cut or break into fragments or small thin slices (ISO, 2019a).

Chop (to)

To reduce particle size by cutting with knives or other sharp-edged instruments (ISO, 2019a).

Clean (to)

To remove materials by any method.

Cleaning

The removal of soil, feed residues, dirt, grease or other objectionable matter (FAO, WHO, 2003).

Clip (to)

To remove the ends of whole grain (ISO, 2019a).

Code of practice

It identifies the essential principles of feed hygiene to ensure the safety of feed for animals and their suitability for animal products for human consumption.

Combustion

A chemical process that usually is rapid and produces heat.

Commercial feed

All materials that are sold and distributed as feed, or to be mixed with feed, for animals except: unmixed seed, whole, processed, or unprocessed; straw, stover, silage, cobs, husks, and hulls; or individual chemical compounds not mixed with other ingredients.

Competent authority

The official authority charged by the government with the official control/surveillance of feed/food hygiene and safety, including setting and enforcing regulatory feed/food hygiene and safety requirements.

Complementary feed

Compound feed that has a high content of certain substances, but it is not sufficient for a ration and so is used in combination with other feed (ISO, 2019a).

Complete feed

A nutritionally adequate feed compounded by a specific formula to be fed as the sole ration and capable of maintaining life and/or promoting production without any additional substance except water.

Compound feed

Mixture of at least two feed ingredients whether or not containing feed additives, for oral animal feeding in the form of a complementary feed or complete feed (ISO, 2019a).

Concentrate

A feed used with another to improve the nutritive balance of the total and intended to be diluted or mixed to produce a supplement or a complete feed; may be unsafe if fed free choice or alone as a supplement.

Condensation

The conversion of a substance (for example, water) from a vapor state to a denser liquid state, usually initiated by a drop in temperature.

Condense (to)

To reduce a material to a dense form by removing moisture.

Condition (to)

To achieve predetermined moisture levels and/ or temperature of ingredients or a mixture of ingredients prior to further processing.

Contaminant

Any substance not intentionally added to food or feed for food producing animals, which is present in such food or feed as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or feed, or as a result of environmental contamination. The term does not include insect fragments, rodent hairs and other extraneous matter (FAO, WHO, 2019a).

Contamination

The introduction or occurrence of a contaminant in feed or food or the feed or food environment.

Control

- when used as a noun: The state wherein correct procedures are being followed and any established criteria are being met.
- when used as a verb: To take all necessary actions to ensure and maintain compliance with established criteria established in the HACCP plan (FAO, WHO, 2003).

Control measure

Any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level (FAO, WHO, 2003).

Convection

The transfer of heat via a circulatory motion in a fluid occurring at non-uniform temperature caused by variations in density and the action of gravity.

Cook (to)

To heat in the presence of moisture to alter chemical and/or physical characteristics or to sterilize.

Cool (to)

To reduce temperature by air movement, usually accompanied by a simultaneous drying action.

Corrective action

Any action taken when a deviation occurs in order to re-establish control, segregate and determine the disposition of the affected product if any and prevent or minimize recurrence of the deviation.

Crack (to)

To reduce particle size by a combined breaking and crushing action.

Crimp (to)

To roll with corrugated rollers, possibly involving conditioning and cooling.

Critical control point (CCP)

A step at which a control measure or control measures, essential to control a significant hazard, is/are applied in a HACCP system.

Critical limit

A criterion, observable or measurable, relating to a control measure at a CCP which separates acceptability from unacceptability of the feed or food.

Cross-contamination

Contamination of a material or product with another material or product, including contamination originating from the previous use of equipment (FAO, WHO, 2013b).

Crumble (to)

To reduce pellets to granular form.

Crumbles

Pelleted feed reduced to granular form.

Crush (to)

See 'roll'.

Cube

See 'pellet'.

Cube, range

See 'pellet' and 'range cube'.

Cut

See 'chop'.

Damper

A valve for controlling airflow.

Degree day

18.31°C (65 degrees Fahrenheit) minus the mean temperature of the day.

Dehull (to)

To remove the outer covering from grain or seeds (ISO, 2019a).

Dehydrate (to)

To remove moisture by heat.

Density

The ratio of the mass of a substance to its volume or the mass of a unit volume of a substance

Density factor

The ratio of actual air density to density of standard air.

Deviation

Failure to meet a critical limit or to follow a good hygienic practice procedure.

Diet

A feed ingredient or mixture of ingredients, including water, which is intended for consumption by animals.

Diluent

An edible substance mixed with nutrients and/ or additives to reduce their concentration and make them more acceptable to animals, safer, and easier to mix uniformly in a feed also, may be a carrier.

Distiller's grain

Residual grain or by-product of a fermentation process in alcohol production from grains, which may be fed wet or dry (ISO, 2019a).

Dress (to)

To make uniform in texture by breaking or screening of lumps from feed and/or the application of water or other liquid.

Dry (to)

To remove water or liquids from materials.

Dust

Small solid particles created by the breaking up of larger particles through processes such as crushing or grinding; to sprinkle with fine particles.

Emulsifier

Substance that makes it possible to form or maintain a homogeneous mixture of two or more immiscible phases in feed (ISO, 2019a).

Evaporate (to)

To reduce moisture in a material and reduce it to a denser form.

Expand (to)

To subject a feed or ingredients to moisture, pressure, and temperature that gelatinize the starch portion and then to increase the volume by abrupt reduction in pressure (ISO, 2019a).

Exposure assessment

The qualitative and/or quantitative evaluation of the likely human intake of biological, chemical, and physical agents via food as well as exposures from other sources if relevant. In the Codex Alimentarius Guidelines on the Application of Risk Assessment for Feed it may also refer to the consideration of the exposure of a food producing animal to a hazard and to an evaluation of the likely amount of a hazard in feed that can transfer to an edible product (FAO, WHO, 2013a).

Extract (to)

To remove fat or oil from materials by heat and mechanical pressure or by solvents.

Extraneous maximum residue limit (EMRL)

Extraneous Maximum Residue Limit (EMRL) refers to a pesticide residue or a contaminant arising from environmental sources due to former agricultural uses not from the use of a pesticide or contaminant directly or indirectly on the food or feed. It is the maximum concentration of a pesticide residue that is recommended by the Codex Alimentarius Commission to be legally permitted or recognized as acceptable in or on a food or animal feed. The concentration is expressed in milligrams of pesticide residue or contaminant per kilogram of the commodity (FAO, WHO, 2019a).

Extrude (to)

To press or push feed through constrictions under pressure (ISO, 2019a).

Fan

A radial-flow or axial-flow device used to move air.

Feed

Any single or multiple materials, whether processed, semi-processed or raw, which is intended to be fed directly to food producing animals (FAO, WHO, 2008a).

Feed additive

Any intentionally added ingredient not normally consumed as feed by itself, whether or not it has nutritional value, which affects the characteristics of feed or animal products. Micro-organisms, enzymes, acidity regulators, trace elements, vitamins and other products fall within the scope of this definition depending on the purpose of use and method of administration (FAO, WHO, 2008a).

Feed grade

Quality of feed suitable for animal consumption (ISO, 2019a).

Feed ingredient

A component part or constituent of any combination or mixture making up a feed, whether or not it has a nutritional value in the animal's diet, including feed additives. Ingredients are of plant, animal or aquatic origin, or other organic or inorganic substances (FAO, WHO, 2008a).

Feed mixture

See 'formula feed'.

Feed safety

Assurance that feed, administered according to its intended use, will not cause adverse health effects to the animals or to food of animal origin.

Fish meal

Product obtained by drying and processing whole fish or parts thereof, of one or various species (ISO, 2019a).

Fines

Any material that will pass through a screen whose openings are immediately smaller than the specified minimum size of crumbles or minimum diameter of pellets.

Flake (to)

See 'roll (to)'.

Flakes

Flat pieces resulting from rolling or cutting an ingredient with or without steam conditioning.

Flour

Soft, finely ground meal obtained from the feedmilling of cereal grains, other seeds, or products and consisting essentially of the starch and gluten of endosperm.

Flow diagram

A systematic representation of the sequence of steps used in the production or manufacture of feed.

Fodder

Plants or plant parts other than separated grains that are fed to or grazed by animals (ISO, 2019a).

Food

Means any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum, and any substance which has been used in the manufacture, preparation or treatment of "food" but does not include cosmetics or tobacco or substances used only as drugs (FAO, WHO, 2019a).

Food safety

Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (FAO, WHO, 2003).

Formula feed

A combination of two or more ingredients with or without additives proportioned, mixed, and processed according to specifications.

Free choice

A feeding system by which animals are given unlimited access to the separate components or groups of components constituting their diets.

Gas

A formless vapour that tends to occupy an entire space uniformly at ordinary temperatures and pressures.

Gelatinize (to)

To rupture starch granules by a combination of moisture, heat, and pressure or by mechanical shear (ISO, 2019a).

Good agricultural practices (GAP)

Collection of principles to apply for on-farm production and postproduction processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability.

Good agricultural practice in the use of pesticides

Includes the nationally authorized safe uses of pesticides under actual conditions necessary for effective and reliable pest control. It encompasses a range of levels of pesticide applications up to the highest authorized use, applied in a manner which leaves a residue which is the smallest amount practicable.

Authorized safe uses are determined at the national level and include nationally registered or recommended uses, which take into account public and occupational health and environmental safety considerations.

Actual conditions include any stage in the production, storage, transport, distribution and processing of food commodities and animal feed (FAO, WHO, 2019a).

Good hygiene practices (GHP)

Fundamental measures and conditions applied at any step within the food chain to provide safe and suitable feed or food.

Good manufacturing practices (GMP)

A series of procedures in a branch or sector in which the standard of conduct is laid down (often with respect to hygiene and safety).

Good practice in the use of veterinary drugs

The official recommended or authorized usage including withdrawal periods, approved by national authorities, of veterinary drugs under practical conditions (FAO, WHO, 2019a).

Grain

Seed from cereal plants.

Grind (to)

To reduce particle size using a hammer mill or roller feed-mill.

Grits

Coarsely ground grain from which barn and germ have been removed and that is usually screened to uniform particle size (ISO, 2019a).

Groats

Grain from which hulls have been removed (ISO, 2019a).

HACCP plan

Documentation or set of documents, prepared in accordance with the principles of HACCP to ensure control of significant hazards in the feed and food business.

HACCP system

The development of a HACCP plan and the implementation of the procedures in accordance with that plan.

Hay

Aerial portion of grass or herbage especially cut, air dried and cured for animal feeding (ISO, 2019a).

Haylage

Silage made from forages that are partially dried (ISO, 2019a).

Hazard

A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard analysis

The process of collecting and evaluating information on hazards identified in raw materials and other ingredients, the environment, in the process or in the feed or food, and conditions leading to their presence to decide whether or not these are significant hazards.

Hazard characterization

The qualitative and/or quantitative evaluation of the nature of the adverse health effects associated with biological, chemical and physical agents, which may be present in food (FAO,WHO 2019a).

Hazard identification

The identification of biological, chemical, and physical agents capable of causing adverse health effects and which may be present in a particular feed or food or group of feeds and foods (FAO, WHO, 2019a).

Heat-process (to)

To subject to a method of preparation involving the use of high temperatures.

Homogenize (to)

To break down particles into evenly distributed globules small enough to remain emulsified.

Homogeneity

Homogeneity describes the evenness of distribution of a feed ingredient within a mixture of several feed ingredients (German Ministry of Food and Agriculture, 2017).

Hull

Outer covering of grain or other seed (ISO, 2019a).

Humidity, absolute

The mass of water vapor per unit volume, grammes per cubic centimeter (or pounds per cubic foot).

Humidity, relative

The ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.

Hydrolyze (to)

To split complex molecules into simple units by a chemical reaction with water.

Kibble (to)

To crack or crush bake or extruded feed that has been cooked prior to or during the extrusion process.

Macro mineral

Mineral required by animals in relatively large amounts (ISO, 2019a).

Mash

A mixture of ingredients in meal form.

Maximum level for contaminants (ML)

The maximum concentration of that substance recommended by the Codex Alimentarius Commission to be legally permitted in that commodity (FAO, WHO, 2019a).

Maximum limit for pesticide residues (MRL)

The maximum concentration of a pesticide residue (expressed as mg/kg) recommended by the Codex Alimentarius Commission to be legally permitted in or on food commodities and animal feeds. MRLs are based on good agricultural practices (GAP) data, and foods derived from commodities that comply with the respective MRLs are intended to be toxicologically acceptable (FAO, WHO, 2019a).

Maximum limit for residues of veterinary drugs (MRL)

The maximum concentration of residue resulting from the use of a veterinary drug (expressed in mg/kg or µg/kg on a fresh weight basis) that is recommended by the Codex Alimentarius Commission to be legally permitted or recognized as acceptable in or on a food. It is based on the type and amount of residue considered to be without any toxicological hazard for human health as expressed by the Acceptable Daily Intake (ADI), or on the basis of a temporary ADI that utilizes an additional safety factor. It also takes into account other relevant public health risks as well as food technological aspects (FAO, WHO, 2019a).

Meal

An ingredient that has been ground or otherwise reduced in particle size.

Medicated feed

Any feed which contains veterinary drugs as defined in the Codex Alimentarius Commission Procedural Manual (FAO, WHO, 2008a).

Micro-ingredients

Vitamins, minerals, antibiotics, veterinary drugs and other materials usually required in feed in small amounts as feed additives.

Mill run

The state in which a material comes from the feedmill ungraded and usually uninspected.

Mix (to)

To combine two or more materials with or without feed additives by agitation to a specific degree of dispersion.

Monitor

The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is under control (FAO, WHO, 2003).

Pallet

A portable platform used for storage or moving of materials and packages.

Palletize (to)

To place material on a pallet for storage or to transport by means of a pallet.

Pearl (to)

To reduce dehulled grain into smooth particles by machine brushing or abrasion (ISO, 2019a).

Pellet (to)

To agglomerate feed by compacting and forcing it through die openings by a mechanical process; the product resulting from this process (hard pellet).

Pellet, soft

A pellet containing a large percentage of liquids and requiring immediate dusting and cooling.

Pesticide

Any substance intended for preventing, destroying, attracting, repelling, or controlling any pest including unwanted species of plants or animals during the production, storage, transport, distribution and processing of food, agricultural commodities, or animal feeds or which may be administered to animals for the control of ectoparasites. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant, fruit thinning agent, or sprouting inhibitor and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. The term normally excludes fertilizers, plant and animal nutrients, food additives, and animal drugs (FAO, WHO, 2019a).

pH

A term that expresses the intensity of the acidic or alkaline condition of a material.

Pop (to)

To expand whole or cracked grain by heat, sometimes under pressure.

Premixture

A uniform mixture of one or more micro-ingredients/additives with a diluent and/ or carrier to facilitate their even distribution in a larger mix.

Prerequisite programme

Programmes including good hygiene practices, good agricultural practices and good manufacturing practices, as well as other practices and procedures such as training and traceability, that establish the basic environmental and operating conditions that set the foundation for implementation of a HACCP system.

Preservative

Substance or, when applicable, microorganism that protects feed against deterioration caused by micro-organisms or their metabolites (ISO, 2019a).

Press (to)

To compact or mould by pressure; to extract fat, oil, or juice under pressure.

Primary feed

A feed formulated from single ingredients, sometimes containing a feed additive or premixture (less than less than 45.5 kg per ton or 100 pounds per ton).

Primary production

Those steps in the food chain up to and including storage and, where appropriate, transport of outputs of farming. This would include growing crops, raising fish and animals, and the harvesting of plants, animals or animal products from a farm or their natural habitat.

Processing aid

Any substance not consumed as a feed by itself, intentionally used in the processing of feed or feed ingredients to fulfil a technological purpose during treatment or processing which may result in the unintentional but technologically unavoidable presence of residues of the substance or its derivatives in the final product, provided that these residues do not have an adverse effect on animal health, human health or the environment and do not have any technological effects on the finished feed.

Product

A material produced from one or more other materials as a result of biological, chemical, or physical change.

Production

All operations such as receipt of materials, production, packaging, repackaging, labelling, relabelling, control, release, storage and distribution of feed ingredients, feed and medicated feed.

Protein

Any of a large class of naturally occurring complex combinations of amino acids.

Puff (to)

To expand whole, cracked, or processed grain by pressure and heating (ISO, 2019a).

Pulverize

See 'grind'.

Quality assurance (QA)

All planned and systematic activities implemented within a quality system to provide adequate confidence that an entity will fulfil quality requirements.

Quality assurance (QA) system

The organizational structure, procedures, processes and resources needed to implement quality assurance.

Quality control

A system based upon sampling and testing, with the intention of ensuring compliance with specification and identifying non-conforming products.

Radiation

The emission of radiant energy (heat) in the form of waves.

Range cube

A large pellet designed to be offered to animals on the ground.

Ration

The amount of total feed that is provided to one animal over a 24-hour period (ISO, 2019a).

Record

Document stating results achieved or providing evidence of activities performed.

Residues of pesticides

Means any specified substance in food, agricultural commodities, or animal feed resulting from the use of a pesticide. The term includes any derivatives of a pesticide, such as conversion products, metabolites, reaction products, and impurities considered to be of toxicological significance (FAO, WHO, 2019a).

Residues of veterinary drugs

Include the parent compounds and/or their metabolites in any edible portion of the animal product and include residues of associated impurities of the veterinary drug concerned (FAO, WHO, 2019a).

Returns

Feed, medicated feed or premixtures generated either during the production process, or subsequently, that are suitable for reworking. Returns originate from a variety of sources each with its special characteristics. They include: out of date stock (good housekeeping must keep this to a minimum in factories, stores, retail premises and on farm), non-conforming feed (e.g. starting up problems, poor texture, deterioration in plant and on farm, errors in ordering or dissatisfaction), sieving on plant processing, where applicable, or at bulk loading of textured feed, flushing and cleaning (resulting from plant scouring and change-over), broken bags and spillage.

Note: A distinction must be made between internal returns that are products which have not left the site, from external returns.

Risk

A function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food. In these guidelines, it may also refer to the probability that a hazard in feed eaten by a food producing animal will transfer to an edible product at a level which may cause an adverse health effect in humans (FAO, WHO, 2013a).

Risk analysis

A process consisting of three components: risk assessment, risk management and risk communication (FAO, WHO, 2019a).

Risk assessment

A scientifically based process consisting of the following steps: (i) hazard identification, (ii) hazard characterization, (iii) exposure assessment, and (iv) risk characterization (FAO, WHO, 2019a).

Risk assessment policy

Documented guidelines on the choice of options and associated judgements for their application at appropriate decision points in the risk assessment such that the scientific integrity of the process is maintained (FAO, WHO, 2019a).

Risk characterization

The qualitative and/or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization and exposure assessment (FAO, WHO, 2019a).

Risk communication

The interactive exchange of information and opinions throughout the risk analysis process concerning risk, risk-related factors and risk perceptions, among risk assessors, risk managers, consumers, industry, the academic community and other interested parties, including the explanation of risk assessment findings and the basis of risk management decisions (FAO, WHO, 2019a).

Risk estimate

The quantitative estimation of risk resulting from risk characterization (FAO, WHO, 2019a).

Risk management

The process, distinct from risk assessment, of weighing policy alternatives, in consultation with all interested parties, considering risk assessment and other factors relevant for the health protection of consumers and for the promotion of fair trade practices, and, if needed, selecting appropriate prevention and control options (FAO, WHO, 2019a).

Risk profile

The description of the food safety problem and its context (FAO, WHO, 2019a).

Roll (to)

To change the shape and/or size of particles by compressing them between rollers, sometimes involving conditioning (ISO, 2019a).

Scalp (to)

To remove larger materials by screening.

Scour

See 'clip'.

Scratch

Cleaned whole, cracked, or cut grain, usually in a mixture.

Screen (to)

To separate various-sized particles by passing over and/or through screens (ISO, 2019a).

Secondary feed

A feed manufactured by mixing supplements with other feed ingredients such as grain.

Self-fed

A feeding system in which animals have continuous free access to some or all components of a ration, either individually or as mixtures.

Separate (to)

To classify by particle size, shape, and/or density.

Separation, magnetic

The removal of ferrous materials by magnetic attraction.

Sift (to)

To pass materials through wire sieves to separate particles of different sizes (ISO, 2019a).

Significant hazard

A hazard identified by a hazard analysis, as reasonably likely to occur at an unacceptable level in the absence of control, and for which control is essential given the intended use of the feed or food.

Silage

Feed resulting from an anaerobic fermentation process of sugars in forage with a high moisture content that is preserved in a succulent condition (ISO, 2019a).

Silage additive

Substance, such as enzymes, microorganisms or chemicals, that is intended to be incorporated into forage to improve the production of silage.

Site

Factories / buildings sharing the same premises, under the same senior management control and involved in various stages of the same continuous process.

Solubles

Liquid containing dissolved substances obtained from processing animal or plant materials, sometimes also containing some fine suspended solids and may be dried.

Specific gravity

The mass of a liquid compared to water, which is assigned a value of 1.0.

Spray dehydrate

To dry materials by spraying them on the surface of a heated drum and then recovering them by scraping from the drum.

Standard air

Dry air at 21.11 degrees Celsius (70 degrees Fahrenheit) and 760 mmHg (torr) (29.92 inches) of mercury, generally equivalent to 1.2041 kg/ m³ (0.075 pounds per cubic foot) or 1013.25 millibars.

Standard atmosphere

The condition when air is at 1 atm and temperature is 20 degrees Celsius (68 degrees Fahrenheit).

Standard conditions

Temperature of 20-degree Celsius (68 degrees Fahrenheit) pressure of 101.325 kPa (14.696 psi) and relative humidity of 52 percent; used as a basis for air conditioning calculations.

Steam (to)

To treat ingredients with steam to alter physical and/or chemical properties (ISO, 2019a).

Step

A point, procedure, operation or stage in the food chain, including raw materials, from primary production to final consumption (FAO, WHO, 2003).

Supplement

A feed used with another to improve the nutritive balance of the ration and performance of the animal; can be fed undiluted, diluted and mixed to produce a complete feed, or free choice with other ingredients of the ration.

Supplier

Organization or person that provides a product.

Temperature/dewpoint

The temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

Toast (to)

To brown and dry by exposure to a fire or gas or electric heat.

Traceability/product tracing

The ability to follow the movement of a food through specified stage(s) of production, processing and distribution. (FAO, WHO, 2019a).

Trace minerals

Mineral nutrients required by animals in micro amounts (measured in units of grams per kg or smaller).

Transfer

Passing of a chemical or biological hazard (including hazardous biotransformation products) from feed of a food producing animal to an edible product of the animal (FAO, WHO, 2013b).

Undesirable substances

Contaminants and other substances which are present in and/or on feed and feed ingredients and which constitute a risk to consumers' health, including food safety related animal health issues (FAO, WHO, 2008a).

Vacuum

A reduction in pressure below atmospheric pressure.

Validation of control measures

Obtaining evidence that a control measure or combination of control measures, if properly implemented, is capable of controlling the hazard to a specified outcome.

Verification

The application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine whether a control measure is or has been operating as intended.

Veterinary drug

Any substance applied or administered to any food producing animal, such as meat or milk producing animals, poultry, fish or bees, whether used for therapeutic, prophylactic or diagnostic purposes or for modification of physiological functions or behaviour (FAO, WHO, 2019a).

Vitamins

Organic compounds, which cannot be adequately synthesized in the body, that function as parts of enzyme systems essential for the transformation of energy and the regulation of metabolism in the body.

Wafer (to)

To agglomerate feed of a fibrous nature by compressing it into a form usually having a diameter or cross section measurement greater than its length; the product of this process.

Wet mill (to)

To steep in water with or without sulphur dioxide to soften grains and facilitate the separation of component parts.

Wet render (to)

To cook with steam under pressure in a closed tank.

Introduction

Animal feed plays a leading role in the global food industry, enabling the sustainable and safe production of food of animal origin throughout the world. Under a wide range of farming conditions, feed, being it produced in industrial feedmills or in more simple on-farm mixers, is the largest and most important component in growing animals for food, traction or transport, fibre and other products.

Globally, feed produced by the feed industry has reached an estimated 1 billion tonnes annually. Commercial production or sale of feed takes place in more than 130 countries and directly employs more than a quarter of a million skilled workers, technicians, managers and professionals. Currently, there are an estimated 8 000 plants dedicated to feed production with capacities greater than 25 000 tonnes per year, along with other production facilities, including premixtures and specialty plants producing lower volumes of high-value products. Together, these plants manufacture more than 600 million tonnes of feed annually. On-farm feed production is estimated to some other 300 million tonnes. Worldwide, commercial feed manufacturing generates an estimated annual turnover of over 400 billion USD.

Global feed production continues to grow in volume and value in response to expanding animal protein demand as a consequence of increases in population, urbanization and citizen purchasing power in many emerging economies. However, in many other countries, feed production remains constant or increases only slowly. Sustainable production of meat, fish, milk, eggs and other products of animal origin requires well formulated feed that addresses the nutritional needs for maintenance, reproduction and production of the animals while taking into account the environmental, economic, health and social sustainability requirements. Safety is one of those key objectives.

Adequate animal nutrition at every stage of growth and production is essential to animal health and welfare; it can reduce farm animal contribution to environmental pollution and climate change by providing only the necessary amounts of highly bio-available dietary nutrients. In addition, adequate nutrition influences critical functions that enable animals to increase their defence against pathogens and increase their resistance to diseases. Dietary choices can promote gastrointestinal tract health, by stabilizing the intestinal microbiota and supporting mucosal barrier function. These in turn make the animal more resistant to diseases and reduce the need for antimicrobials and contribute to the containment of antimicrobial resistance (AMR).

Safe feed enables farms to enhance animal health and welfare, reduces the need to use antimicrobials, ensures food safety, reduces production costs and maintains or improves food quality. Safe feed is also essential for income generation and access to trade while contributing to minimise feed and food losses. For all these reasons, feed production, both at feed plants and on-farm, must be subject, in a similar manner as food production, to the quality assurance of integrated safety systems. However, in many countries, adequate know-how and sufficient awareness among all operators along the whole value chain to ensure feed safety are often lacking. Even where more knowledge is available and control systems are in place, new and unconventional feed ingredients are entering the production chain. These ingredients, which include agro-industrial by-products (such as the ones of the biofuel industry), insects, food processing by-products, food wastes bring with them possible new safety risks.

The increase in international trade of feed and feed ingredients can also bring unforeseen feed safety risks. New agricultural practices, transboundary transfer of resistant pathogens and climate changes to name a few examples, all require continued efforts to guarantee feed safety and strong and transparent communication among all parties involved in the feed/food chain.

A contemporary risk-based approach to feed/food safety requires recognizing its importance and knowing and applying adequate measures to reduce feed-borne risks to public health at all points of the value chain. The principles of risk analysis and the application of Hazard Analysis and Critical Control Point (HACCP) should be therefore incorporated wherever appropriate in the design and implementation of feed safety programmes.

The Codex Alimentarius Commission adopted in 2004 the Code of Practice on Good Animal Feeding (FAO, WHO, 2008a). The Code implies a transition towards a risk-based approach covering the entire feed/food chain. The application of the Code is an important step for the expansion of international trade of feed and products of animal origin. Both feed/food exporting and importing countries can benefit from a greater and safer trade of feed and products of animal origins. However, the Code only looks at effects related to human health. Effects on animal health and the environment are not subject of the Code.

This Manual provides comprehensive information and practical guidelines to assist farmers, producers and all stakeholders along the feed value chain to comply with the Codex

Alimentarius Code of Practice on Good Animal Feeding requirements. It is intended to guide managers of feedmills, the feed industry as a whole and on-farm feed mixers and producers. It will also be of value to national competent authorities, in particular those engaged in feed inspection, in their supervisory roles. It can also serve as a training manual and a guide to setting up national feed associations.

The Manual of Good Practice for the Feed Industry was published in 2010. It was developed through a close collaboration between FAO and the International Feed Industry Federation (IFIF) with the support of the Standards and Trade Development Facility (STDF) established by FAO, the World Organisation for Animal Health (OIE), the World Bank Group, the World Health Organization (WHO) and the World Trade Organization (WTO). This new publication is a fully revised, updated and expanded version of that Manual. It takes into account, even if not specifically addressing them, subsequent Codex Alimentarius documents related to feed, such as the Guidelines on the Application of Risk Assessment for Feed (FAO, WHO, 2013a) and the Guidance for Governments on Prioritizing Hazards in Feed (FAO, WHO, 2013b), as well as many other Codex texts. This new publication addresses recent developments in feed production and benefits from the latest scientific and technical

knowledge, e.g. the reports of the Joint FAO/WHO expert meeting on Hazards associated with animal feed (FAO, WHO, 2019d) and the Joint FAO/WHO expert meeting on Carryover in feed and transfer from feed to food of unavoidable and unintended residues of approved veterinary drugs (FAO, WHO, 2019e).

FAO and IFIF recognize the importance of producing feed of adequate nutritional value to maintain animal health and welfare standards and to help decreasing farm animal contribution to environmental pollution and climate change; however, the focus of this Manual is on food safety and good practices aimed at ensuring it. This Manual may be complemented by other FAO publications that target the other important objectives of feed production mentioned above (see Appendix 5).

Although not dealt with in this Manual, the importance of the indirect impact on food safety of adequate nutrition, and animal health and welfare is also recognized: animals that are healthy and in good body conditions are less likely to transfer hazards from feed to the food they are producing.

The scope of this Manual is mainly on feed used in terrestrial animal production although the increasing contribution of aquaculture to food production is recognised.

How to use this manual

This Manual provides comprehensive information and practical guidelines to assist producers and all stakeholders along the feed value chain to comply with the Codex Alimentarius Code of Practice on Good Animal Feeding (FAO, WHO, 2008a) requirements. It will also be of value to national competent authorities addressing the feed sector and engaged in feed inspection, with their supervisory roles in feed safety.

Full understanding of the concepts and information provided in this Manual requires some knowledge of the principles of risk analysis. For this reason, a brief overview of risk analysis is provided hereafter.

More specifically, sections 1 to 5 address the requirements of the Codex Alimentarius Code above mentioned and start with a box referring to the specific Code text addressed in that particular section (the full text of the Code is available in Appendix 1).

Hazards considered in this Manual are those comprehensively addressed in the expert meetings organized by Food and Agricultural Organization of the United Nations (FAO) and the World Health Organization (WHO) (FAO,

WHO, 2008c; FAO, WHO, 2019d). More specifically, the report on Hazards Associated with Animal Feed provides an updated overview of the current state of knowledge on hazards associated with feed, including feed and products of feed production technologies of increasing relevance). For this reason, the text and the charts in Section 1 refer to the information contained in this latter report.

In addition to the Code of Practice on Good Animal Feeding, this Manual includes Appendices listing: other Codex Alimentarius documents that address feed and feed ingredients (Appendix 2); FAO publications that target other important objectives of feed production, such as ensuring adequate nutritional value for the target animals, decreasing farm animal contribution to environmental pollution and climate change, and others (Appendix 3); and national codes of practices (Appendix 4).

National feed associations play an important role to vehiculate valuable information and to assist producers and operators in ensuring feed safety; Appendix 5 has been included to provide insight on how to set up these associations.

Risk analysis – An overview

Risk analysis is used to evaluate a risk, to identify appropriate measures to control it and to communicate the whole process. The information and evidence that risk analysis produces are essential for regulators and operators to make effective decisions that improve feed safety, and in turn public health.

Several feed hazards (see Table 1) are already known and addressed in feed safety controls. Various factors influence their occurrence, thus altering the risk they present.

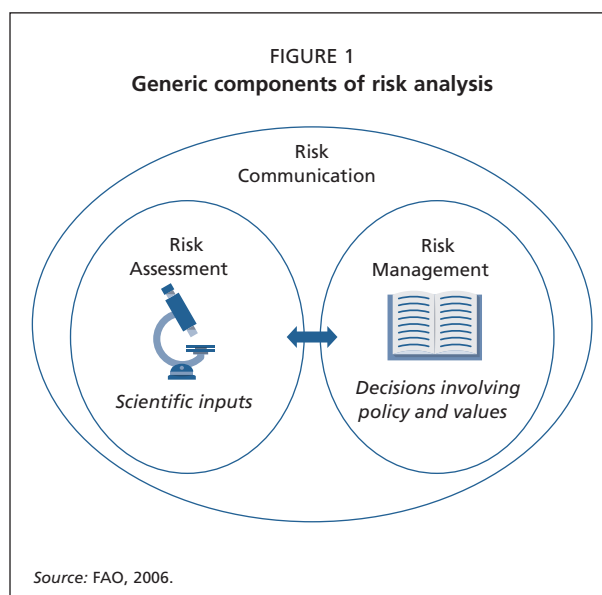
FAO, WHO and Codex Alimentarius have produced extensive and specific publications on risk analysis and risk assessment for application by governments and for application by the Codex Alimentarius (FAO, WHO, 2019a; FAO, 2006; FAO, WHO, 2014a; FAO, WHO, 2007; FAO, WHO, 2008b; FAO, WHO, 2011a; FAO, WHO, 2013a; FAO, WHO, 2013b).

There are three distinct components of risk analysis: risk management, risk assessment and risk communication. The interactivity of these components is essential for a risk analysis to be successful (see Figure 1).

Risk assessment is considered to be the “science-based” component of risk analysis, while risk management is the component in which scientific information and other factors, such as economic, social, cultural and ethical considerations, are integrated and weighed in choosing the preferred risk management options. Risk communication is the interactive exchange of information and opinions throughout the risk analysis process.

INTERNATIONAL AND NATIONAL RISK ANALYSIS FRAMEWORK

Feed safety risk analysis is performed by authorities at the international, regional and national, level. At the international level, Codex Alimentarius feed and food safety standards provide guidance to risk managers. Risk



assessment is carried out by the FAO/WHO expert bodies: JECFA (Joint Expert Committee on Food Additives), JMPR (Joint Meeting on Pesticide Residues) and JEMRA (Joint Expert Meeting on Microbiological Risk Assessment) and ad-hoc FAO/WHO experts meetings. At the national level, competent authorities are responsible for carrying out the full risk analysis process.

RISK ANALYSIS PROCESS

The risk analysis process begins with preliminary risk management, where it seeks to define the issue(s), articulate the objectives of the analysis and identify the questions to be addressed and answered by the risk assessment, when and if it is needed. Risk management and risk assessment should be carried out with full transparency and with intensive dialogue

TABLE 1
Examples of hazards in the feed chain

Biological	Chemical	Physical
Bacteria	Naturally occurring toxins	Metals, parts of equipment
Parasites	Pesticide residues	Glass
Viruses	Veterinary drug residues	Stones
Prions	Potentially toxic elements	Bones
	Chemical contaminants from packaging	Nanomaterials
	Environmental pollutants	Microplastics
		Radionuclides

among the various stakeholders. Risk analysis culminates in the implementation of risk management measures, and subsequent monitoring of their effectiveness by governments, the private sector and other stakeholders.

Risk analysis is comprised of numerous interactions and repetitions of steps between risk management, communication, and assessment, involving unceasing interaction between managers, assessors and other stakeholders. The Codex Alimentarius Commission Procedural Manual (FAO, WHO, 2019a) states that risk analysis should:

- follow a structured approach, gathering the three components
- be based on the best available scientific evidence
- have a consistent application regardless of the type of hazard or country
- be developed in an open, transparent and well documented process
- be transparent about uncertainties and variables
- be evaluated and revised as appropriate and based on new and updated information

Although the responsibility for safety in the feed and food production chain is shared by all from production to use and consumption, it is the government's obligation to provide an institutional and regulatory environment for feed and food safety. For a risk analysis process to succeed, a feed/food safety system should be in place in the country and/or region with the following elements (FAO, 2006):

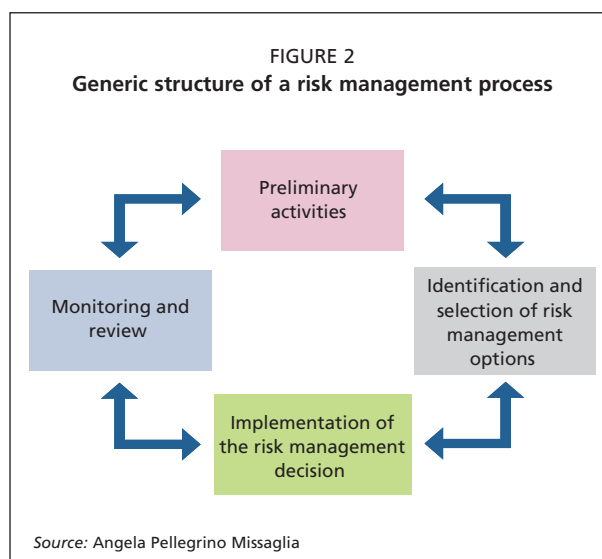
- feed/food laws, policies, regulations and standards
- institutions with clearly defined responsibilities for feed/food management and public health control
- scientific information
- integrated management approach
- inspection and certification systems
- diagnostic and analytical laboratories
- infrastructure and equipment
- monitoring system
- animal and human health surveillance on issues related to feed and food consumption
- ability to react to emergencies
- training
- public information, education and communication

Preliminary risk management

When risk managers identify a feed safety issue, risk management begins a process with a systematic, consistent and simple-to-understand structure.

Figure 2 illustrates the generic structure of risk management, which should be functional in both chronic and emergency situations

Upon detection of a feed safety issue, the available scientific information is compiled into a risk profile, which will guide the course of subsequent actions. If necessary, a risk assessment will be commissioned by the risk managers.



In this case, good communication with risk assessors is paramount, especially to ensure that the scope of the risk assessment is reasonable and achievable, and to define which questions should be answered.

Managers' decision to commission a risk assessment is influenced by factors such as health risk priority ranking, urgency, regulatory needs and availability of resources and data. It is likely that a risk assessment will not be commissioned when the risk is already well described, if the feed safety issue is relatively simple, if the feed safety issue is not of regulatory concern or not subject to regulatory mandate, or if an urgent regulatory response is not required.

In different regions and processes, hazards and subsequently feed safety issues may be of more concern than in others. Therefore, a prioritization process can provide a ranking and help in making the decision to carry out a risk analysis. The Codex Alimentarius Guidance for Governments on Prioritizing Hazards in Feed (FAO, WHO, 2013b) sets out a methodology to rank hazards for risk assessment and risk management priorities. The primary criterion is usually the relative levels of risk that each problem poses to consumer health. Other relevant factors are trade restrictions, ease of resolution of the problem itself and social or political pressure. A defined prioritization process ensures transparency, repeatability and facilitates re-evaluation when new data are available.

Risk assessment

The scientific foundation of a risk analysis is risk assessment. When a population is exposed to a hazard for a certain period, there is a possibility of adverse effects on health. The characterization of these effects is the main objective of risk assessment. The ability to model the relative impacts of different risk control measures is one of the great qualities of risk assessment.

It is important to point out that there are situations where an assessment is not feasible, necessary or available. In other instances, a decision may be taken to use a scientific approach that does not include a risk assessment.

When the commissioning of a risk assessment is approved, risk managers should request the relevant scientific bodies to assemble a team of experts.

The questions to be answered by the assessment must be defined considering the scope of the project and the resources available, and ultimately guide the methodology used by the assessors.

General characteristics of a risk assessment

A risk assessment should be objective and impartial and only scientifically sound information should govern its outcomes. In documenting the process, risk assessors should describe in detail the scientific reasoning and data employed, exposing any biases that may influence the implementation or output of the risk assessment, and state all assumptions clearly.

The separation between assessment and management should be maintained, so that science remains independent of the influence of regulatory policies and values. A high degree of communication and interaction between risk managers and risk assessors should be maintained to ensure the effectiveness of risk analysis.

Sometimes the data needed to obtain quantitative estimates are lacking, and sometimes there are significant uncertainties in the models used to represent the process that contributes to a risk. Risk assessors should explicitly describe the uncertainties contained in the risk estimates and their origins and the influence of the assumptions made on the degree of uncertainty of the outcomes.

Finally, it is important that the risk assessment is peer reviewed. Comparison with processes that used different judgments and assumptions can result in new ideas and perspectives and reinforces transparency.

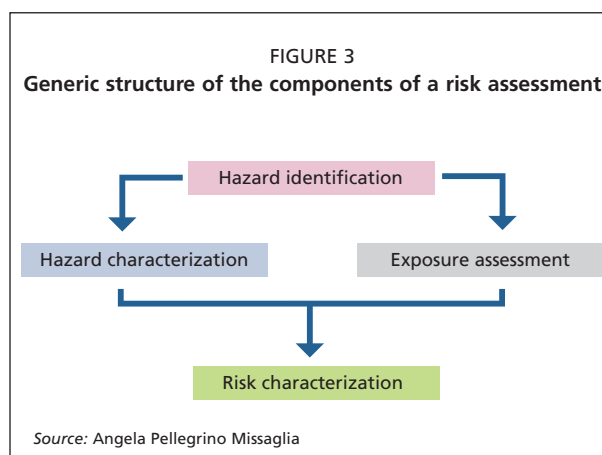
Risk assessment methodology

Risk assessment methodologies vary according to the type of hazard (chemical, physical or biological), the feed safety scenario, the time and resources available.

Risk assessment usually consists of four steps (see Figure 3) and after hazard identification, the order of these tasks is not fixed due to the highly iterative nature of the process (FAO, 2006).

i) Hazard identification

Identifying a hazard of interest is an important step in risk assessment as it enables the assessors to estimate the risks that arise from it.



ii) Hazard characterization

This phase is characterized by the description of the nature and extent of adverse health effects known to be associated with the identified hazard. Assessors establish, where possible, the dose-response relationship for different levels of exposure to the hazard in feed and the likelihood of adverse effects.

iii) Exposure assessment

In the exposure assessment, the amount of hazard consumed by members of the exposed populations is characterized. Data on the hazard levels in feed ingredients added to the primary feed and the general feed environment determine the variation of hazard levels throughout the production chain. These data are combined with feed consumption patterns of the populations to estimate the exposure to the hazard over a given period of time.

iv) Risk characterization

At this phase, the results of the previous steps are integrated to generate a risk estimate. Risk characterization often includes reports on other aspects of risk assessment, such as comparative rankings with risks from other feed, impacts on risk of hypothetical scenarios, and other scientific work needed to reduce knowledge gaps.

The results of risk assessments can range from qualitative to quantitative, with various intermediate formats. In qualitative results, descriptive terms such as high, medium or low are used. In quantitative terms, there are numerical representations and possible inclusion of numerical uncertainty. Intermediate formats are referred to as semi-quantitative.

While the feed risk assessment closely follows the above risk assessment methodology, it is a two-phase process with different outcomes in each phase:

First phase

As the animal is exposed to the feed, the risk assessor should assess the fate of the hazard in the animal. In the case of a chemical hazard, the risk assessor needs to consider the metabolism and possible transfer to food, parent compound or metabolites. The animal's metabolism may reduce the toxicity of the hazard but could also transform the hazard into a more toxic compound. In the case of a biological hazard, growth of the microorganisms is a more relevant factor, whereas metabolism refers more to compounds such as toxins that could be produced by the microorganism and not by the animal. Exposure to a hazard may also pose possible health risks for the animal, which influences the transfer of the hazard to food. Therefore, possible health risks from the hazard in the feed ingredient, the resultant mixed feed and the remaining feed for the animals exposed or other animals potentially consuming the feed may need to be assessed.

Second phase

The food risk assessment addresses possible human health risks resulting from exposure to the hazard that may be transferred into food of animal origin. This follows the regular process for food risk assessment.

Risk management

Risk management should follow a structured approach including preliminary risk management activities (*described before*), evaluation of risk management options, implementation of risk management decisions and monitoring and review of the decision taken. The risk management process should be transparent, consistent and fully documented.

Evaluation of risk management options

Evaluation of risk management options is the weighing of available options for managing a feed/food safety issue in light of scientific information on risks and other factors and may include reaching a decision on an appropriate level of consumer protection. Optimization of feed control measures in terms of their efficiency, effectiveness, technological feasibility and practicality at selected points throughout the feed/food-chain is an important goal. A cost-benefit analysis could be performed at this stage.

The outcome of the preliminary risk management activities and the risk assessment should be combined with the evaluation of available risk management options to reach a decision on management of the risk. Risk management options should be assessed in terms of the scope and purpose of risk analysis and the level of consumer health protection they achieve. The option of not taking any action should also be considered.

To avoid unjustified trade barriers, risk management should ensure transparency and consistency in the decision-making process in all cases. Examination of the full

range of risk management options should, as far as possible, take into account an assessment of their potential advantages and disadvantages. Risk management should consider the economic consequences and the feasibility of risk management options.

Implementation of the risk management decisions

Risk managers should develop an implementation plan that describes how the decisions will be implemented, by whom and when. National/regional authorities should ensure an appropriate regulatory framework and infrastructure. To effectively execute feed/food safety control measures, parties involved in the food production chain generally implement complete feed/food control systems using comprehensive approaches such as good agricultural practices (GAP), good veterinary practices (GVP), good husbandry practices (GHbP), good manufacturing practices (GMP), good hygiene practices (GHP) and hazard analysis and critical control point (HACCP) systems.

Risk managers should consider both non-regulatory measures and regulatory controls. Risk management decisions should be proportionate to the level of risk, whether an intervention is a single risk management option or a combination of them. Flexibility in the choice of individual measures applied by industry is a desirable element, as long as the overall programme can be objectively shown to achieve the stated goals. Ongoing verification of the application of food safety measures is essential.

Monitoring and review of risk management measures

Monitoring and review is the gathering and analyzing of data so as to give an overview of the risks to feed/food safety and human health. Monitoring and review aim to determine the effectiveness of the risk management measures chosen and need for potential adjustment and to check for unintended or unforeseen effects.

Risk managers should establish a process to monitor and review whether the risk management measures have been properly implemented and whether or not an outcome has been successful. This should also include the monitoring and review of provisional decisions. The execution of this phase is the joint action of producers and governmental agencies, and public health surveillance is performed by national competent authorities.

Decisions must undergo periodic reviews, especially when new information comes to light with discoveries, scientific progress or even data gathered during the inspection and monitoring of applied risk management measures. Lately, the need to start a new risk analysis cycle can be determined.

TABLE 2

Table 2: Key points and steps for effective use of risk communication

i) Identifying a feed safety issue
Open communication between all parties is invaluable for an accurate definition of the issue. Information about a particular feed safety issue can be brought to the risk manager through a wide range of potential sources and managers then seek information from other sources that may contain knowledge about the issue.
ii) Developing a risk profile
At this step, essential communication takes place between risk managers and risk assessors or other scientists developing the risk profile. Experts working on the risk profile should also establish their own communications network with the external scientific community and industry, seeking to gather sufficient body of scientific information.
iii) Establishing risk management goals
When managers set the objectives of risk management (and whether an assessment is feasible or necessary), communication among assessors, managers and external stakeholders is essential. Managers should not set goals in isolation. Once set, objectives should then be communicated to all stakeholders.
iv) Developing a risk assessment policy
A risk assessment policy provides essential guidelines for scientific decisions and judgments, sometimes subjective and imbued with certain values, that must be taken by risk assessors throughout an assessment. Communication between assessors and managers is of utmost importance at this stage and necessary for solving complex and any other issues that may arise. Contributions from outside groups to these policy decisions are also appropriate and valuable.
v) Commissioning a risk assessment
When risk managers formally request assessors to carry out a formal assessment, good early communication contributes significantly to the quality of the outcome. Again, the most important communication focus is between managers and assessors, seeking the questions to be answered by the assessment, the guidelines provided by the assessment policies, and the form of the outcomes. Clear communication about the scope and objectives of the process, time and resources available are also important. Stakeholder participation at this stage of the process is limited due to the need to avoid political influences and interests.
vi) Execution of the risk assessment
Communication between managers and risk assessors is essential during the assessment process. The questions to be answered are refined or revised as the information is developed and external groups with relevant data may be invited to interact with the assessment team.
vii) Completion of risk assessment
When the assessment is completed and delivered to risk managers, there is again intense communication between risk managers and risk assessors, as they need to understand the outcomes of the assessment, the implications for risk management and the associated uncertainties. There is also sharing of results with the public and stakeholders, who will provide their comments and reactions.
viii) Ranking risks and setting priorities
At this stage, the assessors engage in broad dialogue with stakeholders. Priority setting is a process inherently value laden. Ranking risks to be prioritized by risk assessment and risk management is therefore a fundamentally social-political process.
ix) Identifying and selecting risk management options
Decisions on issues such as risk distribution and equity, economics, cost effectiveness. Effective risk communication during this stage is critical to the success of risk analysis.
When management options are weighted, the review process can become a political dispute. If properly handled, this situation can clarify the values and choices that need to be considered when selecting risk management options, resulting in a transparent decision-making process.
x) Implementation
To ensure the effective implementation of the risk management decision, managers should work closely with whom the implementation falls.
xi) Monitoring and review
At this stage, managers need to collect the data needed to assess whether management measures are having the desired effects. In addition to those designated as responsible for monitoring and review, other groups may be consulted or brought to the attention of the authorities. Risk managers sometimes use a formal risk communication process to decide if a new initiative is needed for further risk control.

Source: FAO, 2006

Risk communication

Risk communication is an integral component of risk analysis and aids the transmission and collection of relevant information between the assessment team and all stakeholders, including citizens, governments and non-governmental organizations. Successful communication is a prerequisite for the effectiveness of management and assessment processes and contributes to the transparency of risk analysis by fostering greater understanding and acceptance of risk management decisions.

In emergency situations, effective communication among participants is critical for helping people understand risks and make informed decisions. When there is less urgency, solid and iterative communication usually elevates the quality of risk management decisions.

While communication is essential throughout the risk analysis application, its effective use is particularly critical in several key points and steps of the process (see Table 2)

RISK ASSESSMENT VERSUS HACCP HAZARD ANALYSIS

The term risk assessment is often used in the context of implementing HACCP in feed production. HACCP is a tool to assess hazards and establish control systems focusing on prevention rather than relying on end-product testing. Hazard analysis is applied according to the first principle of HACCP to identify hazards in specific feed ingredients and process steps and therefore decide which are significant to animal and human health. This assessment is more of a qualitative nature.

Risk assessment is the qualitative and/or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization and exposure assessment. This could also be described as the likelihood that potential harmful health effects occur from the presence of a hazard in feed. The outcome of risk assessments may give input for HACCP, but it is a distinct process from HACCP. HACCP applies to the producer/manufacturer level, while risk assessments are done for populations.

Therefore, the final output of the risk assessment, the final characterization of risk, is really different from hazard analysis. The only term in common between HACCP and risk analysis is hazard identification, which is the beginning of the study of any hazards to identify them (Oyarzabal, 2015).

RISK ASSESSMENT AND PRODUCT REGISTRATION/AUTHORIZATION

Different jurisdictions have different regulatory procedures for pre-market authorization of new and/or specific intended use of any type of ingredients in the manufacturing of feed. These technical dossiers may require complete information on the product being placed on the market as well as its efficacy, mode of application, restrictions, etc. A new risk assessment may have to be conducted to be presented to the authorities or an already published risk assessment can be used in the dossier required by the local regulation. Similarly, the competent authority will make use of the risk assessment to register/authorize or not the product and define the authorization conditions. Therefore, the same or a similar risk assessment approach as previously described may be used.

SECTION 1

Health hazards associated with feed

All feed and feed ingredients should meet minimum safety standards. It is essential that levels of undesirable substances are sufficiently low in feed and feed ingredients that their concentration in food for human consumption is consistently below the level of concern. Codex Maximum Residue Limits and Extraneous Maximum Residue Levels set for feed should be applied. Maximum residue limits set for food, such as those established by the Codex Alimentarius Commission, may be useful in determining minimum safety standards for feed.

Undesirable substances

The presence in feed and feed ingredients of undesirable substances such as industrial and environmental contaminants, pesticides, radionuclides, persistent organic pollutants, pathogenic agents and toxins such as mycotoxins should be identified, controlled and minimised. Animal products that could be a source of the Bovine Spongiform Encephalopathy (BSE) agent should not be used for feeding directly to, or for feed manufacturing for, ruminants. Control measures applied to reduce unacceptable level of undesirable substances should be assessed in terms of their impact on food safety.

The risks of each undesirable substance to consumers' health should be assessed and such assessment may lead to the setting of maximum limits for feed and feed ingredients or the prohibition of certain materials from animal feeding.

Codex Alimentarius Code of Practice on Good Animal Feeding (CXC 54-2004)

Hazards to human health that can be transferred from feed to food of animal origin, therefore resulting in a food safety risk, may be introduced in the feed/food chain through feed and drinking water for animals. Feed may be contaminated during production, handling, storage, transportation and use. Hazards in feed may also result from accidental or deliberate human intervention (e.g. fraud, adulteration). The expansion of international trade of feed and feed ingredients may also increasingly spread hazards.

Hazards in feed can be biological, chemical or physical. Each hazard is associated with sources and routes of contamination and exposure. Previously unidentified hazards may be associated with new or increasingly used feed or feed ingredients (e.g. food and agro-industrial products, insects, former food products, marine resources or with new feed production technologies).

New agricultural and manufacturing practices, availability of new feed ingredients, increasing pathogen resistance, climate changes and decrease in biodiversity will all demand particular attention in pursuing prevention of contamination, sharing of data and a continuous communication among feed and food stakeholders (Fink-Gremmels, J., ed., 2012)

BIOLOGICAL HAZARDS

Processing of feed ingredients typically involves steps like heat and/or addition of certain substances followed by cooling. These manufacturing processes may help reduce biological contamination. However, with insufficient hygiene and/or inadequate heating and cooling conditions, the growth of certain pathogens may occur. Furthermore, transports in uncleaned vehicles or in uncontrolled temperature or humidity settings can affect the survival and growth of pathogens.

To identify and characterize pathogens, understanding the factors that affect the sources and routes of contamination remains crucial to prevent further contamination.

Salmonella spp.

Salmonella are gram-negative bacteria ubiquitous in nature and common in the environment. More than 2500 serotypes of *Salmonella* are reported. All serovars are considered as potential pathogens to humans and are an important pathogen also in animals. In both humans and animals, the infection is transmitted by the faecal or oral route.

A wide spectrum of serovars of *Salmonella* can be isolated from feed, including those most commonly isolated

from clinical cases of human salmonellosis, like subspecies typhimurium and enteritidis.

Animals acquire infection following ingestion of faecally contaminated feed. Infected animals often become silent carriers without clinical signs of disease. Infected animals shed the microbe and constitute a potential source for the spread of the infection to other animals, including wildlife and the environment.

The major risks for *Salmonella* contamination in feed-mills and feed are the introduction of *Salmonella*-contaminated feed ingredients. In all countries, this is a continuous risk for introducing *Salmonella* to the feed/food chain. Control measures include prevention of contamination, reduction of multiplication and procedures to kill the pathogen. A major focus should be to prevent the introduction of contaminated feed ingredients. The major risk feed ingredients are proteins of animal origin followed by the vegetable proteins, the latter including e.g. soybean meal which is produced in crushing plants where the same approach for the control as in feedmills can be applied.

Listeria monocytogenes

Listeria monocytogenes is a gram-positive bacterium that occurs widely in both agricultural and feed / food processing environments. In comparison to other non-spore forming, foodborne pathogenic bacteria (e.g. *Salmonella* spp., enterohemorrhagic *Escherichia coli*), *Listeria monocytogenes* is resistant to various environmental conditions such as high salt or acidity. *Listeria monocytogenes* grows at low oxygen conditions and refrigeration temperatures, and survives for long periods in the environment and in the processing plant.

Some sources of contamination from *Listeria monocytogenes* include soil, sewage, forage and water. With respect to unprocessed feed, such as plant products that either are not or minimally processed, such as silage, *Listeria monocytogenes* can have the opportunity to proliferate if production is not properly controlled. Brewers' grain and other processed feed ingredients of plant origin could also harbour significant *Listeria* cells.

Listeria monocytogenes in silage is noted as related to animal listeriosis and asymptomatic carriage in dairy cattle, sheep and goats. *Listeria monocytogenes* has been detected in poultry feed both prior to and after heat treatments. Feedmills have been suggested as a source of *Listeria monocytogenes* indicating potential re-contamination of pellet feed. The prevalence of *Listeria monocytogenes* in feed and feed ingredients is believed to be low in ingredients with a low water activity such as hay and cereal grains.

Enterohemorrhagic *Escherichia coli*

Escherichia coli is a gram-negative bacterium that is commonly found in the intestinal flora of humans and warm-blooded animals. Some *Escherichia coli* are pathogenic and cause human illnesses. Among these, *Escherichia coli* O157:H7 is one of the most common enterohemorrhagic *Escherichia coli* (EHEC) reported. EHEC is a strain of *Escherichia coli* that produces a Shiga toxin. Shiga-toxin producing *Escherichia coli* (STEC), that is also known as verotoxin-producing *Escherichia coli* (VTEC), is a foodborne zoonotic agent of concern to public health. STEC can be transmitted via the faecal-oral route often by cross contamination, e.g. via feed, water, food, or environmental sources, as well as contact with infected animals.

Hazard	<i>Salmonella</i> spp.
Sources	Contaminated feed ingredients of oil seed or fruit origins, of marine origin (fish meal), or terrestrial animal origin (meat (and bone) meal). Environmental sources such as poultry houses and poultry litter. Breeder and slaughter animals including asymptomatic carriers (swine, poultry, and cattle); wild birds and rodents; crushing and feed producing plants especially when hygiene controls are insufficient since this may allow pathogenic growth.
Transfer to food of animal origin	High
Potential impact on human health	High

Source: adapted from FAO, WHO, 2019d

Hazard	<i>Listeria monocytogenes</i>
Sources	Ubiquitous: soil, sewage, water, feed (unprocessed feed, forage, silage), feedmills, contaminated food (meats and meat products including cured meats, dairy products like unpasteurized raw milk and soft cheeses, and prepared seafood like smoked fish).
Transfer to food of animal origin	Medium
Potential impact on human health	High especially for young, old, pregnant and immunocompromised persons.

Source: adapted from FAO, WHO, 2019d

Escherichia coli O157:H7 has rarely been detected in cattle feed, however some literature suggests that feed may be a source of *Escherichia coli* O157:H7 in cattle. Time and temperature combinations that were applied in commercial pelleting processing had been investigated and it was concluded that these would not effectively kill high *Escherichia coli* O157:H7 numbers in feed.

***Clostridium* spp.**

Clostridium spp. consist of gram positive, spore forming bacteria that have been identified as a concern in feed for food producing animals, yet to a lesser extent as compared to *Salmonella* spp. Nevertheless, it is also important to note that clostridial toxins and spores cannot be easily neutralized through heat and pressure treatments of feed, meaning further contamination can result during the compounding process. *Clostridium perfringens* is ubiquitous, being found in soil, contaminated food (e.g. raw meat and poultry), decaying vegetation, marine sediment, the intestinal tracts of birds, poultry litter, as well as the intestines of humans and animals. *Clostridium perfringens* has been commonly reported in faeces and soil; due to its possible presence in soil-contaminated feed, it is reported as a component of feed and can be present as either vegetative cells or endospores.

Although *Clostridium perfringens* is commonly isolated from the environment and the intestinal tracts of broilers, its significance in feed contamination has been questioned as *Clostridium perfringens*-associated diseases need initiators in addition to microorganism presence. *Clostridium perfringens* is considered one of the most common causes of foodborne illnesses. Food poisonings due to *Clostridium perfringens* can arise in food of animal origin when meat is undercooked or when spores survive the cooking processes. Also, if cooked food is improperly stored (e.g. prolonged storage at room temperature), spores can germinate and rapidly multiply.

***Brucella* spp.**

Brucella is a gram-negative small coccobacillus. Humans can contract brucellosis through food of animal origin like milk, milk products or undercooked meat that are contaminated with *Brucella* spp.

Brucellosis is very widespread in many regions of the world. *Brucella* may spread in several ways including through direct contact with infected tissues or fluids of infected animals, consumption of colostrum or milk from infected animals or consumption of feed or water that has been contaminated from infected tissues or fluids.

Hazard	<i>Escherichia coli</i> (Shiga-toxin producing <i>E. coli</i> , STEC)
Sources	Cattle, pigs, birds, other herbivores (e.g. as carriers), pasture grass, feed (silage), water, food (e.g. unpasteurized milk, undercooked ground beef, contaminated raw products).
Transfer to food of animal origin	Medium-low
Potential impact on human health	High

Source: adapted from FAO, WHO, 2019d

Hazard	<i>Clostridium</i> spp.
Sources	Ubiquitous: soil, decaying vegetation, marine sediment, poultry litter, feed (silage, haylage, grain), carcass contamination of feed, contaminated food (raw meat, poultry, dairy), intestinal tract of humans and animals.
Transfer to food of animal origin	Medium-low
Potential impact on human health	High

Source: adapted from FAO, WHO, 2019d

Hazard	<i>Brucella</i> spp.
Sources	Animals: ingestion of infected tissues or fluids, such as aborted fetuses, birth tissues and fluids, and colostrum or contaminated feed. Humans: exposure to contaminated environments or objects, occupational exposure (e.g. to infected animals), foodborne (e.g. from contaminated food of animal origin, such as (raw) milk or milk products like cream or cheese or undercooked meat).
Transfer to food of animal origin	Medium
Potential impact on human health	High

Source: adapted from FAO, WHO, 2019d

Mycobacterium

Mycobacterium species, mixed-gram bacillus from the *Actinobacterium* phylum, are responsible for several important human and animal chronic diseases worldwide, as pulmonary, skin and intestinal tract colonizer. Some recognized diseases in humans are tuberculosis, leprosy and ulcerative colitis. The *Mycobacterium avium* complex strains are associated with tuberculosis and very common in food, water and soil.

Mycobacterium are widespread in the environment, particularly in aquatic reservoirs. Sources of contamination of feed are numerous and include animal carcasses accidentally harvested simultaneously with fodder and soil particles. *Mycobacterium* easily survives in more acidic soil, in a state of vegetative dormancy. This microorganism does not survive drying processes, i.e. in hay or grain, but it was reported that *Mycobacterium avium* subspecies *paratuberculosis* is able to survive in grass silage. Spreading of contaminated manure from infected farms could be a source of this bacterium.

Viruses

Feed can be contaminated with viruses during storage, transportation and processing.

Prions

Bovine spongiform encephalopathy (BSE) is the main representative form of transmissible spongiform encephalopathies (TSEs), caused by the presence of prions, which

are modified forms of host specific proteins. These proteins are strongly heat resistant, persistent in the animal system and cause irreversible neuropathological disorder. Scrapie is a related TSE affecting sheep and goats. The pathological form of the prion protein accumulates primarily in nervous system organs because of its resistance to proteolytic enzymes. The epidemiology and background of prions as a feed and food contaminant differs mainly from those of chemical or biological contaminations: prion diseases always have a progressive and irreversible nature, there is a genetic basis and resistance, or cure does not exist. Elaborate analyses revealed that the most likely route for infection of susceptible animals is by oral ingestion of prions. These prions originate from certain ruminant animal by-products used as feed ingredients. Restrictions on the use of certain feed ingredients vary from country to country. OIE recommends at least to avoid feeding ruminant by-products to ruminants with exceptions of milk, tallow and gelatine.

Several measures developed for inactivating prions at some stage in the feed and food production chain, such as composting, chlorine treatment and severe cleaning, heat treatment and acid or alkaline treatment appeared to be not fully effective. It is transmissible between individual of the same species, and affected animals must be killed,

Hazard	<i>Mycobacteria</i>
Sources	<i>Mycobacterium avium</i> subspecies <i>paratuberculosis</i> (MAP): faecal-oral transmission, free range wild ruminants, contaminated pastures and feed. <i>Mycobacteria</i> in fish: ingestion of contaminated feed, other infected fish, faeces of other fish.
Transfer to food of animal origin	High for fish, low for food
Potential impact on human health	Low

Source: adapted from FAO, WHO, 2019d

Hazard	Porcine epidemic diarrhea virus (PEDV)
Sources	Transmission: faecal-oral route in a herd; contaminated fomites, transport (equipment), feed storage facilities, and personnel; PEDV-positive aerosols; contaminated feed or ingredients.
Transfer to food of animal origin	Low
Potential impact on human health	Low

Source: adapted from FAO, WHO, 2019d

Hazard	Prions
Sources	Ruminant animal by-products used as feed ingredients. Some specific organs can contain prions: brain, spinal cord, trigeminal ganglia, distal ileum, spleen and eyes. These organs are indicated as specified risk material (SRM) and are not allowed to enter the food processing chain or are recommended to be removed by OIE.
Transfer to food of animal origin	High. Prions can easily be transferred when SRM is included in food of animal origin.
Potential impact on human health	High. Variant Creutzfeld-Jacob (vCJD) is the human version of BSE. vCJD, as BSE, is irreversibly lethal.

Source: adapted from FAO, WHO, 2019d

and the carcasses must be destroyed to limit contamination potential. Confirmation of suspected case is possible mainly by histological direct analysis from brain samples collected from euthanized animals. International focus of surveillance now included the testing of targeted, high-risk cattle as the most effective way to detect BSE-infected animals.

Endoparasites

Endoparasites are parasites that live in the body of the host. Some endoparasites such as *Taenia*, *Diphyllobothrium*, *Echinococcus*, *Trichinella* and *Toxoplasma* are of a human health concern and can be associated with feed.

In the phylum Platyhelminthes, an important class of Cestoda includes the tapeworms of the genera *Taenia*, *Diphyllobothrium* and *Echinococcus*. Taeniasis is the intestinal infection of tapeworms, of which *Taenia solium* (pork tapeworm) and *Taenia saginata* (beef tapeworm) are the most important. Cysticercosis is the infection of tissues caused by cysticerci resulting from ingestion of *Taenia* eggs. Diphyllbothriasis is the infection caused by tapeworms from the *Diphyllobothrium* genus of which is commonly caused by *Diphyllobothrium latum*. Echinococcosis is a parasitic disease of tapeworms from the *Echinococcus* genus and is a zoonosis.

In the phylum Nematoda, *Trichinella* is a related genus. Trichinosis is caused by nematodes (roundworms) from *Trichinella* spp. and is acquired by ingesting meat containing cysts (encysted larvae). *Trichinella spiralis* is the classical causative agent.

In the phylum Apicomplexa, which contains parasitic protozoa propagated by spores, *Toxoplasma* is a related genus. Toxoplasmosis is caused by *Toxoplasma gondii*, which mainly infects warm-blooded animals, including humans.

CHEMICAL HAZARDS

Various chemical hazards may be present in feed. Some of them, such as dioxin and heavy metals are produced by industrial processes contaminating air, water and soil, and can be present in the environment. Others, such as mycotoxins are ubiquitously present in grains and grain

by-products. Plant toxins also occur ubiquitously in many parts of the world and are affecting animals and humans.

Persistent organic pollutants (POPs)

Persistent organic pollutants (POPs) are chemical substances that persist in the environment, bio-accumulate through the feed/food chain and may cause adverse effects to human health. They are ubiquitous and lipophilic, consequently they bioaccumulate in lipid rich tissues of animals.

Dioxins (PCDDs and PCDFs) and dioxin-like PCBs (dl-PCBs)

Dioxins is a generic term used for polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs). In practice, only the seven PCDDs and ten PCDFs with at least four chlorines and containing chlorines at all four positions 2,3,7 and 8 are relevant, since these tend to accumulate in the food-chain and the human body. Twelve PCBs, containing at least four chlorines and none (non-ortho) or just one (mono-ortho) chlorine at the ortho-position, have properties that are very similar to the more persistent PCDD/Fs. These polychlorinated biphenyls (PCBs) are termed dioxin-like PCBs (dl-PCBs).

Dioxins, including PCDDs, PCDFs and dl-PCBs are pervasive in the environment. Although dioxins and dl-PCBs show similarities in their toxicological and chemical behaviour, their sources are different.

PCBs, including dl-PCBs, were produced intentionally and in considerable amounts between the 1930s and 1970s and were used in a wide range of applications. PCBs are still in use in existing closed systems and contained in solid matrices (e.g. sealing materials and electrical capacitors). Certain commercial PCBs are known to be contained with PCDFs and could therefore be regarded as a potential source of dioxin contamination.

Today, release of dl-PCBs occurs from leakages, accidental spills and illegal disposal and through emissions via air from thermal processes. Migration from sealants and other old matrix applications are of minor importance.

Hazard	Endoparasites
Sources	<i>Taenia</i>: Ingesting eggs (larvae) coming from undercooked meat such as pork or beef. <i>Diphyllobothrium</i>: Consumption of infected fish. <i>Echinococcus</i>: Ingesting eggs from contaminated food, water, or soil, or by direct contact with animal hosts. <i>Trichinella</i>: Consumption of infected raw or poorly cooked meat; horse and game meat are reported as secondary food vehicles. <i>T. nativus</i> has been noted to occur in the meat of carnivores such as polar bears and walruses. <i>Toxoplasma</i>: Consumption of raw or undercooked meat, especially pork or mutton, yet game meat (red meat and organs) have also been reported. Fresh produce, seafood, and dairy products have been reported as secondary food vehicles.
Transfer to food of animal origin	Medium
Potential impact on human health	High

Source: adapted from FAO, WHO, 2019d

Dioxins are also formed as unwanted by-products from several human activities including certain industrial processes (e.g. production of chemicals, metallurgical industry) and combustion processes (e.g. waste incineration). Accidents at chemical factories have been shown to result in high emissions and contamination of local areas. Other dioxin sources include domestic heaters, agricultural and backyard burning of household wastes. Natural processes such as volcanic eruptions and forest fires can also produce dioxins.

When released into the air, dioxins can deposit locally on plants on soil, thus contaminating feed. Dioxins can also be widely distributed by long-range atmospheric transport. The amount of deposition varies with proximity to the source, plant species, weather conditions and other specific conditions (e.g. latitude, altitude, temperature).

The bulk of human dietary intake of dioxins and dl-PCB is due to the deposition of these substances in the lipid component of food of animal origin (e.g. poultry, fish, eggs, meat and milk). In lactating animals, dioxins and dl-PCBs are excreted partly with milk fat, and in laying hens the contaminants are concentrated in the fat portion of the yolk in laid eggs. To reduce this transfer, control measures at the feed and feed ingredients level should be considered with the application of good agricultural, feeding, and manufacturing and storage practices. The Codex Alimentarius Code of Practice on Good Animal Feeding addressed practices to be applied in the commercial and on-farm production of feed (FAO, WHO, 2008a). Measures to reduce dioxin and PCB levels in feed would have a significant effect on their concentrations in food of animal origin originating from farm animals, including farmed fish. Such measures may include: (FAO, WHO, 2018)

- identification of possibly contaminated areas in the feed supply ecosystem
- identification of the origin of frequently contaminated feed or feed ingredients
- monitoring the compliance of feed and feed ingredients with nationally established guideline levels or maximum levels, if available.

At levels of exposure much higher than those occurring in food, these compounds may cause cancer and they were

classified as carcinogens by the International Agency for Research on Cancer (IARC), but not genotoxic (FAO, WHO, 2019d).

Addressing the food safety risks posed by dioxins and dl-PCBs in feed, requires information on the lipid content of the feed and on the congener profile of these hazards in the feed, which impacts their transfer from feed to food. In general, once absorbed, some congeners are metabolized, thus altering the congener profile. Dioxins and dl-PCBs are only slowly eliminated and as such, levels found in food are dependent on the levels in feed and the duration of exposure. Accumulation of dioxins in liver is particularly important in the case of sheep and goats (FAO, WHO, 2019d).

Non dioxin-like PCBs (ndl-PCBs)

Ndl-PCBs are man-made chemicals produced as mixtures with different chlorination grade called e.g. Aroclors, Kaneclors or Clophens. Due to their much higher levels and hence more simple detection, ndl-PCBs have been monitored longer than dioxins. This refers in particular to the more abundant congeners, formerly termed indicator ndl-PCBs (PCBs 28, 52, 101, 118, 138, 153, 180). PCB 118 is a mono-ortho PCB and actually considered a dl-PCB. In European Union legislation, this PCB was therefore removed from the set and the remaining 6 PCBs are now termed non dioxin-like or ndl-PCBs. The six ndl-PCBs make up only part of the total PCBs in the various mixtures applied in the past. Due to the widespread use and contamination of the environment, ndl-PCBs can be detected in feed at low levels of magnitude of µg/kg feed (FAO, WHO, 2019d).

Ndl-PCBs were produced as technical mixtures and used in electrical transformers, heat exchange equipment and also in certain paints and coatings. Due to their persistence in the environment, the production of ndl-PCBs was stopped but for the same reason, they are still around and may enter the feed/food chain. Burning of the PCB-oil results in the formation of PCDFs. Also, certain building materials can be contaminated with ndl-PCBs. The use of sewage sludge as fertilizer may contaminate the soil and plants. In the case of dioxins and dl-PCBs, fish meal and fish oil may contain relatively high levels of ndl-PCBs, and as a result also feed used in aquaculture. A decrease in

Hazard	Dioxin and dl-PCBs
Sources	Anthropogenic and natural; elevated environmental levels in plants and soil in industrial areas; fishmeal and fish oil produced using fish harvested from contaminated areas; clay minerals; direct drying of feed ingredients, using inappropriate fuel.
Transfer to food of animal origin	High for milk and eggs. High for fish. Medium for meat of farm animals. High for livers.
Potential impact on human health	High

Source: adapted from FAO, WHO, 2019d

the levels has been observed with the increased awareness of the aquaculture industry, the use of fish meal and fish oil sourced from areas of low contamination, application of decontamination procedures and the change from fish ingredients to those of plant origin.

The Codex Alimentarius Commission adopted a revision of the Code of Practice for the Prevention and Reduction of Dioxins, Dioxin-like PCBs and Non-dioxin-like PCBs in Food and Feed to address ndl-PCBs and to update provisions particularly related to feed (FAO, WHO, 2018).

Mycotoxins

Mycotoxins are secondary metabolites produced by fungi of various genera when they grow on agricultural products before or after harvest or during transportation or storage. Some fungi such as *Fusarium* spp. typically infest grains before harvest; others such as *Penicillium* spp. can invade grain after harvest, while *Aspergillus* spp. can grow on grains both before and after harvest. It is important to emphasize that the presence of the fungi does not necessarily imply that mycotoxins can be found. Conversely, the absence of fungi does not necessarily mean the absence of mycotoxins.

Both intrinsic and extrinsic factors influence fungal growth and mycotoxin production on a given substrate. The intrinsic factors include water activity, pH, and redox potential whereas extrinsic factors which influence mycotoxin production are relative humidity, temperature and availability of oxygen.

Mycotoxins can be found in feed and feed ingredients such as maize, sorghum grain, barley, wheat, rice meal, cottonseed meal, groundnuts, soybeans and other legumes. Most are relatively stable compounds and are not destroyed by processing of feed and may even be concentrated.

Different animal species metabolize mycotoxins in different ways. In pigs, ochratoxin A can undergo entero-hepatic circulation and is eliminated very slowly while it is rapidly excreted by poultry species. The polar mycotoxins such as fumonisins tend to be excreted rapidly.

Mycotoxins or their metabolites can be detected in meat, visceral organs, milk and eggs. Their concentration in food is usually considerably lower than the levels present in the feed consumed by the animals and unlikely to cause acute intoxications in humans. However, residues of

carcinogenic mycotoxins, such as aflatoxin B1 and M1 and ochratoxin A when present in food of animal origin pose a threat to human health and their levels should be monitored and controlled. When aflatoxin B1 contaminated feed is consumed by milk producing animals, like dairy cows, goats and sheep, the mycotoxin can be metabolized in the animal's body, and is excreted as aflatoxin M1 in the milk. Although less potent than aflatoxin B1, aflatoxin M1 is also a carcinogenic compound.

Aflatoxins are found regularly in commodities produced in tropical and subtropical regions, such as peanuts, and maize. Aflatoxin contamination is most common in African, Asian and South American regions, but also occurs in the warmer areas of North America and Europe.

Ochratoxin A is produced by *Penicillium* and *Aspergillus* species in multiple plants. Affected commodities include cereal grains and their finished products, pulses and nuts.

Ochratoxin A is fat soluble and can be found in blood. This toxin is mainly stored in kidney and liver and is transferred into food of animal origin, but this transfer is generally low. Ochratoxin may also be transferred to eggs, especially when feed contamination reaches high levels.

Fusarium mycotoxins commonly occur in small grain cereals, like wheat, barley and oats, as well as in maize or in soybeans. The plant is infected during pre-harvest and mycotoxins are produced mainly during the field period.

Transfer of *Fusarium* mycotoxins in the animal's body to food of animal origin like meat, eggs, liver and milk is very limited, as are the consequences for human health via these routes. An exception may be α -zearalanol (zearanol), a metabolite of zearalenone (ZEN), which has been detected in milk of dairy cows.

Grain-fed animals are more exposed to different mycotoxins when comparing to grazing animals. Also, some fungi produce more than one mycotoxin and some mycotoxins are produced by more than one fungal species.

Co-contaminated samples with higher concentrations might exert adverse effects due to synergistic interactions of the mycotoxins. Emerging mycotoxins and masked mycotoxins may also contribute to the overall toxicity of the feed and their presence is frequently detected with multi-mycotoxin liquid chromatography-mass spectrometry (LC-MS/MS).

Hazard	Non-Dioxin like PCBs
Sources	Anthropogenic; technical PCB-mixtures for electrical transformers, heat exchange equipment, etc.; paints and coatings; fishmeal and fish oil produced using fish harvested from contaminated areas; direct drying of feed ingredients, using inappropriate fuel; pieces of old paints and sealants; leaking of equipment.
Transfer to food of animal origin	High for milk and eggs. High for fish. Medium for meat and tissues of farm animals.
Potential impact on human health	Unclear due to mixtures with PCDFs and dl-PCBs.

Source: adapted from FAO, WHO, 2019d

Since by-product feed, such as bran, straw, distiller's dried grains with solubles (DDGS), often concentrate the mycotoxins of the original substrate, they contribute excessively to the overall contamination of feed and therefore need special attention.

The trichothecene mycotoxins, which include deoxynivalenol (DON), zearalenone (ZEN), nivalenol (NIV) and T-2/HT-2 toxins, are found in multiple cereal grains. DON is the most regulated trichothecene in feed ingredients worldwide. Maize (and derived products) grown in temperate climate zones can contain DON and ZEN, whereas maize from sub-tropical areas is more often contaminated with fumonisins and aflatoxins, especially after drought stress and/or insect damage. The highest concentrations of ZEN were reported for wheat bran, maize and products thereof (e.g. maize flour, corn flakes). Silage and forage are significant sources of ZEN.

Ergot alkaloids are produced by *Claviceps* fungi that occur in various small cereal grains, in which they appear as sclerotia in the developing ears. Ergot alkaloids occur in various feeds, at varying levels, mainly in cereal grains and cereal by-products, and rye, sorghum and millet and by-products derived from them.

Mycotoxin contamination during feed and feed ingredients production depends on local weather conditions. Therefore, the presence of fungi and mycotoxins originating from plant infection can never be fully prevented. With the current climate changes trends (global warming, non-conventional rain, severe droughts and unexpected flooding) in different areas around the world, the overall conditions for production of pre-harvest mycotoxins can be reached more frequently. Other causes of increased mycotoxin contamination could be due to long-term distance transport, increased shipment size and long duration storage of large batches.

The toxic effects of feed contaminated with aflatoxins can be decreased by ammoniation. Another procedure that has shown promise is ozonation. Binders can be added

to feed and feed ingredients to reduce bioavailability of mycotoxins in the digestive tract. Mineral adsorbents such as mineral clays are often used to bind aflatoxins and other mycotoxins. Activated carbon, binders based on yeast and mannanoligosaccharides are also applied.

Plant toxins

Plant toxins are metabolites produced by the plants with a wide range of toxicity to animals and humans.

While some plants occur ubiquitously around the world (i.e. *Solanum* spp., *Lolium* spp.), others are restricted to certain geographical areas, such as *Indigofera* spp. that occur in tropical and subtropical regions. *Euphorbia helioscopia* or *E. nubica*, in Africa results in poisoning the dams as well as their suckling kids. Moreover, susceptibility between animal species (considering age, size, sex and physiological stage) can differ depending on the chemical nature of the toxins, the amount and type of the toxin eaten (i.e. alkaloids, solanines, saponins, oxalates, glycosides, gossypol, etc.), parts of the plant eaten (whole, leaves, roots, seeds), the maturity stage of the plant, and the environmental and geographical area of the plant, which means that issues connected to plant toxins can be very local. Concentrations of plant toxins can vary among the season (rainy or dried) and between years, making estimations difficult.

The most important plants involved in oxalate intoxication of ruminants include halogeton (*Halogeton glomeratus*), soursob (*Oxalis* spp.), rhubarb (*Rheum raphaniticum*), curly dock (*Rumex crispus*), purslane (*Portulaca oleracea*), lamb's quarter (*Chenopodium album*), bassia (*Bassia hyssopifolia*), greasewood (*Sarcobatus vermiculatus*), pigweed (*Amaranthus* spp.), Russian thistle (*Salsola kalis*) and sugar beets (*Beta vulgaris*). Species of grasses in the genus of *Cenchrus*, *Panicum* and *Etaria* which are widely cultivated in tropical and subtropical areas can also accumulate toxic amounts of oxalate. Other plants causing liver disease and photosensitization (sensitivity to sunlight) are often grouped together, as

Hazard	Mycotoxins
Sources	Aflatoxin: maize, groundnuts, sunflower products, copra. Ochratoxin A: cereal grains, pulses, nuts. <i>Fusarium</i> mycotoxins: wheat, barley, oats, maize, maize gluten feed, soya hulls. Ergot alkaloids: rye, sorghum, tall fescue.
Transfer to food of animal origin	Medium for aflatoxin B1 to milk (as for aflatoxin M1) Low for aflatoxin B1 to eggs, meat, etc. High for ochratoxin A in blood/serum. Medium for ochratoxin A in kidney and liver. Low for ochratoxin A in other products. Low for <i>Fusarium</i> mycotoxins. Low for ergot alkaloids.
Potential impact on human health	High for aflatoxin M1 in milk. Inconclusive for ochratoxin A in kidney/liver. Not applicable for other mycotoxins, except maybe α -zearalenol (zearanol) in milk.

Source: adapted from FAO, WHO, 2019d

photosensitivity is often a secondary symptom of liver disease caused by poisonous plants (*Allium* spp., *Hypericum perforatum*). Other plants contain pyrrolizidine alkaloids (PAs), causing muscle degeneration, liver necrosis, death (*Thermopsis rhombifolia*, *Amsinkia intermedia*, *Senecio* spp., *Symphytum* spp.) or contain neurotoxins as piperidine alkaloids (e.g. *Conium maculatum*). Other plants contain cyanogenic glycosides compounds that are converted to hydrogen cyanide or prussic acid causing neuronal disorders lack of coordination and death (i.e. *Acroptilon repens*, *Centaurea solstitialis*).

The main route of exposure of animals to plant toxins is through grazing or consumption of plants such as *Brassica* leaves, hay and silage of plants such as *Colchicum autumnale*, *Senecio jacobaea*, *Equisetum* spp., *Tiiglochin* spp..

Pastures often contain weeds that are potentially dangerous to livestock. The toxic compounds in plants are usually a defense mechanism against predation and have a distinct, unpleasant odour or a bitter taste and are not preferentially grazed. Consumption of unpalatable plants will increase under some circumstances, primarily if other forage is not available. Some plants, like those that accumulate nitrates (i.e. *Sorghum bicolor*, *Sorghum halapense*, *Chenopodium* spp., *Amaranthus* spp.) can increase in toxicity after rainfall or on cool, cloudy mornings and evenings.

Toxin-producing plants may occur in grasslands used as forage. Naturally occurring toxins can include PAs (e.g. jacoline from *Senecio jacobaea*) and other alkaloids (e.g. atropine, cocaine, ephedrine, morphine, nicotine, solanin), terpenes (e.g. camphor, pinene), tetrahydrocannabinol, gossypol, isoflavones, and glycosides (e.g. cyanogenic glycosides, digitalis), glucosinolates, ricin, theobromine, tropane alkaloids and saponins. Transfer of some of these toxins to food such as milk and meat has been demonstrated.

The Codex Alimentarius Code of Practice for the Prevention and Reduction of Pyrrolizidine Alkaloid Contamination in Food and Feed addresses this contaminant with regard to weed control. Management practices to reduce exposure of food-producing animals to PA containing plants (livestock and bees) and management practices to reduce presence of PAs in commodities (raw and processes) may be added in future when more information on existing practices and their efficacy will become available. (FAO, WHO, 2014b).

Pesticides residues

Pesticide residues refer to any specified substance in food, agricultural commodities, or feed resulting from the use of a pesticide. In the Codex Alimentarius Database of Pesticides Residues in Food and Feed (FAO, WHO, 2019b), information can be obtained on Codex Alimentarius maximum residue limits (MRLs or CXLs) and Codex Alimentarius extraneous maximum residue limits (EMRLs) for pesticide and commodity combinations. The names and definitions of commodities can be found in the Codex Alimentarius Classification of Foods and Animal Feeds including the groups and subgroups on which group MRLs are based on (FAO, WHO, 1993). Pesticide residues may constitute a significant source of contamination of environmental factors such as air, water and soil. Residues of pesticides might be associated with the feed ingredients of plant origin, such as grains. Pesticides are a group of chemicals used for the destruction or control of insects, weeds, fungi, bacteria, etc. Their primary classes are fumigants, insecticides, fungicides, bactericides, herbicides or rodenticides. Most of the pesticides have the ability to destroy a wide variety of pests or weeds, but some are developed against specific pests or pathogens. The characteristics of pesticides, such as high lipophilicity, bioaccumulation, long half-life and potential of long-range transport, have increased the chances of contaminating the environment, even after many years of application.

Organochlorine (OCs) residues

Major representatives of the group of organochlorine pesticides (OCs) are dichlorodiphenyltrichloroethane (DDT), lindane (γ -HCH), α - and β -HCH, aldrin and dieldrin, endrin, chlordane, heptachlor, toxaphene (camphechlor), hexachlorobenzene (HCB) and endosulfan. These substances have been used extensively in the past as insecticides and are mostly present as environmental contaminants. Endosulfan is one of the few organochlorine pesticides that is still in use in some countries although in 2011 endosulfan was added to the list of persistent organic pollutants to be eliminated worldwide. The dominant toxic effects of OCs are to the nervous system and the liver.

There is limited and declining use of OCs for plant protection in developing countries. DDT is still used in some

Hazard	Plant toxins
Sources	Plants consumed by the animals while grazing, preserved roughages (e.g. hay), grain, feed and feed ingredients, by-products from the bio-fuel production (e.g. rapeseed meal). Note: Plants and toxins of concern may be very different in various regions of the world.
Transfer to food of animal origin	Some toxins with genotoxic and carcinogenic properties show transfer to meat, milk and eggs. This has been reviewed for pyrrolizidine alkaloids (PAs). The rate of transfer depends on the type of PA.
Potential impact on human health	Low/medium

Source: adapted from FAO, WHO, 2019d

areas to control the spread of malaria by mosquitoes. OCs are often found in feed due to their persistence in the environment. Highest levels generally occur in fats and oils of animal and plant origin. OCs are generally fat soluble and transfer to fatty tissues, liver, eggs and milk. Some of the OCs bioaccumulate in animal tissues. Sources of pesticide residues in feed include pesticide-treated plants and deliberate addition of pesticides to control various pests, including substances used in pesticide formulations (carriers, aggregates, additives), off-target movement of sprays, use of grain treated prior to seeding with fungicides or insecticides but subsequently (accidentally) utilized in feed and the use of feed prepared from treated plants in ways not envisaged by the regulators approving plant use (e.g. use of fruit and vegetable culls).

Veterinary drug residues

Veterinary drugs are administered to animals for preventative or therapeutic purposes or for growth promotion. The most practical way of administering drugs to a large number of animals is to incorporate the approved veterinary drugs into feed.

Residues of veterinary drugs can be present in feed as a result of the carryover in feed during feed production and when ingredients of animal origin (terrestrial and aquatic) are used. In addition, antibiotics used in the fermentation

process to control biological contamination during the production and processing of certain feed ingredients (e.g. vitamins, DDGS, insects) can also be a source of contamination.

If carryover is not properly managed, contaminated feed can directly harm species that are sensitive to the unintended veterinary drug they consume, resulting in residues in food of animal origin such as meat, milk and eggs that render them unsafe for human consumption and contribute to AMR (FAO,WHO 2019e).

Potentially toxic elements (PTEs)

Some minerals are essential for health and productivity of animals and have well defined nutritional and biochemical roles. Many other minerals naturally occur at trace levels in the food and tissues of animals but are not typically suspected to play a useful nutritional purpose and are considered incidental contaminants.

Animals may be exposed to potentially toxic elements from a wide variety of sources. Feed and feed ingredients, especially those derived from plants, are a common source of potentially toxic levels of minerals. Mining, smelting and other industries are often associated with local areas of mineral contamination to the water, soil and air, and, ultimately, the plants grown in that area. Feed and feed ingredients of animal origin may also be sources of toxic levels of minerals e.g. fishmeal.

Hazard	Organochlorine pesticides residues
Sources	Anthropogenic; Environmental contamination; Fatty feed ingredients of animal origin, especially fish derived products such as fish oil; Improper disposal of chemical wastes; For endosulfan, vegetable oils are a main contributor to dietary exposure.
Transfer to food of animal origin	High for DDT, β -HCH, aldrin, dieldrin, endrin, heptachlor, HCB. Medium for lindane, α -HCH, chlordane. Low for endosulfan. Variable for toxaphene.
Potential impact on human health	High - important representatives have been classified as Group 1, 2A or 2B-carcinogen.

Source: adapted from FAO, WHO, 2019d

Hazard	Veterinary drugs residues
Sources	Anthropogenic (therapeutic, prophylactic and growth promotion) and natural (produced by micro-organisms). Cross-contamination from medicated feed (e.g. accidental, in production plant). Feed produced from animals or plants previously exposed to antibiotics. Wastewater and excreta contaminated with residues, exposure of cultured fish. Antibiotics used in processes of which products can be used as feed (e.g. industrial fermentation processes such as for biofuel production from agricultural commodities).
Transfer to food of animal origin	Usually high for kidney and liver of terrestrial animals (withdrawal times not respected in case of accidental feed contamination). Variable (low-high) for other food products (e.g. milk, eggs).
Potential impact on human health	Low for most antibiotics. Low for coccidiostats.

Source: adapted from FAO, WHO, 2019d

Mineral supplements are commonly added to animal diets to correct deficiencies found in pastures, forages and other dietary ingredients. Some mineral supplements may contain potentially toxic levels of minerals, depending upon the source of the supplement and the method of its processing. Toxic levels of minerals may accidentally occur due to mistakes in feed formulation and manufacturing or from contamination during storage or transportation.

Often animals can serve as an important buffer for the high mineral concentrations found in some plants or supplements, thereby reducing human exposure to potentially toxic minerals. However, levels of some minerals may accumulate in animal tissues intended for human consumption to concentrations that might adversely affect human health.

Arsenic

Inorganic arsenic compounds are highly toxic; whereas organic arsenic compounds are much less so. Toxicity also depends on the valency of arsenic; trivalent arsenic is more toxic than pentavalent arsenic. Inorganic arsenic is classified by the IARC as a human carcinogen.

Arsenic levels vary greatly but are generally high in marine organisms including fish. However, there are many chemical forms of arsenic in fish, and the dominant form in fish is arsenobetaine, which is considered non-toxic to humans and is excreted rapidly, unmetabolized. Concentrations of arsenic in feed reflect the amount and source of fish meal included. Groundwater aquifers in some areas of America and Asia have naturally high levels of arsenic. These chemicals enter the feed/food chain and are present in water and air. Arsenic levels in feed and feed ingredients of plant origin depend on their levels in the soil and their characteristics, the arsenic compound(s) present, plant species and arsenic levels in water used for irrigation. Exposure of animals to inorganic arsenic via drinking water is much higher than via feed in those areas where naturally polluted ground water sources are used.

Transfer of inorganic arsenic from feed to food of animal origin is low. In mammals, inorganic arsenic is metabolized into organic arsenic. The contribution of food of terrestrial animal origin to human exposure to arsenic is considered insignificant.

Cadmium

Cadmium causes adverse effects in kidneys, skeleton and the respiratory system in humans and animals.

Levels of cadmium in feed of plant origin depend on levels in soil, soil characteristics, use of phosphatic fertilizers and plant species. Mineral supplements, such as zinc oxide, have occasionally be shown to contain unacceptable cadmium levels.

Transfer of cadmium to muscle of livestock is generally low, whereas significant levels can occur in crustaceans. Cadmium present in feed ingredients and ingested soil accumulates in the kidneys and liver of livestock. As the elimination of half-time of cadmium in livestock is very long, the duration and level of exposure determine levels in these organs.

Mercury

Organic mercury, mainly methylmercury, is far more toxic than inorganic mercury. The critical effect of inorganic mercury is kidney damage. Organic mercury main adverse effects are on the nervous system. Methylmercury is bio-magnified up the marine feed/food chain, and highest concentrations are found in predatory, large fish.

Fishmeal is an important contributor of methylmercury in feed. Bait fish may be a significant source of methylmercury for certain marine culture predatory fish such as tuna. Methylmercury levels in plant-based feed are very low.

Levels of methylmercury in farm animals are usually at or below the limit of quantification (LOQ).

Hazard	Arsenic	Cadmium	Mercury	Lead
Sources	Anthropogenic and natural, environmental contamination, ingredients of animal origin, especially fish meal, animals drinking water, water for irrigation.	Industrial, environmental contamination, anthropogenic and natural, some fertilizers, cadmium-containing water for irrigation.	Anthropogenic, industrial and environmental contamination. Bait fish for predatory fish, fishmeal in aquaculture salmonids.	Anthropogenic and natural, environmental contamination.
Transfer to food of animal origin	Low for mammals, poultry and fish.	Low for muscle of livestock and fish, significant levels can occur in crustaceans. Low or absent for milk and eggs.	High for large fish.	Low for milk and meat. Low for kidney, liver or muscle of sheep.
Potential impact on human health	Insignificant.	Low	High for organic mercury, mainly methylmercury.	High for children. Low for adults.

Source: adapted from FAO, WHO, 2019d

Lead

Lead affects neurodevelopment and acts on the nervous system and gastrointestinal tract. The major source of lead exposure to grazing animals is ingestion of soil. Mineral supplements such as zinc oxide, have occasionally been shown to contain unacceptable lead levels. In terrestrial species lead accumulates in bones, kidney and liver, whereas transfer of lead to animal muscle and milk is generally low.

Other potentially toxic elements

Other elements such as selenium, chromium, copper and nickel may be of concern depending on the type and level of contamination in feed.

PHYSICAL HAZARDS

Physical hazards can be defined as those that can be introduced into feed and feed ingredients via the manufacturing process, storage and transport. Except for some rare examples (e.g. the migration of inks into food), physical hazards do not transfer to animal tissues and as such should not be of concern for food safety.

Radionuclides

Radionuclides are hazards of a physical nature that may pose a food safety risk. Of specific importance are caesium-134, caesium-137, strontium-90 and iodine-131 present in feed (including forages) which may transfer to food. Major sources include contaminated soil, water and forage. Transfer of radioiodine to milk, radio-strontium to bone, and radio-caesium to milk, eggs and meat has been demonstrated. Considerations for a risk assessment include the half-life of the radioactive elements and its toxicokinetics. Radioactive iodine disappears in a relatively short time with a half-life of 8 days. Biological half-life of forms of caesium is longer than 60 days. Approximately 90 percent of radioactive caesium in feed consumed by animals is excreted in faeces and urine, the remainder is excreted in milk or remain in muscle. Radioactive substances distributed in muscles can be excreted gradually by feeding cattle with non-contaminated feed.

Nanomaterials

Some feed additives can have the form of nanomaterials and their risk is under investigation. Some examples include mycotoxin binders, delivery vehicles for trace elements and vitamins, and as carriers for nutrients.

Because of their small size, nanomaterials can exhibit different physico-chemical properties and biological effects compared to their respective bulk materials. Very limited information is available on the potential transfer of nanomaterials from feed to food. There remains a lack of reliable characterization data of the nanomaterial in the product and inadequate material characterization in the

toxicological studies performed. The risk assessment of nanomaterials still heavily relies on animal studies.

Environmental contamination of nanoparticles may result in animal exposure, including fish in aquatic environments. The physical properties of these particles may act as a carrier to increase animal exposure to other contaminants to animals.

HAZARDS OF FEED AND PRODUCTS OF FEED PRODUCTION TECHNOLOGIES OF INCREASING RELEVANCE

New feed ingredients such as insects, algae, krill, other marine resources, as well as by-products from the agro-food and biofuel industries and even from industrial processes are being used in the production of feed.

Their use can present new challenges for feed safety and bring concerns about the hazards which may be introduced through the materials that are used in their processing. The safety of the new feed and feed ingredients can be determined by identifying all incoming material used to produce the feed and their potential hazards, understanding the manufacturing process and by a risk characterization of the final product. All steps of the manufacture of these ingredients need to be considered including all processing aids used to treat or collect the material (FAO, WHO, 2019d).

Insects

There are more than 1900 edible species of insects. In the future, insects are expected to attract more and more interest as an alternative protein source, produced commercially and in large amounts for feed production. Insects may be able to partially replace traditional feed ingredients very rich in proteins fishmeal or rich in energy like other animal fats. They may also to a lesser extent replace other less concentrated feed ingredients such as soy, maize, grains

The most important insects produced for feed and food are crickets, mealworms, flies and silkworms. Insects with the largest immediate potential for large-scale feed production are larvae of *Hermetia illuscens* (black soldier fly), *Musca domestica* (common housefly) and *Tenebrio molitor* (yellow mealworm).

Insects and insect-derived products used as feed ingredients are marketed as (i) whole insects; (ii) processed into e.g. a powder or paste; (iii) as an extract such as a protein isolate or fat/oil.

Former food products and food processing by-products

There is a worldwide trend to increase the recycling and reuse of former food products and food processing by-products into the feed/food chain and this may lead to a greater presence of hazards in feed.

Former food products can include materials that remain after, or are produced during the processing, manufacture, preparation or sale of food, at any point of the food supply chain and collected at restaurants, retail, or from household food scraps (e.g. food that passes the expiry date, with mislabelling, packaging damage; kitchen and catering waste). Most of the time, their traceability cannot be ensured.

Food processing by-products are specific types of former food collected from food processing plants (e.g. misshaped food or unsold surplus) whose traceability is easier to ensure. If not clearly separated from other residues; they may include production material not intended as edible material (FAO, WHO, 2019e).

Biofuel by-products

The increasing production of environmentally friendly biofuels yields by-products that may be used as feed. For instance, DDGS and wet distiller's grain (WDG) are protein feed ingredients from the bioethanol production. Crude

glycerol from bio-diesel production is an energy source in feed and plant press cakes/meals from bio-diesel production are other protein rich feed ingredients.

Other industrial by-products

The use of by-products from industrial processes as feed is increasing and could lead to the presence of new hazards. The entire industrial manufacturing process must be considered to identify hazards which may be present in the by-product used as a feed ingredient. Many mineral feed ingredients originate from industrial processes: for example, lime from kiln dust; copper reclaimed from circuit boards and batteries; zinc oxide from waste sites, etc. New fatty acid ingredients are produced from the further processing of residual material of vegetable oils production. New cellulose ingredients are derived from wood processing pulp and paper.

These new production processes may cause the presence of unacceptable level of residues of heavy metals, dioxins, furans, PCBs and new processing chemicals in feed ingredients.

Hazard	Insects
Potential hazards	General: The presence/level of potential hazards strongly depends on the substrates used, the insect species, the harvest stage, the farming and harvesting conditions and post-harvest processing. • Biological: pathogenic bacteria, viruses, prions. • Chemical: chemical contaminants, such as heavy metals, dioxins, veterinary drug residues, pesticide residues, mycotoxins, plant toxins, insect toxins. - The limited data available indicate that insects may accumulate heavy metals, in particular cadmium, from their substrates; accumulation of mycotoxins seems unlikely. For the other chemicals too few data are available to draw conclusions. • Other: allergic proteins
Potential human health impact and feed-animal transfer	Due to lack of scientific data, it is difficult to fully evaluate the potential impact on human health at this time.

Source: adapted from FAO, WHO, 2019d

Hazard	Former food products
Potential hazards	Chemical: • Specific for former food products: - Plasticizers or dispersants as part of packaging material, which can diffuse into the packed food material. Phthalates are the most common group. - Certain raw materials for plastic production are classified as endocrine disruptors (e.g. bisphenol A). - Some printing inks isopropylthioxanthone (ITX) show toxic properties. - Acrylamide and semicarbazide in bakery waste. Other hazards: • Dioxins, potentially toxic elements and mycotoxins. Physical: • Remnants of packaging materials.
Potential human health impact and feed-animal transfer	Chemical: • See impacts for hazards such as dioxins, potentially toxic elements and mycotoxins. Physical: • See impact of nanomaterials.

Source: adapted from FAO, WHO, 2019d

Hazard	Biofuel by-products
Potential hazards	Chemical: • DDGS/WDG: - Mycotoxins, including aflatoxins, ochratoxin, fumonisins, deoxynivalenol, nivalenol, T-2 and HT-2-toxin, zearalenone and ergot alkaloids; co-occurrence of several mycotoxins is frequently found. - Residues of antibiotics, such as virginiamycin, streptomycin, ampicillin, penicillin, erythromycin, tylosin, monensin and tetracycline. Crude glycerol: • methanol • sodium Plant press cakes: • Plant toxins, e.g. phorbol esters in <i>Jatropha curcas</i> kernel meal, ricin in castor cake (<i>Ricinus communis</i> L.).
Potential human health impact and feed-animal transfer	Chemical: • DDGS/WDG: - Mycotoxins - Residues of antibiotics: (i) the concentrations are relatively low and consequently the risk that residues of the antibiotics will end up in food of animal origin are very low. Nevertheless, these low contents could potentially contribute to the development of antibiotic resistance; (ii) inclusion of DDGS in medicated feed could give rise to drug interactions that could lead to potential hazards, but the risk is considered low due to the low concentrations of the antibiotics.

Source: adapted from FAO, WHO, 2019d

Hazard	Aquatic products of plant origin
Potential hazards	Chemical: • Inorganic: - Iodine, which can be present at high levels in macro-algae (seaweed). - Arsenic, of which both the organic and inorganic (particularly toxic) forms concentrate in seaweeds (e.g. Hijiki) and microalgae. - Other heavy metals, particularly cadmium, since these are taken up by algae from water. • Organic: - Environmental residues of pesticides and other persistent organic pollutants, such as dioxins, lectins, phlorotannins and other phenolics, naturally produced by seaweeds. - Organic forms of heavy metals, e.g. methylmercury. - Polycyclic aromatic hydrocarbons (PAH). - Toxins from toxin-producing microalgae (e.g. harmful algal blooms) adventitiously present in aqueous environment, e.g. co-harvested with macroalgae. Biological: • Bacterial pathogens such as faecal zoonotic pathogens. Such pathogens could originate, for example, from run-off and discharge feed into estuarine waters, which can then be taken up by algae acting as reservoir. This would particularly also apply to the case of microalgae being used for wastewater treatment. Physical: • Micro- and nanoparticles taken up from aqueous (e.g. marine) environment.
Potential human health impact and feed-animal transfer	Chemical: • Same as previously mentioned for, heavy metals, organic pollutants and nanoparticles. • Iodine in seaweed: - May cause hyperthyroidism in humans. - Transfer to food (e.g. milk and eggs) will occur to a substantial extent. Biological: Pathogens transferred from nutrient sources (e.g. manure, wastewater) used in micro-algal conversion to products or by-products used as feed. Physical: Inconclusive with few data on uptake and on toxicity in target livestock species.

Source: adapted from FAO, WHO, 2019d

Aquatic products of plant origin

Aquatic plants live both in saltwater and freshwater. Recently, interest has increased for the cultivation and feed use of plants such as duckweed (Lemnoideae family encompassing the *Landoltia*, *Lemna*, *Spirodela*, *Wolffia* and *Wolffiella* genera).

Algae are a large and biologically diverse group of non-flowering plants growing in fresh water and marine environments. The three main groups are brown, red and green algae. Current utilization of algae is primarily as food, however utilization as feed ingredients is increasing. A different group, blue-green algae, can produce a series of toxins and have currently only a limited application in the food sector.

Macro-algae (seaweed) are used as feed ingredients or feed additives (e.g. as iodine-rich supplement). Microalgae or their protein-rich biomass retained after oil extraction are also used as feed ingredients or additives (e.g. *Spirulina*, omega-3-PUFA-rich oil from microalgae).

Aquatic plants uptake the minerals from the surrounding waters, such as agricultural and industrial waste streams. Through removal of the minerals by the plants, they will concentrate these minerals, which will then be recycled via the use of harvested plants as fertilizer or feed. Moreover, they can be used to concentrate trace elements useful for animal nutrition. Under optimal conditions, the presence

of nitrogen-containing compounds (particularly ammonia) induces high protein levels valued for feed purposes.

Aquatic products of animal origin

Fishing activities have a significant output of side-products (others than by-products from fish processing such as fish oil or fish meal) that are not used as food but are processed into feed.

i) Bycatch: this includes species not relevant for human consumption or juvenile specimens that are not suitable for sale.

ii) Fish parts in wastewater from fish processing plants.

Both ingredients are hydrolysed and used as feed ingredients. Due to the process to produce fish hydrolysate, no major biological hazards are expected, provided that the feed ingredient is properly stored.

Fish hydrolysate could present chemical hazards (e.g. methylmercury, dioxins and other POPs) comparable to the more conventional feed ingredients, fish meal and fish oil. Differences in the concentrations of contaminants may be related to composition of feed ingredients, in terms of dry matter, protein and fat.

The use of the ocean bycatch may introduce nano- and microplastics in the feed hydrolysate: both kinds of particles are significantly present in marine, and especially ocean, environments as a result of plastic debris produced

Hazard	Aquatic products of animal origin
Potential hazards	Chemical: - Fish hydrolysates and silages: - Contaminants that bio-accumulate through aquatic feed/food chain (such as persistent organic pollutants including dioxins, PCBs, flame retardants, chlorinated pesticides) and others that tend to accumulate in fish (e.g. potentially toxic elements); - Preservatives and their impurities and metabolites, such as BHT and ethoxyquin that are used to prolong storability of fish hydrolysates and other feed ingredients of aquatic animal origin, and which can be transferred from feed to food of animal origin. Biological: - Fish hydrolysates and silages: Zoonotic pathogens present in ingredients such as dead fish from earth ponds, particularly those that can survive processing conditions, e.g. <i>Clostridium botulinum</i> (spore-forming). Physical and other: - Fish hydrolysates and silages: Nano and microplastics: may be transferred to tissues of marine organisms used as feed ingredients.
Potential human health impact and feed-animal transfer	Chemical and biological: - Same as previously mentioned for persistent organic pollutants (including dioxins, non-dioxin-like PCBs, organochlorine pesticide residues) and potentially toxic elements, and spore-forming microorganisms. - Fluorine in krill: - Transfer to food of animal origin is low and does not contribute significantly to consumer exposure. Physical: - Inconclusive and only limited data, e.g. on uptake and toxicity of micro- and nanoplastics in target livestock species.

Source: adapted from FAO, WHO, 2019d

by shipping and fishing activities as well as from environmental release of plastic particles from packaging and other products. Trophic transfer of nano- and microplastics does take place from the marine environment through to fish, by-products from fish processing and fish hydrolysates. However, the two kinds of contaminants are quite different.

Microplastics have a size $> 1 \mu\text{m}$, thus, absorption in the fish organism and intracellular bio accessibility are very low or absent; however, they may end up in fish hydrolysates due to their presence in the gut content. Microplastics are unlikely to have any transfer from feed to tissues. Pollutants, e.g. heavy metals, may adhere to microparticles and be carried into the feed.

Nanoplastics might be bio accessible; a transfer from feed to food cannot be excluded. The small size (in particular when below 100 nm) results in two characteristics

of potential concern: i) the ability to enter into the cells and interact with macromolecules, including DNA, with toxicological effects are still to be properly investigated; and ii) the nanoparticles have a relatively wide surface, thus are able to catch and transport other molecules, including toxic contaminants such as POPs.

Due to fishing quotas and environmental concern, a steady increase in feed ingredients (mainly fishmeal and fish oil) produced from aquaculture has been witnessed.

Macroplankton crustacean populations called krill can also be a valuable source of feed, due to their high availability in the Antarctic and North Atlantic seas as well as nutritional properties, such as the high content of omega-3 fatty acids.

Krill organisms are at the bottom of the feed/food chain; thus, they are not expected to undergo a major bioaccumulation of toxic contaminants such as methylmercury.

SECTION 2

General principles and requirements

Feed and feed ingredients should be obtained and maintained in a stable condition so as to protect feed and feed ingredients from contamination by pests, or by chemical, physical or microbiological contaminants or other objectionable substances during production, handling, storage and transport. Feed should be in good condition and meet generally accepted quality standards. Where appropriate, Good Agricultural Practices (GAP), Good Manufacturing Practices (GMPs) and, where applicable, Hazard Analysis and Critical Control Point (HACCP) principles should be followed to control hazards that may occur in food. Potential sources of contamination from the environment should be considered.

Parties that produce feed or feed ingredients, those that rear animals for use as food and those that produce such animal products need to collaborate to identify potential hazards and their levels of risk to consumers' health. Such collaboration will enable the development and maintenance of appropriate risk management options and safe feeding practices.

Feed ingredients

Feed ingredients should be obtained from safe sources and be subject to a risk analysis where the ingredients are derived from processes or technologies not hitherto evaluated from a food safety point of view. The procedure used should be consistent with the Working Principles for Risk Analysis for Application in the Framework of the Codex Alimentarius. Manufacturers of feed additives, in particular, should provide clear information to the user to permit correct and safe use.

Monitoring of feed ingredients should include inspection and sampling and analysis for undesirable substances using risk-based protocols. Feed ingredients should meet acceptable and, if applicable, statutory standards for levels of pathogens, mycotoxins, pesticides and undesirable substances that may give rise to consumers' health hazards.

Labelling

Labelling should be clear and informative as to how the user should handle, store and use feed and feed ingredients. Labelling should be consistent with any statutory requirements and should describe the feed and provide instructions for use. Labelling or the accompanying documents should contain, where appropriate:

- information about the species or category of animals for which the feed is intended;
- the purpose for which the feed is intended;
- a list of feed ingredients, including appropriate reference to additives, in descending order of proportion;
- contact information of manufacturer or registrant;
- registration number if available;
- directions and precautions for use;
- lot identification;
- manufacturing date; and
- "use before" or expiry date.

Traceability/product tracing and record keeping of feed and feed ingredients

Traceability/product tracing of feed and feed ingredients, including additives, should be enabled by proper record keeping for timely and effective withdrawal or recall of products if known or probable adverse effects on consumers' health are identified. Records should be maintained and readily available regarding

the production, distribution and use of feed and feed ingredients to facilitate the prompt trace-back of feed and feed ingredients to the immediate previous source and trace-forward to the next subsequent recipients if known or probable adverse effects on consumers' health are identified.

Special conditions applicable to emergency situations

Operators should, as soon as reasonable, inform the competent authorities in the country if they consider that a feed or feed ingredient does not satisfy the feed safety requirements established in this Code. The information should be as detailed as possible and should at least contain a description of the nature of the problem, a description of the feed or feed ingredients, the species for which it is intended, the lot identifier, the name of the manufacturer and the place of origin. The competent authorities and operators should immediately take effective measures to ensure that those feed or feed ingredients do not pose any danger to consumers' health.

As soon as it becomes likely that a particular feed or feed ingredient is to be traded internationally and may pose a danger to consumers' health, the competent authorities of the exporting countries should notify, at least, the competent authorities of the relevant importing countries. The notification should be as detailed as possible and should at least contain the particulars indicated in the previous paragraph.

Inspection and control procedures

Feed and feed ingredients manufacturers and other relevant parts of industry should practice self-regulation/auto-control to secure compliance with required standards for production, storage and transport. It will also be necessary for risk-based official regulatory programmes to be established to check that feed and feed ingredients are produced, distributed and used in such a way that foods of animal origin for human consumption are both safe and suitable. Inspection and control procedures should be used to verify that feed and feed ingredients meet requirements in order to protect consumers against food-borne hazards. Inspection systems should be designed and operated on the basis of objective risk assessment appropriate to the circumstances. Preferably, the risk assessment methodology employed should be consistent with internationally accepted approaches. Risk assessment should be based on current available scientific evidence.

Monitoring of feed and feed ingredients, whether by industry or official inspection bodies, should include inspection and sampling and analysis to detect unacceptable levels of undesirable substances.

Feed additives and veterinary drugs used in medicated feed

Feed additives and veterinary drugs used in medicated feed should be assessed for safety and used under stated conditions of use as pre-approved by the competent authorities.

Veterinary drugs used in medicated feed should comply with the provisions of the Guidelines for the Design and Implementation of National Regulatory Food Safety Assurance Programmes Associated with the Use of Veterinary Drugs in Food Producing Animals.

Borderlines between feed additives and veterinary drugs used in medicated feed may be set to avoid misuse.

Feed additives should be received, handled and stored to maintain their integrity and to minimize misuse or unsafe contamination. Feed containing them should be used in strict accordance with clearly defined instructions for use.

Antibiotics should not be used in feed for growth promoting purposes in the absence of a public health safety assessment.

Feed and feed ingredients

Feed and feed ingredients should only be produced, marketed, stored and used if they are safe and suitable, and, when used as intended, should not represent in any way an unacceptable risk to consumers' health. In particular, feed and feed ingredients contaminated with unacceptable levels of undesirable substances should be clearly identified as unsuitable for animal feed and not be marketed or used.

Feed and feed ingredients should not be presented or marketed in a manner liable to mislead the user.

Recalls

Records and other information should be maintained as indicated in sub-section 4.3 of this Code to include the identity and distribution of feed and feed ingredients so that any feed or feed ingredient considered to pose a threat to consumers' health can be rapidly removed from the market and that animals exposed to the relevant feed can be identified.

Codex Alimentarius Code of Practice on Good Animal Feeding (CXC 54-2004)

FEED INGREDIENTS

The safety of feed ingredients is essential to produce safe feed, which in turn is critical to the production of food of animal origin.

The safety of feed ingredients should be assessed prior to their use in feed. Feed ingredients should be produced according to procedures that minimize potential hazards and promote appropriate product safety, meeting all applicable legislations. Any feed ingredient suspected of possible contamination should not be used in the production of feed, unless the hazard can be reduced or eliminated to an acceptable level during the feed manufacturing.

Worldwide, there are many different systems used by the feed industry to ensure the safety of the various feed ingredients. According to their regulations, some countries have:

- negative lists
- lists of ingredients that can be used under limitations
- exclusion lists for certain ingredients and their amounts
- positive lists that include ingredients that can be used according to limitations or intended uses.

Procurement of feed ingredients is one of the most important activities to ensure the production of safe feed. Purchasers should evaluate suppliers based on their ability to supply products in accordance with pre-established specifications. Purchasing specifications of feed ingredients should be clearly defined and agreed with suppliers.

Suppliers can be evaluated through supplier visits, supplier third party certification, purchase contracts, monitoring of the ingredient supplied upon receipt and a combination of these techniques. Suppliers approval programmes and controls of feed ingredients received are fundamental.

Criteria for the selection of suppliers should be determined, such as:

- requirements to become an approved or unapproved supplier
- requirements for a provisional supplier until fully approved
- approval of an existing supplier based on the company's purchasing experience
- approval of suppliers in emergency situations (e.g. business disruption of previously approved suppliers).

Ingredient specifications are of great importance in a feed safety system. Specifications are the basis for the agreements with suppliers, for the formulation of feeds, for the HACCP study and the derived controls to be implemented. Many of the potential hazards that are addressed in the HACCP system during feed production and processing are already present in the feed ingredients. Some of them will not be eliminated or reduced to the acceptable levels during feed processing and the main control measure should be based on purchasing requirements to acquire only safe feed ingredients.

The first principle of HACCP is meant to conduct a hazard analysis and identify the control measures. All potential hazards that are likely to occur and associated with each process step should be listed and a hazard analysis should be conducted to identify the significant hazards and consider any measures to control them. The process of collecting and evaluating information on hazards identified in feed ingredients, in the environment, in the process or in the feed, and conditions leading to their presence to decide whether or not these are significant hazards is defined as hazard analysis.

Information should be recorded and available to ensure that feed ingredients are stored and used as appropriate to avoid the introduction of hazards.

Information should allow for:

- the establishment of efficient recall procedures
- better quality and process controls
- unnecessary repetition of measurements
- the possibility of correlating product data with feed ingredients characteristics and processing data
- better planning to optimize the use of feed ingredients for each product type
- ease of information retrieval in feed safety management audits.

As it is detailed in Section 5 – Methods of Sampling and Analysis - continuous sampling of feed ingredients should be carried out to allow for a risk based monitoring enabling to ensure that the required safety standards are met. Testing for any suspected hazards, plus a constant effort to apply GMPs, will minimize feed contamination.

LABELLING

Product labelling should provide the users with all necessary information to properly handle, store, and use the feed and feed ingredients and to prevent health hazards entering the food chain. It is important that users are adequately trained to fully understand and appropriately use labelling information.

Labelling information on species and categories of animals for which the feed is intended is necessary as the risk to human health may change when certain feed or feed ingredients are fed to different species or categories of animals (e.g. mammalian proteins when fed to ruminants).

Insufficient product information, and/or inadequate knowledge of general feed and feed safety, can lead products to being mishandled at later stages in the food chain. Such mishandling can result in feed contamination or products becoming unsuitable for human consumption, even where adequate control measures have been taken earlier in the feed chain.

All labelling information related to the source of feed and feed ingredients (e.g. name of the product, name and address of the manufacturer, country of origin, lot identification, manufacturing date, list of ingredients, quantitative ingredients declaration, instructions for use, storage conditions, best storage time) are essential for record keeping, traceability/product tracing and products recall, as necessary. This information may also help with effective stock rotation. Correct labelling will assure correct information to be supplied to working inventories, packaging and other records.

Medicated feed labelling or accompanying documentation will require specific information on the active veterinary drug ingredients, species and class of animals for which the feed is intended, purpose or indications of use, warning and caution statements. Warning statements include the

withdrawal times and other statements related to protection of human health.

TRACEABILITY/PRODUCT TRACING AND RECORD KEEPING OF FEED AND FEED INGREDIENTS

Traceability/product tracing may be applied in the food chain, when and as appropriate, to contribute to the protection of human health from foodborne hazards, deceptive marketing practices and the facilitation of trade on the basis of accurate product description (FAO, WHO, 2006).

The traceability/product tracing tool should be able to identify at any specified stage of the feed/food chain (from production to distribution) from where the feed came (one step back) and to where the feed went (one step forward), as appropriate to the objectives of the feed/food inspection and certification system (FAO, WHO, 2006).

A traceability system on its own is insufficient to achieve feed safety; however, it can contribute to the effectiveness and/or efficiency of associated feed safety measures, e.g. when providing information on suppliers or customers involved in potential feed safety issues thus enabling targeted product withdrawal and/or recall.

The implementation by a feed business of a traceability system depends on (ISO, 2007):

- technical limits inherent to the organization and products (i.e. nature of feed ingredients, size of the lots, collection and transport procedures, processing and packaging methods)
- the cost benefits of applying such a system
- the requirements of the country of origin and the country of destination.

When designing the traceability system, the feed business should clearly identify its objectives on the basis of predefined principles (Table 3) (ISO, 2007).

TABLE 3
Principles and objectives of a traceability system

Principles	Objectives
Systems should be: • verifiable • applied consistently and equitably • results oriented • cost effective • practical to apply • compliant with any applicable regulations or policy • compliant with defined accuracy requirements	The feed business should identify its objectives that can be: • to support feed safety objectives • to meet customer specifications • to determine the history or origin of the product • to facilitate the withdrawal and/or recall of products • to identify the responsible organizations in the feed and food chain • to facilitate the verification of specific information about the product • to communicate information to relevant stockholders and consumers • to fulfill any local, regional, national or international regulations or policies, as applicable • to improve the effectiveness, productivity and profitability of the feed business

In designing the traceability system, the feed business should determine and document the flow of feed ingredients within its control in a manner which meets the objectives. The feed business should define the information:

- to be obtained from the suppliers
- to be collected concerning the product and process history
- to be provided to its customers and suppliers.

In the development and implementation of a traceability system, it is necessary to take into consideration the existing operation and management systems present in the feed business. Procedures to manage traceability information should include a means to link and record the flow of information concerning materials and products. The feed business should establish procedures that include at least the following (ISO, 2007):

- product definition
- lot definition and identification
- documentation of flow of materials and information including media for record keeping
- data management and recording protocols
- information on retrieval protocols.

When the feed business participates in a traceability system with other companies, the development of the system should consider the links in the chain to be established as each company identifies its immediate prior supplier and its immediate subsequent customer.

The traceability system as any other in a feed business safety system will have to be managed. Responsibilities will have to be assigned, documentation will have to be prepared, good planning of all requirements and steps to be implemented will be addressed, training of the personnel who can affect and that are responsible for the various tasks of the system will have to be in place, a monitoring system will have to be established along with key performance indicators, internal audits and consequently a review of the system.

Review of the system will be in place whenever changes are necessary. Review should include but is not limited to (ISO, 2007):

- traceability test results
- traceability audit findings
- changes to products or processes
- traceability-related information provided by other companies in the feed and food chain
- corrective actions related to traceability/product tracing
- customer feedback, including complaints, related to traceability/product tracing
- new or amended regulations affecting traceability/product tracing
- new statistical evaluation methods.

The application of traceability/product tracing should consider the capabilities of developing countries. If in the

context of a traceability/product tracing tool an importing country has objectives or outcomes of their feed and food inspection and certification system which cannot be met by an exporting country, the importing country should consider the provision of assistance to the exporting country, especially in the case of developing countries. The traceability system should not be more trade restrictive than necessary (FAO, WHO, 2006).

As the demands and increasing information is needed for the integration of the feed and food production management, more sophisticated and detailed traceability systems will be required. These will have to be developed in conjunction with equipment project and design, IT solutions, manufacture processing design that are practical, technically feasible and economically viable.

RECALL

Under the national legal framework, feed business operators should only be allowed to market safe feed. This usually includes a provision that requires feed business operators to recall unsafe feed from the market. The key components of a legal recall framework include (FAO, WHO, 2012):

- Provisions for feed business operators to have recall plans in place and to test the plans periodically.
- Provisions to empower the competent authority to enforce recalls, when required.
- Provisions for feed business operators to have traceability systems in place that, at a minimum, enable them to record from whom supplies are purchased and to whom final products are sold (the “one-step-back and one-step-forward” principle).
- Provisions for feed business operators to notify the competent authority when they have reason to believe that the feed, they have supplied is unsafe.
- Provisions for feed business operators or the competent authorities to inform consumers adequately about the health hazards of the specific unsafe feed.

Responsibility of the competent authorities

The main responsibility of the competent authority is to protect consumers against health risks. Under a national recall system, the responsibility for monitoring/coordinating and enforcing a recall may be spread across different agencies. Key responsibilities of the competent authorities involved in the coordination and enforcement of feed recalls may include some of the following actions, depending on the nature of the recall (FAO, WHO, 2012):

- Establish an effective national recall system.
- Initiate a recall of unsafe feed as a result of an outbreak of foodborne disease or monitoring and surveillance programmes that indicate an unacceptable level of risk and require feed business operators to remove unsafe feed from the market.

TABLE 4

Examples of requirements and actions in a feed traceability system in the feed plant

Purchase of the feed ingredients
• Define and document the selected supplier, quantity, type of feed ingredient and reference specification. • Document all the information of the supplier: name, address, place, phone, contract number, location of the production, production process. • Document the date and place of delivery and means of delivering transport.
Reception of feed ingredients at the feed plant
• Document and keep certificate of analysis issued by supplier for the batches in question, information on approved and rejected lots, results of inspections prior to shipment (the latter information may be kept by supplier and requested when needed). • Document the number of the batches or the combination of batches for the feed ingredient received. • Record the weight of the received batches. • Inspect the vehicle that transported the goods, recording the name, address, information of vehicle and load conditions and other requirements established in the receiving procedures. • Proceed and record the inspection results on the incoming feed ingredients and their deviations from specifications, if any. • Segregate and record the suspected or rejected lots based on the inspections of incoming feed ingredients. • Take, label, seal and keep, for a defined period of time and under suitable storage conditions, samples from all batches received. • Allocate an internal batch number to the received batch or combination of batches and record all the data on the receiving batch such as: supplier, quantity, type, delivery date and time. Make the identification unique and linked to the previous records: results of receiving inspection, results of vehicle inspection.
Storage of feed ingredients at the feed plant
• Record the number, location and date that feed ingredients were filled into the silos or tanks. This information should be linked to the reports and data on the silo and tank empty measurement and cleaning. • Document the storage and transport sequences and any nonconformities observed.
Weight and dosage of feed ingredients
• Allocate a product number per product, per production date. Record the information on the daily production data. • Record the data of the weight of products from silos and tanks per product, per production date. Actual dosage should be recorded for comparison with the planned dosage established in the formula.
Grinding and mixing
• Allocate the product number to a production line and date. • Record the allocated dosage of all added products and the mixing operations.
Crumbling, coating and sieving
• Allocate the product number to a production line and date. • Record the allocated dosage of all added products and the crumbling, coating and sieving operations.
Packaging/storage of the feed
• Record the silo and tank number where feed will be filled in. This information should be linked to the reports and data on the silo and tank empty measurement and cleaning. • Record the packaging line, type of packaging, batch number of packaging materials and link with data collected on receiving of these goods. • Record the label of the feed product, the packaging date and the validity date. • Samples should be taken, labelled, sealed and stored for a defined period of time.
Storage of the feed
• Record the silo, tank, shelf number where feed will be stored.
Distribution
• Record the data on the sale order, lot of feed sold, name of the customer, location, date of delivery, number of the invoice. • Inspect the vehicle that will transport the feed, recording the name, address, information of vehicle and load conditions and other requirements established in the dispatch procedures. • Record the date feed was delivered to customers' premises.

- Engage with feed business operators to develop guidance on the establishment, implementation and maintenance of recall plans and traceability.
- Provide advice to feed business operators on the assessment of risk and appropriate risk management actions.

- Provide a system/mechanism to allow feed business operators to notify the competent authority when they have reason to believe that the feed they have supplied is unsafe.
- Assist the recalling feed business operator in undertaking activities associated with the recall.

- Verify the effectiveness of the recall activities.
- Provide a system/mechanism to allow feed business operators to report on the progress of recall activities.
- Cooperate with relevant government agencies at national and international levels.
- Conduct an ongoing feed safety investigation, where necessary, to identify additional possibly implicated feed.
- Order and enforce a recall if a feed business operator has failed to comply with their legal obligations.
- Ensure that consumers and customers are informed, and their questions and concerns are managed appropriately.
- Seize or order the destruction, re-processing/re-conditioning or alternative use of recalled feed where necessary.
- Work with feed businesses to ensure that appropriate actions are put in place to prevent a recurrence of the hazard that caused the production or sale of unsafe feed.
- Notify the relevant authorities if the unsafe feed has been exported.

Responsibility of the feed business operators

Feed business operators have the primary responsibility, once they have identified or been notified that they have supplied unsafe feed to the market, to recall such feed in the interest of protecting public health. Key responsibilities of feed business operators involved in the recall may include the following actions (FAO, WHO, 2012):

- Establish and maintain a recall plan using the appropriate documented operational procedures.
- Maintain records of their feed suppliers (including feed ingredients) and sold feed to, as part of the feed traceability system.
- Establish procedures for verification of traceability and recall (e.g. conduct regular recall simulation exercises to ensure that contact lists are up to date and staff is trained appropriately).
- Train staff to execute the recall plan.
- Remove unsafe feed/food rapidly from the market.
- Inform the consumers concerned, if the feed under recall has reached them.
- Notify and cooperate with the competent authority when undertaking recall activities.
- Notify other relevant feed/food business operators within the food chain.
- Communicate recall details and information to relevant parties and respond to media and consumer queries.
- Manage the recalled product appropriately (safe disposal or reprocessing).

- Undertake a regular evaluation of their recall plan, taking into consideration lessons learned from previous recalls. As a result of this analysis it may be necessary to revise the recall plan.

SPECIAL CONDITIONS APPLICABLE TO EMERGENCY SITUATIONS

When a feed safety emergency arises timely communication of the nature and extent of the emergency to all relevant parties is essential to minimize potential adverse public health effects, including action taken by the exporting country to ensure prompt action can also be taken by the importing countries (FAO, WHO, 2016).

Experience has shown that information about feed safety emergencies must be integrated in a single system to ensure food safety. Information on the nature and extent of the feed safety emergency, including a risk assessment when completed, should, where possible, be clearly and completely described by the relevant competent authorities. If the basis for the food safety emergency is related to the use of feed, the specific nature of the feed related problem and its impact on food safety should be indicated.

Feed business operators have the responsibility for ensuring feed safety and are thus responsible for contributing to the management of feed safety emergencies related to their products. They are also responsible for having in place systems capable of effective tracing of feed lots and for providing timely and relevant information to the competent authorities and other relevant stakeholders, including customers and/or consumers, on matters of relevance for managing feed safety emergencies. They are also responsible for providing training or instruction to staff and for internal communication.

A feed business operator should be able to readily provide information about what feed it has, where it came from and to whom it has been supplied. The keeping of records that can be transmitted digitally and are searchable should be encouraged so as to facilitate the tracing of product through more complex distribution networks in a timely fashion.

Given the global nature of feed trade, the impact of a feed safety emergency may be widespread. The competent authority of the country where the feed safety emergency is identified should, to the best of its ability and in cooperation with other competent authorities, determine all potential recipient countries of the implicated feed and all countries from which the potentially contaminated feed or feed ingredients were imported. All relevant information in relation to the feed safety emergency should be provided to the competent authorities of the countries identified in this way (FAO, WHO, 2016).

The competent authorities should identify the source of the hazards and, once the source is identified, take

appropriate measures, where possible, to reduce or eliminate the hazards. In emergency situations, traceability/product tracing is important for the prompt identification of the source of the hazards (see Box 1) (FAO, WHO, 2016).

The competent authority should take account of whether the feed involved has or is likely to have been distributed at the wholesale, retail or consumer level. They should also consider the quantity of feed distributed, whether it may be in transit to a trading partner, and implement risk management and communication measures, accordingly, including a notice of recall at one or more of these levels of feed distribution.

Initial information exchange should occur as fast as possible, even if it is not complete, as an early warning. Further information can be exchanged as soon as it becomes available. The early warning systems have been considered as a mechanism of response when a feed or food safety

emergency requires appropriate actions to prevent the spread of a contamination, distribution of contaminated products, etc.

Early warning systems are processes aimed at reducing the impact of hazards by providing timely and relevant information in a systematic way. The provision of timely and effective information, through identified institutions allows individuals exposed to the hazard to take actions to avoid or reduce their risks and prepare for effective response (Brazzola and Helander, 2018).

The following constitutes the overall information that should be exchanged between competent authorities of both exporting and importing countries involved in a feed safety emergency (FAO, WHO, 2016).

Nature of the feed safety emergency

The nature of the feed safety hazard causing the feed safety emergency should be described and may include the following as appropriate:

- biological hazard (specify organism or toxin of concern)
- chemical hazards (e.g. residues of pesticides/veterinary drugs, heavy metals and toxins, industrial or environmental contaminants)
- physical hazards (e.g. foreign bodies, radionuclides)
- other identified hazards (e.g. inherent chemicals in feed or produced through processing, processing/packaging faults)
- unknown agent (specify serious adverse health effects associated with consumption of specified feed).

In each of the above cases, the following should be notified from the relevant feed business operator to the competent authority:

- the specific feed safety hazard, and its level or prevalence (on the basis of available information)
- the sampling and methods of analysis used (where applicable)
- any assumptions made.

The nature and extent of any adverse human health effects associated with a feed safety emergency should be described.

Identification of feed

The concerned feed should be thoroughly described. The following information should be provided if available:

- description and quantity of product(s), including brand, the name(s) of the product listed on the label shelf life
- type and size of package(s)
- lot identification, including lot code, dates of production and processing, and identification of premises where last packed or processed
- other identification marks/stamps (e.g. bar codes, universal product code (UPC))

BOX 1

Feed / food safety emergency situations

In the event that a feed or food emergency is identified, the exchange of information should take into account:

- Its nature and extent, where possible, described clearly and completely by the relevant competent authorities.
- The exchange of information on safety emergencies to be conducted between official contact points designated by the competent authorities.
- The information to all known affected and potentially affected countries without delay by the country that detected the safety emergency situation, whether it is an importing or exporting country.
- The sharing of information by competent authorities detecting a food safety emergency to enable all affected and potentially affected countries to make informed risk management and/or risk communication decisions.
- The availability and provision of clear, relevant, factual and timely information to all stakeholders to the extent possible.
- Flow of the information that should be transparent and continue during all phases of the emergency situation to enable continuous evaluation and development of the emergency response.

Adapted from Codex Alimentarius Principles and Guidelines for the Exchange of Information in Food Safety Emergency Situations (CXG 19-1995)

- name and address of producer, manufacturer, packer, seller, exporter or importer, as appropriate
- pictorial image
- export certificate(s) reference number(s), official name and mark.

In case the product has been exported an indication of the countries should also be provided, as soon as it is known, to enable them to identify quickly whether they are likely to be affected, and to help them locating the affected feed.

Affected or potentially affected population group(s)

Feed safety emergencies may predominantly affect certain segments of a population. In such instances, this information should be communicated.

Shipping and related information

Information on the following should be provided if available:

- exporter name and contact information
- importer name and contact information
- container and shipping details, including port of origin and destination
- applicable harmonized system codes used to ship the implicated product
- consignee(s) and shipper(s) and contact information.

Action taken by exporting or importing country

Information on action taken where available:

- measures taken to identify and prevent the sale and export of the feed
- measures taken to recall feed from markets including whether these recalls are voluntary or mandatory
- measures taken to prevent further problems
- measures taken to reduce the risk by appropriate physical treatment
- methods of diagnosis and treatment of affected persons

BOX 2 INFOSAN

INFOSAN (International Food Safety Authorities Network) is the FAO/WHO network for the dissemination of important information about feed and food safety issues globally. This includes one Emergency Contact Point from the authority responsible for national feed and food safety emergency response and additional focal points from other national agencies involved in feed and food safety. INFOSAN liaises with relevant national authorities to collect, validate and if required, share information at the international level.

- measures taken regarding final disposition (e.g. destruction of the feed)
- laboratory analysis
- any additional information that may be useful to assess the risk.

Details of the designated primary official contact point and of the relevant competent authority

Full contact details, including the name of the competent authority, address, telephone, email address of persons or offices that can supply further information that may be sought by affected or potentially affected countries to assist in the management of the feed safety emergency. A website address should be used where available to provide up-to-date information.

INSPECTION AND CONTROL PROCEDURES

The production of safe feed and feed ingredients is a shared responsibility of feed operators and competent authorities. Feed safety rely on effective control procedures and feed inspection programmes, implemented by both feed operators and competent authorities. The confidence of feed users, in the safety of their supply, and ultimately of consumers in the safety of the food, depends in part on their perception as to the effectiveness of control measures.

Self-control programmes assist feed operators to comply with applicable regulatory standards and other requirements (e.g. specifications defined by the manufacturer or purchasers). Self-control programmes should encompass feed ingredients and feed. Self-control programmes may include physical inspections, sampling procedures, chemical and microbiological analyses, actions in case of noncompliance, responsibilities of the staff involved in the production and feed safety control.

Competent authorities are responsible to carry out regulatory feed inspection to verify compliance with statutory requirements. Surveillance inspections are conducted to determine whether a feed business is substantially in compliance with the regulations. Compliance inspections are conducted to evaluate a firm's compliance with the provisions of the regulations and to document inspectional observations supporting possible enforcement action. Utilizing a scientific and risk-based approach will improve the ability to prioritize and allocate inspection resources by targeting feed businesses, facilities, products and processes posing the greatest risks to animal or human health.

The frequency and intensity of controls by inspection systems should be designed to take account of risk and the reliability of controls already carried out by those handling the products including producers, manufacturers, importers, exporters and distributors (FAO, WHO, 2010).

The nature and frequency of inspection, sampling and testing should be based on the risk to human health and safety presented by the product, its origins and the history of conformance to requirements and other relevant information. Control should be designed to account for factors such as: the risk to human health posed by the product; the likelihood of non-compliance with requirements; history of conformity of producers, processors, manufacturers, exporters, importers and distributors.

Laboratory testing is an important part of any safety control and feed safety assurance programmes. This is the process of measuring specific components of a feed or feed ingredient sample to assure that it meets safety specifications. Tests involve measurements of biological, chemical and physical properties to assess the safety of a product in comparison to a predetermined standard.

FEED ADDITIVES AND VETERINARY DRUGS USED IN MEDICATED FEED

Codex maximum residue limits (MRLs) for different types of veterinary drugs in food can be found in the Codex Alimentarius Database for Residues of Veterinary Drugs (FAO, WHO, 2019f).

While there is a great deal of variability in national feed regulations and animal production systems, most veterinary drugs added to feed are antimicrobials, coccidiostats or growth promoters.

There is worldwide concern on the use of antimicrobial drugs and how to minimize the potential adverse impact on public health resulting from their use in food producing animals, in particular the development of AMR (FAO, WHO, 2005).

Antimicrobial drugs are powerful tools for the treatment of infectious diseases in animals and humans. It is essential that all countries put in place the appropriate systems to ensure that the use of antimicrobial drugs is minimized and that when necessary they are manufactured, marketed, distributed, prescribed and used in accordance with national legislation and international requirements (FAO, WHO, 2011a).

The most practical method of administering veterinary drugs to large numbers of animals on a daily basis is by incorporation into feed.

Veterinary drugs should be used according to good practices which include the use of approved and authorized substances by the national authorities and follow the recommendations for their withdrawal periods. The use of veterinary antimicrobial drugs in food producing animals is part of good veterinary and good animal husbandry practices and takes into consideration disease prevention practices according to the Codex Alimentarius Code of Practice to Minimize and Contain Antimicrobial Resistance, currently under revision (FAO, WHO, 2005).

BOX 3

Antimicrobial resistance (AMR)

Antimicrobial resistance refers to the ability of a micro-organism (bacteria, fungi, viruses, and parasites) to survive in the presence of an antimicrobial compound, which it was previously unable to do. As a result, human, livestock and aquaculture antimicrobials (antibiotics, antivirals, parasiticides, fungicides) and crop antimicrobials (pesticides, antibiotics and fungicides) that were once effective treatments for disease lose their efficiency or become completely ineffective. This leads to a reduced ability to successfully treat infections; increased mortality; more severe or prolonged illnesses; increased costs due to prolonged treatment and increased use of antimicrobial; production losses in agriculture; and ultimately reduced livelihoods and food security. AMR is one of the top ten global health threats and it is of increasing concern for both humans and animals.

Medicated feed is usually manufactured by commercial feedmills regulated and inspected by competent authorities. However, some national regulations authorize on farm production of medicated feed. Small feed manufacturers, generally on farm facilities, may produce feed for only a single species and use only a small number of medicated feed ingredients. Large feed manufacturers, generally the largest on farm operations and commercial feedmills may use a variety of veterinary drugs to produce medicated feed for many species (e.g. poultry, cattle, swine, horses) and classes (e.g. starter, grower, finisher, breeder) of food producing animals. In these operations there are many types of equipment that are cross utilized to produce medicated and non-medicated feed. According to GMP, no matter the size of the feed manufacturing facility, adequate procedures should be established and used for all equipment in the production and distribution of medicated feed to avoid unsafe contamination of medicated and non-medicated feed.

Feed containing veterinary drugs must be used in accordance with clearly defined instructions. Feed ingredients approved as feed additives, including veterinary drugs, must have proven efficacy supporting their use, be safe for animals consuming the feed and for consumers of products originating from treated animals, and be safe for the users, workers and the environment.

During feed manufacturing, veterinary drugs may be carried over from medicated to non-medicated feed. Carry-over of a veterinary drug can occur during feed processing, handling, delivery or storage. The type of drug, number

of species exposed, feed production and delivery systems determine the hazards associated with drug carryover. Carryover may lead to serious adverse effects on human and animal health depending on the drug and the quantity and distribution of the feed that was contaminated. Even low-level carryover of veterinary drugs may cause residues in food (e.g. eggs or milk) from animals consuming feed containing carryover drug residues. Although such residues are not always an animal health or food safety concern, they may cause trade issues. Residues of veterinary drugs may be present in feed when ingredients of animal origin (terrestrial and aquatic) are used, but this is not always considered a significant source of drug carryover.

There are several causes of unwanted drug carryover from medicated feed. Significant amounts of drug or medicated feed may remain in any part of the feed manufacturing and distribution system and contaminate subsequent batches of feed. Residual medicated feed can remain in mixers, surge bin conveyors and elevators as well as bin and bulk feed trucks. Leaking connections can cross-contaminate feed. Sequencing and flushing procedures are normally used by manufacturers to minimize drug carryover.

The type of feed and the composition of the veterinary drug are important factors determining the amount of carryover. The electrostatic properties of some drugs, particularly those in powder form such as the sulfonamides and coccidiostats, cause them to adhere to equipment surfaces, making it very difficult to completely clean equipment between batches of feed. Some manufacturers have responded to this problem by producing granular prepa-

rations with reduced electrostatic properties, and this has reduced but not eliminated problems with carryover of these drugs. Other manufacturers have adopted different cleaning systems such as scraping the surfaces of the equipment, to minimize drug carryover.

Despite appropriate inclusion into a batch of feed, segregation of the veterinary drug from the feed may lead to variable drug concentrations in the medicated feed and cause carryover. Segregation can occur in premixtures and mixed feed. Segregation is caused by differences in particle size, shape or density of ingredients in medicated feed. Particles tend to segregate when there is a large size difference between ingredients. In parts of the production system where particles free-fall through the air, particle shape affects the movement of materials. Flat particles tend to fall more slowly and remain where they land, while particles that are round or cuboidal fall faster and tend to roll outwards toward the container wall. Particles with high density are less affected by free-fall air resistance than those of low density. Less dense particles tend to migrate towards container walls by the air currents within the container. The processes of segregation and desegregation can cycle during the entire feed production and delivery process. Initially, feed ingredients and medications can be evenly dispersed by the mixing process, become segregated as the feed mixture drops into the surge bin, get remixed during flow from the surge bin auger to the elevator leg, then become segregated again as feed is discharged from the leg and free-falls into the holding bin over the pellet mill. (FAO, WHO, 2019e).

SECTION 3

Good production practices

Production, processing, storage, transport and distribution of feed and feed ingredients

The production, processing, storage, transport and distribution of safe and suitable feed and feed ingredients is the responsibility of all participants in the feed chain, including farmers, feed ingredient manufacturers, feed compounders, truckers, etc. Each participant in the feed chain is responsible for all activities that are under their direct control, including compliance with any applicable statutory requirements.

Feed and feed ingredients should not be produced, processed, stored, transported or distributed in facilities or using equipment where incompatible operations may affect their safety and lead to adverse effects on consumers' health. Due to the unique characteristics of aquaculture, the application of these general principles must consider the differences between aquaculture and terrestrial-based production.

Where appropriate, operators should follow GMPs and, where applicable, HACCP principles to control hazards that may affect feed and food safety. The aim is to ensure feed safety and in particular to prevent contamination of animal feed and food of animal origin as far as this is reasonably achievable, recognising that total elimination of hazards is often not possible.

The effective implementation of GMPs and, where applicable, HACCP-based approaches should ensure, in particular, that the following areas are addressed.

Premises

Buildings and equipment used to process feed and feed ingredients should be constructed in a manner that permits ease of operation, maintenance and cleaning and minimises feed contamination. Process flow within the manufacturing facility should also be designed to minimise feed contamination. Water used in feed manufacture should meet hygienic standards and be of suitable quality for animals. Tanks, pipes and other equipment used to store and convey water should be of appropriate materials which do not produce unsafe levels of contamination.

Sewage, waste and rain water should be disposed of in a manner which avoids contamination of equipment, feed and feed ingredients.

Receiving, storage and transportation

Chemical fertilizers, pesticides and other materials not intended for use in feed and feed ingredients should be stored separately from feed and feed ingredients to avoid the potential for manufacturing errors and contamination of feed and feed ingredients.

Processed feed and feed ingredients should be stored separately from unprocessed feed ingredients and appropriate packaging materials should be used. Feed and feed ingredients should be received, stored and transported in such a way so as to minimize the potential for any cross-contamination to occur at a level likely to have a negative impact on food safety.

The presence of undesirable substances in feed and feed ingredients should be monitored and controlled.

Feed and feed ingredients should be delivered and used as soon as possible. All feed and feed ingredients should be stored and transported in a manner which minimizes deterioration and contamination and enables the correct feed to be sent to the right animal group.

Care should be taken to minimize deterioration and spoilage at all stages of handling, storage and transport of feed and feed ingredients. Special precautions should be taken to limit fungal and bacterial growth in moist and semi-moist feed. Condensation should be minimized in feed and feed ingredient

manufacturing and processing facilities. Dry feed and feed ingredients should be kept dry in order to limit fungal and bacterial growth.

Waste feed and feed ingredients and other material containing unsafe levels of undesirable substances or any other hazards should not be used as feed, but should be disposed of in an appropriate manner including compliance with any applicable statutory requirements.

Personnel training

All personnel involved in the manufacture, storage and handling of feed and feed ingredients should be adequately trained and aware of their role and responsibility in protecting food safety.

Sanitation and pest control

Feed and feed ingredients, processing plants, storage facilities and their immediate surroundings should be kept clean and effective pest control programmes should be implemented.

Containers and equipment used for manufacturing, processing, transport, storage, conveying, handling and weighing should be kept clean. Cleaning programmes should be effective and minimize residues of detergents and disinfectants.

Machinery coming into contact with dry feed or feed ingredients should be dried following any wet cleaning process.

Special precautions should be taken when cleaning machinery used for moist and semi moist feed and feed ingredients to avoid fungal and bacterial growth.

Equipment performance and maintenance

All scales and metering devices used in the manufacture of feed and feed ingredients should be appropriate for the range of weights and volumes to be measured, and be tested regularly for accuracy.

All mixers used in the manufacture of feed and feed ingredients should be appropriate for the range of weights or volumes being mixed and be capable of manufacturing suitable homogeneous mixtures and homogeneous dilutions, and be tested regularly to verify their performance.

All other equipment used in the manufacture of feed and feed ingredients should be appropriate for the range of weights or volumes being processed, and be monitored regularly.

Manufacturing controls

Manufacturing procedures should be used to avoid cross-contamination (for example flushing, sequencing and physical clean-out) between batches of feed and feed ingredients containing restricted or otherwise potentially harmful materials (such as certain animal by-product meals, veterinary drugs). These procedures should also be used to minimise cross-contamination between medicated and non-medicated feed and other incompatible feed. In cases where the food safety risk associated with cross-contamination is high and the use of proper flushing and cleaning methods is deemed insufficient, consideration should be given to the use of completely separate production lines, transfer, storage and delivery equipment.

Pathogen control procedures, such as heat treatment or the addition of authorised chemicals, should be used where appropriate, and monitored at the applicable steps in the manufacturing process.

Codex Alimentarius Code of Practice on Good Animal Feeding (CXC 54-2004)

GENERAL PRINCIPLES

Feed producers, manufacturers, handlers, transporters and users should be aware of the hazards associated with feed and feed ingredients, the production and manufacturing processes, and the environment in which the feed is produced, handled, stored, transported and used.

Good production practices should ensure that the presence of hazards is minimized during feed production,

processing, handling, storage, transport and use.

GMP should be properly applied as a prerequisite for an effective HACCP system.

Control measures that are essential to achieve feed safety should be scientifically validated. The application of control measures should be subject to monitoring, corrective actions, verification and documentation, as appropriate to the nature of the feed product and the size of the feed business.

Feed safety systems should be reviewed to determine if modifications are needed. This should be done periodically and whenever there is a significant change that could impact the potential hazards and/or the control measures (e.g. new process, new ingredient, new product, new equipment, new scientific knowledge) associated with the feed business.

Appropriate communication about the feed and feed production/manufacturing process should be maintained among all relevant parties to ensure feed safety across the entire feed/food chain.

Management commitment to feed safety

Fundamental to the successful functioning of any feed safety system is the establishment and maintenance of a positive feed safety culture acknowledging the importance of human behaviour in providing safe feed. The following elements are important in cultivating a positive feed safety culture:

- commitment of the management and all personnel to the production and handling of safe feed
- leadership to set the right direction and to engage all personnel in feed safety practices
- awareness of the importance of feed safety by all personnel in the feed business
- open and clear communication among all personnel in the feed business, including communication of deviations and expectations
- the availability of sufficient resources to ensure the effective functioning of the feed safety system.

Management should ensure the effectiveness of the feed safety systems in place by:

- ensuring that roles, responsibilities, and authorities are clearly communicated in the feed business
- maintaining the integrity of the feed safety system when changes are planned and implemented
- verifying that controls are carried out and working and that documentation is up to date
- ensuring that the appropriate training and supervision are in place for personnel
- ensuring compliance with relevant regulatory requirements
- encouraging continual improvement, where appropriate, considering developments in science, technology and best practices.

GOOD MANUFACTURING PRACTICES

GMPs are the practices and procedures that ensure the safety of feed and should be applied throughout the feed chain. GMPs are prerequisite programmes to the implementation of HACCP and are intended to prevent, control and detect potential contamination including cross-contamination that could occur during feed manufacturing.

Location of feed establishment

Potential sources of contamination should be considered when deciding where to locate feed establishments, as well as the effectiveness of any reasonable measures that might be taken to protect feed. Establishments should be located in areas that are not exposed to undesirable levels of smoke, dust and other contaminants.

Establishments should normally be located away from:

- environmentally polluted areas and industrial activities which pose a serious threat of contaminating feed
- areas subject to flooding (unless sufficient safeguards are provided)
- areas prone to infestations of pests or the presence of domestic and wild animals
- areas where wastes, either solid or liquid, cannot be removed effectively.

Measures taken to protect against potential sources of contamination should be documented and reviewed for effectiveness. Access by non-employees should be controlled in a manner depending on the risk to feed safety. Where it is not feasible to control access to the establishment, measures to prevent contamination should be taken (ISO, 2016a).

Buildings and facilities

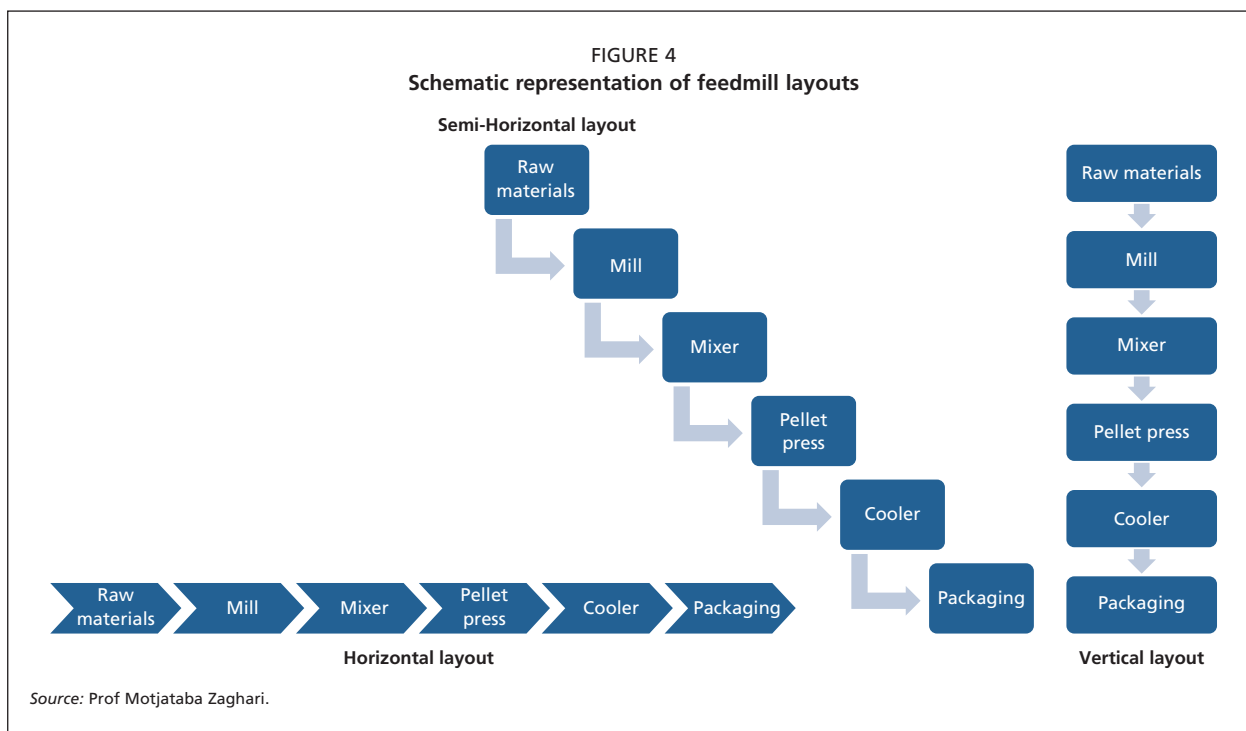
The design and construction of all buildings and facilities should ensure that feed and feed ingredients are protected from hazards. There should be adequate space for all operations and the safe storage of equipment and materials. Capacity and characteristics of silos, bins, equipment and installation should be carefully planned. Easy access should be possible for maintenance and cleaning operations. Location, design and construction of premises should deter pests and restrict access by rodents, birds and other pests to a minimum.

Figure 4 provides examples of lay outs of production lines in horizontal, semi-horizontal and vertical designs.

Design and layout

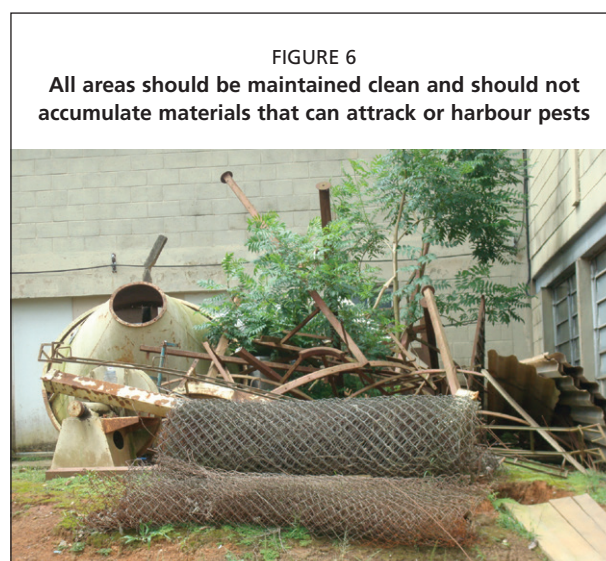
The internal design and layout of establishments should permit good hygiene practices, including protection against cross-contamination. Activities should be adequately separated by physical or other effective means where cross-contamination may result.

Buildings and facilities should be designed to allow easy access for cleaning, including access to the inside of relevant equipment. There should be enough space to satisfactorily conduct all process operations and product inspections. The building exterior should be designed, constructed and maintained to prevent entry of contaminants and pests. There should be no unprotected openings, air intakes should be appropriately located, and the roof, walls and foundation should be maintained to prevent leakage.



Gardens, other vegetation and surface waters (e.g. pools) should not be allowed, but if necessary for other uses should be limited to the external areas because they are attractive for birds and other pests and therefore increase the risk of contamination. Vegetation should be tended, removed or otherwise managed to address feed safety hazards. Parking areas, external areas and all access routes to the manufacturing plant should be designed to avoid contamination of the production area, for example by the tracking of mud or snow by vehicles.

Where necessary, designated and appropriately designed storage areas for toxic, explosive or inflammable materials should be provided and located away from manufacturing, storage and packing areas.



Intake and loading facilities should be designed and constructed to maintain the safety of incoming feed ingredients and outgoing finished feed. Access points to bulk material receiving lines should be identified and secured from unintended use and contamination. Controls should be in place to avoid contamination by water or pests.

Processes and workspaces should be designed, constructed and maintained to control feed safety hazards.

Internal structure and fittings

Structures within the establishment should be built of durable materials. They should be easy to maintain and clean and, where appropriate, to disinfect. The following specific

FIGURE 7
Unloading of feed ingredients in an uncovered area.
Ingredients can be contaminated by pests,
birds and water from the rain



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FIGURE 8
Openings in the ceiling allow the entry of pests,
birds and dust that can contaminate
the production environment



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conditions should be satisfied where necessary to ensure the safety of feed:

- The surfaces of walls, partitions and floors should be made of impervious materials with no toxic effect in intended use.
- Walls and partitions should have a smooth surface that enables and facilitates cleaning.
- Floors should be constructed to allow adequate drainage and cleaning, when necessary due to the nature of operation.
- Ceilings and overhead fixtures should be constructed and finished to minimize the build-up of dirt and condensation, and the shedding of particles.
- Roofs in manufacturing and storage locations should be self-draining and should not leak.
- Windows should be easy to clean, constructed to minimize the build-up of dirt, be fitted with removable and cleanable insect-proof screens.
- Doors should have smooth, non-absorbent surfaces and be easy to clean.
- Working surfaces, such as weighing tables, that may come in direct contact with feed ingredients should be in sound condition, durable and easy to clean and maintain.
- Testing areas and laboratories should be designed, located and operated to prevent contamination of materials and production areas of the establishment.
- Standing water should be prevented and/or removed.

Water supply

Any water coming into contact with feed and feed ingredients should be of potable quality. There should be an adequate supply of potable water with appropriate facilities for its storage, distribution and temperature control. Potable

water parameters can be found in the WHO guidelines for drinking water quality (WHO, 2017).

Use of reclaimed or recycled water should be justified by a risk assessment. Reclaimed or recycled water should have a separate supply system, identified and not connected to or otherwise prevented from refluxing into the primary or potable water systems.

Non-potable water, for use in fire control, steam production, refrigeration and similar purposes should have a separate system. Non-potable water systems should be identified and should not connect or allow reflux into potable water systems. All hoses, taps and other similar possible sources of contamination should be designed to prevent back-flow or siphoning.

Water treatment chemicals, where used, should be food compatible. Chemical treatment should be monitored and controlled to ensure the correct dosage is delivered.

Cleaning facilities

Adequate facilities, suitably designated, should be provided for cleaning utensils and equipment. Such facilities should have an adequate supply of hot and cold water, where appropriate. Facilities should ideally be constructed of corrosion-resistant materials that can easily be cleaned and should be provided with potable water at temperatures appropriate for the cleaning chemicals used. All cleaning chemicals should be food compatible.

Equipment for cleaning facilities should be adequately separated from feed storage, processing and packaging areas to prevent contamination. Cleaning and sanitizing agents should be fit for purpose, clearly identified, stored separately and used only in accordance with documented instructions. Utensils should be fit for purpose, maintained and stored to prevent contamination.

Personnel hygiene facilities

Personnel hygiene facilities should be available to ensure that an appropriate degree of personal hygiene can be maintained. Personal hygiene facilities and toilets should be located, available, clearly designated and maintained to prevent contamination. When appropriate, facilities should include:

- Adequate means of hygienically washing and drying hands, including wash basins and a supply of hot and cold, or a suitably controlled temperature water.
- A constant supply of potable water.
- An adequate number of toilets of an appropriate hygienic design with hand wash basins in proximity provided with soap, paper towels or other suitable means for drying hands.
- Toilets should be as far away from the production line as possible.
- Adequate changing facilities for personnel.

Facilities should be suitably located and designed. Whenever the nature of operations requires, there should be facilities to wash and/or disinfect hands in product handling areas.

Air quality, temperature and ventilation

Adequate means of natural or mechanical ventilation should be provided to:

- Minimize airborne contamination of feed from aerosols and condensation droplets, especially in open production systems.
- Control ambient temperatures where these may adversely affect feed safety. If necessary, heating, cooling or air-conditioning systems should be designed and installed so that air intake or exhaust vents do not cause contamination of products, equipment or utensils.
- Provide ventilation of sufficient capacity to prevent grease and condensation from collecting on walls and ceilings.
- Control humidity and ensure the safety and suitability of feed.

Ventilation systems should be designed and constructed to ensure intakes draw only clean air. Ideally, design should ensure that air flows from clean areas to contaminated areas. Mechanical ventilation systems should be adequately maintained and cleaned.

Air and gases that come into direct contact with feed, including those used for transferring, blowing or drying, should not compromise feed safety. The fuel used as the combustion source should be fit for purpose (ISO, 2016a).

FIGURE 9
Personnel hygiene facility in a bad condition.
Facilities should be clean, with a supply of potable water, liquid soap and means for drying hands



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FIGURE 10
Lockers for personnel items in a bad condition.
Not in accordance with GMP



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FIGURE 11
Lockers in an appropriate condition and showing good hygiene and cleanliness



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FIGURE 12
Light without protection and allowing contamination when broken



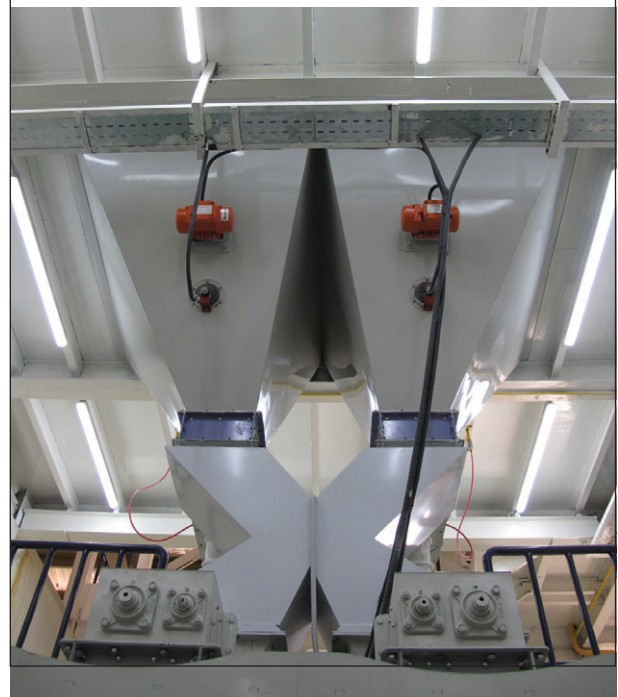
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FIGURE 13
Light well protected



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FIGURE 14
New lighting system (occupies less space, does not allow for dust collection, is not attractive for insects, is well protected, and has better light distribution)



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Lighting

Lighting sources should be sufficient to ensure that hygienic conditions are maintained throughout the production and storage areas, as well as where equipment and utensils are cleaned, in hand-washing areas and toilets. Where artificial lighting is required, it should be designed to ensure that it reflects true colours.

BOX 4

Recommended lighting conditions

540 lux in inspection areas
220 lux in work areas
110 lux in other areas

FIGURE 15
Scale not properly placed leading to errors
during weighing of ingredients



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Adequate lighting conditions are particularly important in areas where feed is visually inspected, or instruments are monitored. Light fixtures should be designed in such a way to prevent contamination in the case of breakages.

Equipment

Equipment and containers should be made of nontoxic materials, capable of being appropriately disassembled to allow proper maintenance, cleaning and inspections. Equipment should be placed away from the walls to facilitate cleaning and maintenance and to inspect and prevent pest infestation.

Equipment designed to achieve and control specific process conditions such as temperature, humidity and air flow should be provided with appropriate metering devices and their accuracy checked regularly. These requirements are intended to ensure that:

- Harmful or undesirable microorganisms or their toxins are eliminated or reduced to safe levels or their survival and growth effectively controlled.
- Where appropriate, critical limits established in HACCP based plans can be monitored.
- Temperatures and other conditions necessary to feed safety are achieved and maintained.

Containers for waste, by-products and inedible or dangerous substances should be specifically identifiable and adequately constructed. Containers that hold dangerous substances should be identified and lockable to prevent contamination of products and environment. No containers used for holding waste or harmful materials should be used for holding feed.

Utensils, such as spoons and knives used to open bags or weigh feed additives and veterinary drugs, should be tethered or otherwise kept safe and not placed on the floor or over feed ingredients bags and pallets.

FIGURE 16
Scale properly placed and protected



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Mixers must be appropriate for the range of weights and volumes required to obtain homogeneous mixtures. Batch weight and mixing time should be adjusted according to feed formula (volume, density, and component characteristics) for avoiding segregation and agglomeration of particles.

All feeders, conveyers, gates and dosing equipment used in the manufacture of feed and feed ingredients should be tested regularly for accuracy.

Weighing equipment such as scales and other metering devices should be appropriate for the weights and volumes to be used. Accuracy of the weighing and dosage equipment should be compatible with the items to be weighed.

Where bulk bins are in use, controls should be in place to ensure only the correct feed ingredients are loaded into any bin. Sieves, screens, filters and separators should be regularly checked for possible damage and to ensure their effective operation.

Equipment, containers and other utensils that come into contact with feed, should be designed and constructed to ensure that, where necessary, they can be adequately cleaned and maintained to avoid contamination of feed. Equipment, containers and utensils should be made of materials with no toxic effect for the intended use. Coatings, paints, chemicals, lubricants and other materials used for surfaces or equipment that may have contact with feed

should be food grade and such that they will not contribute to unacceptable contamination of feed.

Calibration methods and frequencies should comply with manufacturers' recommendations for all equipment monitoring and/or controlling devices that may have an impact on feed safety. Calibration of equipment should be performed by appropriately trained personnel. All measuring and dosing devices used in the manufacture of feed and feed ingredients should be fit for purpose.

Measuring and dosing devices essential to feed safety should be identified and should meet the following conditions (ISO, 2016a):

- Calibrated prior to initial use and recalibrated at specified intervals, against measurement standards traceable to international or national measurement standards; where no standards exist, the basis for calibration should be documented.
- Adjusted or readjusted as necessary.
- Identified to enable the calibration status to be determined.
- Safeguarded from adjustments that would invalidate the measurement result.
- Protected from damage and deterioration when appropriate.

The objectives of all above premises and facilities requirements and recommendations are summarized in Table 5.

TABLE 5
Premises layout and design recommended practices

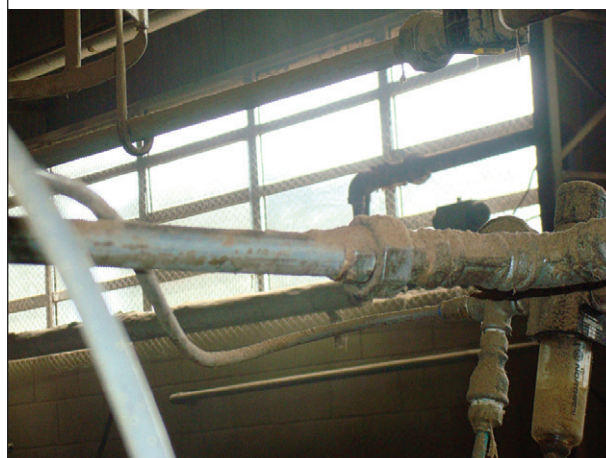
Premises design and facilities	Recommended practices	Objective
Location	Away from polluted areas, areas subject to flooding, pest infestations and presence of wastes.	Avoid feed contamination.
Design and lay out	Physical separation of activities that can cause contamination. Covering and protection of receiving and loading facilities. Enough space to conduct operations. Prevention against the entry of pests and contaminants. Appropriate storage of hazardous materials. No cross-connection between sewage and drainage systems.	Enable good cleaning operations. Prevent external and cross-contamination. Prevent contamination through weather, pests and others.
Internal structures and fittings	Walls, doors and partitions with smooth surface. Windows fitted with removable and cleanable screens. Floors with adequate drainage.	Allow cleaning. Avoid build-up of dirt.
Equipment	Made of nontoxic materials. Control operation conditions efficiently. Easy to disassemble, clean and maintain. Identify waste and dangerous substances containers.	Avoid feed contamination, cross contamination and carryover. Monitor critical control points (CCPs) efficiently. Avoid accidental and malicious contamination.
Water supply	Potable water, where needed, according to WHO guidelines. Monitored and controlled chemical treatment.	Avoid feed and equipment contamination.
Drainage and waste disposal	Constructed not to cross-connect with potable water.	Avoid feed and equipment contamination.
Cleaning facilities	Corrosion resistant and easily cleanable. Separated from production and storage areas.	Prevent contamination. Maintain utensils and small equipment in cleaned conditions.
Hygiene facilities	Provided with means for washing and drying hands. Hand wash basins near toilets. Availability of soap and paper towels. Constant supply of potable water. Availability of protective clothing.	Maintain adequate personal hygiene to avoid feed contamination. Avoid people to pass through/enter areas without washing hands.
Air quality, temperature and ventilation	Control of temperature, humidity and ventilation, where necessary. Install gas detector and alarm, if possible. Air flow from clean to contaminated areas.	Minimize air-borne contamination of feed.
Lighting	Adequate artificial or natural lighting sources. Protected lighting fixtures.	Ensure hygienic and inspection conditions. Protect food so that it is not contaminated by breakages.
Storage	Permit adequate maintenance, cleaning and inspection activities. Cleaned as soon as possible after product damage or spillage. Separate areas for rejected products, waste material and chemicals.	Avoid deterioration and spoilage of stored materials. Prevent contamination of other areas.

FIGURE 17
Processing equipment lacking maintenance



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FIGURE 18
Accumulation of product in the equipment,
lacking cleaning



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Personal hygiene

People known or suspected to be suffering from or to be a carrier of a disease or illness likely to be transmitted through feed, should not be allowed to enter any process area if there is a likelihood of them contaminating feed. Any person so affected should immediately report any illness or symptoms of illness to management and be assigned suitable duties or sent home.

Symptoms which should be reported to management, include:

- jaundice
- diarrhoea
- vomiting
- fever
- sore throat with fever
- visibly infected skin lesions (boils, cuts, etc.)
- discharges from the ear, eye or nose.

Feed handlers should maintain personal cleanliness and, where appropriate, wear suitable protective clothing, head covering and safety footwear. These protective clothes should be kept in a hygienic condition. Clothing should be designed to not only protect the personnel where necessary, but also to avoid contamination of feed by personnel. Where gloves are worn, controls should be in place to ensure these are maintained in a hygienic condition and do not get into the feed.

There should be clear rules on smoking and eating/drinking on site. Designated facilities should be provided away from areas where feed is handled, stored or processed. Personal effects, such as items that might fall out of pockets and which may pose a threat to the safety of feed, should not be carried into areas where feed is stored, processed or handled.

Contractors and any other person, including staff members, visiting the processing and handling areas should

wear protective clothing and adhere to the other personal hygiene provisions.

Cleaning

Cleaning should remove residues and dirt that may be a source of contamination. Cleaning is of particular importance also to avoid that prohibited feed ingredients (e.g. ruminant protein banned in many countries for ruminant feed) enter in the feed chain.

The cleaning methods and materials must be compatible with feed. Defined standards of cleanliness should be employed to ensure that exposure to pests and pathogens is minimized at all stages of processing, storage and handling.

Cleaning programmes should be established and documented to ensure that processing, storage and handling facilities are cleaned in a manner that is sufficient to maintain feed safety at all times. Where identified in the risk assessment, sanitizing programmes should be established and documented. Programmes should be monitored, verified and where appropriate validated for continuing suitability and effectiveness. Facilities and equipment should be maintained in a condition which facilitates wet or dry cleaning and/or sanitation. Dry process areas should be dry after wet cleaning or sanitation. An authorized person should carry out inspections of cleaning and a record of all inspections should be kept.

Only food compatible cleaning and disinfectant/sanitizing agents should be allowed to come into contact with feed and should be used in accordance with manufacturers recommendations and safety data sheet requirements. Where cleaning agents and disinfectants/sanitizers come into contact with feed, one must ensure that control systems provide the correct and effective dilution levels at all times.

Cleaning and disinfection/sanitizing chemicals must be stored, where necessary, separately in clearly identified containers to avoid the risk of (malicious or accidental) contamination.

Cleaning and, when applicable, sanitizing programmes should specify, as a minimum, the following (ISO, 2016a):

- areas, items of equipment and tools to be cleaned and/or sanitized
- responsibility for the tasks specified
- cleaning/sanitizing method and frequency.

Measures should be taken to prevent contamination when compressed air is used to “blow down” debris in a facility as not to spread contaminated material.

Cleaning tools should be fit for purpose, maintained and stored to prevent contamination.

Cleaning in the production of medicated feed

Sequencing

Sequencing is a pre-planned order of production of medicated feed designed to control veterinary drug carryover into subsequent batches of feed for target or non-target species. When the order of feed production through common equipment occurs in an acceptable sequence, specific cleanout of the equipment is not required, which is a great economical savings in feed production. The feed industry prefers sequencing over flushing or cleaning because it prevents downtime of the manufacturing system between batches of feed and minimizes waste of useable feed. The ordering sequence in which feed batches are processed determines the likelihood of unsafe carryover.

The production of medicated feed having the same drug(s) should be scheduled in sequence so that the higher inclusion levels are produced first and ending with the lowest inclusion level. This lowest inclusion level sequence should be followed by a non-medicated feed for the same animals before producing feed for a non-target species.

When manufacturing feed for a single species (e.g. swine) with a veterinary drug with an established withdrawal time, the feed should be mixed in the following order: nursery ration containing the veterinary drug, sow feed, grower ration and finally the finisher ration. The closer the animal species is to slaughter/harvest, the more caution must be taken with finisher feed.

When using a sequencing pattern to avoid unacceptable drug carryover, it is imperative that detailed feed production records are kept identifying the last batch so that human errors are minimized. Veterinary drugs with special toxicity characteristics require special risk mitigation during feed production. Whenever the planned sequencing is broken, the validated cleaning procedure should be applied.

Sequencing may also be used to clean out bins on bulk trucks. Depending on the type of system on the bulk truck, the feedmill and operators of the bulk trucks must carefully

schedule how the trucks are loaded and the order the bins are unloaded on the truck if the truck has multiple bins. The feed manufacturer should be able to document when and how the bins on their bulk trucks are sequenced. They should also be able to demonstrate adequate cleaning of bins prior to addition of another batch of feed to the bins on the truck. All cleaning regimens should be properly validated to prove efficacy and fit for purpose (FAO, WHO, 2019e).

Flushing

Flushing involves taking an appropriate feed ingredient, usually ground grain, and moving a sufficient quantity of it through the feed manufacturing system to “flush” out any medicated feed that remains. The quantity will depend on the type of equipment and should be verified with the manufacturer as to have the best performance for the cleaning. The first portion of the flush feed will be more highly contaminated than the last portion, and this must be considered if the first flushing batch of feed is fed to a non-target animal species and when samples are taken for quality control and regulatory purposes. Because of this, most countries’ medicated feed regulations dictate that “first-flush” feed is not used as feed for laying hens, lactating dairy cows, or as the finishing feed for animals before slaughtering/ harvesting.

After the mixer is flushed, the new flush material passes through the entire production system in the same manner as the previous medicated feed. Once this occurs, the flush material must be stored in a separate bin for use in an identical medicated feed. For bulk deliveries, some commercial manufacturers use the same flush material to flush their bulk trucks out after deliveries are made to the farm. Some manufacturers elect to simply discard the flush material to prevent inadvertent cross-contamination (FAO,WHO, 2019e).

Physical cleanout

Physical cleanout is done when employees enter areas of a production system and clean the system by sweeping, scraping, washing and disinfecting. This is the most effective way of cleaning out portions of a production system to eliminate the risks of veterinary drug carryover. But the loss of manufacturing time is significant compared to sequencing and flushing. Some feedmills do physical cleanout only when necessary, such as when mixing feed using liquid ingredients (e.g. fat or molasses) that create residues within the system which cannot be removed through other operations (FAO, WHO, 2019e).

Contamination during storage, transport and processing

Cross-contamination at the feedmill

Within a feedmill, different feed can be manufactured in the same production line and pass through the main mixer. The potential for cross-contamination from carryover of veterinary drugs occurs at different points throughout the production line, such as the main mixer, the surge bin, the bucket elevator, the holding bins, the pellet mill, the pellet cooler and the holding bins, before loading onto the delivery trucks.

Cross-contamination during the transport and unloading of the feed

Cross-contamination may take place in the bin of the delivery truck during successive loadings of feed into the same bin (intra-bin contamination). It may also take place in the transfer system, when traces of previously transported medicated feed remain in the conveyor screws and cross-contaminate the non-medicated feed subsequently delivered to a farm. To minimize the risk during feed delivery, the use of well-maintained trucks, the use of back bins to reduce the length of the circuit, and the careful flushing or cleaning after delivery are possible risk reduction measures (FAO, WHO, 2019e).

Maintenance

Equipment should be subject to a programme of planned maintenance that ensures it is kept in safe and effective working condition. Records should be kept of any maintenance carried out on equipment critical to the production of safe feed.

Engineers and contractors working on site should be controlled in such a way that maintenance and building works do not adversely affect feed safety. There should be a procedure in place to ensure that no tools, parts or pieces of equipment are out of place, appropriate cleaning and tidying has been completed prior to recommencing activities in areas where maintenance or building works have been undertaken. Maintenance requests that affect feed safety should be given priority.

Maintenance activities should be performed in a manner that prevents contamination. Temporary repairs should not compromise feed safety. Replacement by a permanent repair should be included in the maintenance schedule. The procedure for releasing maintained equipment back to production should specify sanitation and pre-use inspection measures. Lubricants and heat transfer fluids should be fit for purpose where there is potential for direct or indirect contact with materials (ISO, 2016a).

Pest control

Active measures should be taken to control and limit pest activity throughout all process, storage and handling areas. Potential problems should be identified with all classes of

animals (e.g. birds, insects, reptiles and mammals) whether they are wild, feral or domestic. Records should be maintained to show that risks from pests are adequately managed and consistently under control.

Animals should, wherever possible, be excluded from the grounds of feed manufacturing establishments and the area surrounding stores and processing plants. Where the presence of pests is unavoidable, procedures should be implemented to protect feed from potential contamination. Wherever there is a significant risk from pests, access points should be proofed against their entry. Doors should be kept closed whenever possible and be close-fitting and proofed against pests when closed.

Buildings should be kept in good repair and condition to prevent pest access and to eliminate potential breeding sites. Holes, drains and other places where pests are likely to gain access should be kept sealed wherever possible. Where sealing is not possible, measures such as wire mesh screens should be in place to reduce the possibility of pest entry.

Pest infestations should be dealt with promptly and any actions taken should be compatible with feed. Only appropriately qualified/trained personnel should carry out any control treatment required.

All bait containers should be fixed in their intended position unless there is a specific reason why this is not appropriate. Open bait containers and loose baits should not be positioned in areas where their use may result in a hazard to feed.

Pest control procedures should be documented and ensure that no materials designed to kill or deter pests can contaminate feed. Pest control records should include:

- details of any pesticide/insecticide used, including safety data sheets
- qualifications of personnel involved in pest control activities

FIGURE 19
Closed hopper that avoids the entry of birds



- map(s) indicating the location of any bait stations and the types of baits used
- records of any pests found
- details of corrective actions implemented.

The feed business should have a designated person to manage pest control programme and/or deal with qualified contractors at the establishment.

The pest control programme should include a list of approved pesticides for use in specified areas of the establishment. Requirements relating to the storage of hazardous materials should apply to all pesticides used at the establishment. Pesticide use and application should be restricted to qualified individuals and should be controlled to avoid feed safety hazards. Records of pesticide use should be maintained to show the type, quantity and concentrations used. Target pest and method of application should be identified.

Waste

Waste and material that is not appropriate for feed must be identified as such, kept separate and removed. Waste should not be allowed to accumulate in feed processing, handling and other working areas.

Waste should be collected and stored in clearly identified bins or containers and segregated to eliminate the likelihood of accidental or inadvertent use. Waste should be disposed of legally and according to any applicable environmental regulations.

Containers used to hold waste should not be used for feed. Containers used to store waste that is attractive to pests should be covered. Such waste containers should also be stored away from processing and storage areas and removed from site as frequently as practical. Waste storage must be kept appropriately clean and should be included in the cleaning and sanitizing programmes.

Provision should be made for the segregation, storage and removal of waste. Removal frequencies from production areas should be managed to avoid accumulations. Waste accumulation should occur only in designated areas. Materials designated as waste should be disposed of in a manner that prevents unauthorized use.

Drains

All drains must be designed and maintained in a manner that ensures they do not present a hazard to any feed.

No wastewater or material recovered from wastewater systems should be incorporated into feed ingredients.

Drains should have sufficient capacity to handle expected loads. Drains should not be located such that materials would be contaminated if a leak occurred. Open and close drainage direction should not be from a contaminated area to a clean area.

Storage

Storage areas for feed and feed ingredients should be separated to prevent cross-contamination. These facilities should be free of chemicals, fertilizers, pesticides and other potential contaminants.

Feed and feed ingredients should be stored in such a way that they can be identified easily and that confusion with other products is prevented. Medications and medicated premixtures should be stored in a secure place and with restricted access to authorized personnel only. Any rejected or returned products should be clearly identified and held in segregated areas to prevent their accidental use.

Feeds, which are approved and according to specifications, should be stored in suitable packaging materials or containers. Medicated feed should be stored in a separate and secure area, away from non-medicated feed and be clearly identified.

FIGURE 20
Waste should be disposed appropriately and maintained covered to avoid contamination and deter pests



FIGURE 21
Organized and well maintained area for waste disposal



Storage facilities should be designed and constructed to prevent the entry of pests. Storage conditions should be appropriate for the intended use of the material. Storage areas for dry materials should be kept dry and appropriately ventilated. Measures should be taken to prevent contamination when materials are stored directly on the floor.

Sufficient space should be maintained between packaged materials and walls to allow inspection, cleaning and pest control activities to be carried out. Areas should be cleared completely and cleaned on a routine basis. Packaging should be fit for purpose.

Feed and feed ingredients should be kept cool and dry to prevent mould growth. Temperature and humidity should be controlled where necessary.

Stock control measures should be adequate to ensure that neither feed or feed ingredients deteriorate prior to use/dispatch or during storage. Wherever practical, feed and feed ingredients must be used and supplied on a first in, first out basis.

Hazardous compounds not intended for inclusion in feed should be segregated and secured when not in use.

Materials with restricted use should be stored segregated to avoid cross contamination or unintended use.

Transport

Both feed and feed ingredients should be adequately protected during transport. All means of transport, whether owned or contracted, bulk or packed and by water, rail or land should be appropriately cleaned to control and minimize the risk of contamination.

The most appropriate method of cleaning will depend on the nature of the loads being carried. Generally, load compartments should be kept dry and sweeping or vacuuming used wherever this is effective. Where wet or sticky materials are being carried, it will be necessary to use a pressure washer or steam cleaner.

Vehicles used for the transport of medicated feed and other materials that present a high risk (including those subsequently identified to be infested with insects or pathogens) should be cleaned completely, sanitized and dried before they are used again for the transport of feed. Attention should be paid to contracted transport and maintenance of clean transport should be a condition of hire. Compliance with this requirement should be monitored at all times.

No materials from previous loading should remain in the tank trucks, boxes or other containers before being loaded with the feed and feed ingredients. Containers should be clean and dry prior to loading.

Checks should be made that the previous loads carried in any transport are compatible with the subsequent load being feed. The previous loads carried should be confirmed and guarantees sought that no transport used to carry feed has been used to transport material likely to result in long-term contamination.

All vehicles used for transport of feed and feed ingredients should be subject to regular cleaning and sanitizing programmes to ensure clean transport conditions and no accumulation of residual material.

Products should be protected from contamination and kept dry. When transport in closed vehicles is not possible, loads should be covered. The cover should also be maintained in a clean, sanitized and dry condition.

Vehicles, conveyances and containers should be maintained to ensure cleanliness and conditions consistent with material and product specifications and should provide protection against damage or contamination of the material. Where appropriate, control of temperature and humidity should be applied and recorded. Cleaning procedures should be documented, and cleaning actions between loads should be recorded.

FIGURE 22
Well organized storage



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FIGURE 23
Bad bulk storage conditions



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Training

Feed safety training is fundamentally important to the feed business. All personnel should be aware of their role and responsibility in protecting feed from contamination or deterioration. Personnel should have the knowledge and skills necessary to enable them to handle feed hygienically. Those who handle cleaning chemicals or other potentially hazardous chemicals should be instructed in proper use to prevent contamination of feed.

All personnel should be aware of their roles and responsibilities in maintaining feed safety. All training activities should be documented.

Periodic assessments of the effectiveness of training and instruction programmes should be made, as well as routine supervision and checks to ensure that procedures are being carried out effectively.

Managers and supervisors should have the necessary knowledge of feed hygiene principles and practices to be able to judge potential risks and take the necessary actions.

Training programmes should be regularly reviewed and updated. Systems should be in place to ensure that personnel associated with the feed business, such as maintenance staff, remain aware of all procedures necessary to maintain the safety of feed. Records should be kept of training activities conducted.

Elements to consider when determining the extent of training include the nature of hazards associated with the feed and the manner in which the feed is produced, processed, handled and packed, including the likelihood of contamination. Aspects related to literacy, education, language, culture and gender should also be taken into consideration and addressed as appropriate.

Topics to be considered for training programmes could include the following as appropriate to a person's duties:

- the principles of feed safety applicable to the feed business
- the measures relevant to the feed business that are used to prevent contaminants
- the importance of good personal hygiene, including proper hand washing and wearing, when needed, appropriate clothing for feed safety
- the good hygiene practices applicable to the feed business
- appropriate actions to take when feed safety problems are observed.

PREREQUISITE PROGRAMMES

Programmes such as GAP and GMP, as well as other practices and procedures, such as training and traceability, which establish the basic environmental and operating conditions of a feedmill, are considered prerequisite programmes and set the foundation for implementation of the HACCP system.

These programmes, documented as standard operational procedures (SOP's), detail their implementation, monitoring and verification and all records with the required evidences.

Table 6 lists the main prerequisite programmes and topics to be included in the SOP's.

HAZARD ANALYSIS AND CRITICAL CONTROL POINT (HACCP)

HACCP, which is science-based and systematic, identifies specific hazards and measures for their control to ensure the safety of feed and food. HACCP is based on prevention and reduces reliance on end-product inspection and testing.

The HACCP system, as it applies to the feed/food safety management, uses the approach of controlling critical points in the feed/food handling to prevent feed/food safety problems. The HACCP system can be applied throughout the feed/food chain from primary producers to the final users.

Development of a HACCP system may identify the need for changes in processing parameters, in processing steps, in manufacturing technology, in end product characteristics, in methods of distribution, in the intended use or in the GMPs applied. Any HACCP system should be capable of accommodating changes, such as advances in equipment design, processing procedures or technological developments.

Beside enhancing feed/food safety, other benefits of applying HACCP include more effective use of resources by focusing on critical areas and fewer recalls through identification of feed/food safety problems before product is released. In addition, the application of HACCP systems can aid review by competent authorities and promote international trade by increasing confidence in feed/food safety.

It is recognized that implementation of HACCP may be challenging for some businesses. However, HACCP principles can be applied flexibly in individual operations and businesses may use external resources (e.g. consultants) or adapt a generic HACCP plan provided by the competent authority, academia or other competent bodies (e.g. trade or industry associations) to the specific site circumstances.

Principles of the HACCP system

The HACCP system is designed, validated and implemented in accordance with the following seven principles (FAO, WHO, 2003):

- PRINCIPLE 1: Conduct a hazard analysis.
- PRINCIPLE 2: Determine the critical control points (CCPs).
- PRINCIPLE 3: Establish critical limit(s).
- PRINCIPLE 4: Establish a system to monitor control of the CCP.

TABLE 6
Main prerequisite programmes

Prerequisite programmes	Topics to be included in a SOP	Key points to consider
Supplier approval	Selection of suppliers	- Criteria to be used to select and qualify suppliers of feed ingredients. - List of approved suppliers.
	Management of suppliers	- Monitoring of the performance of the suppliers and update of their status. - Update of the list of approved suppliers.
	Emergency situations	Qualification of non-approved suppliers in situations of disqualification of another supplier that needs to be replaced, shortage of feed ingredients in the market; any other incident that refrains the already qualified supplier to deliver the product.
Control of incoming feed ingredients	Inspection upon receiving	Process of inspection of feed ingredients, packaging and other materials upon receiving.
	Inspection of vehicles and conveyances	Process to inspect the vehicles and conveyances to verify the integrity and safety of feed ingredients, packaging and other materials delivered.
	Non-conforming feed ingredients, packaging and other materials	Conditions under which non-conforming feed ingredients, packaging and other materials will not be accepted.
Cleaning	Cleaning programs	Areas and equipment that shall be submitted to a cleaning process (areas of the establishment, equipment, elevated structures, utensils, etc.).
	Details of the cleaning programs	Areas, items of equipment and tools to be cleaned/sanitized; responsibility for the tasks specified; cleaning/sanitizing/ flushing methods and frequency.
	Validation, monitoring and verification of the cleaning activities	Monitoring, verification and where appropriate validation for continuing suitability and effectiveness.
Personnel hygiene	Personal behavior	Detailed rules to be followed (smoking, eating, protective equipment, hand washing, etc.).
	Hygiene facilities and toilets	Hygiene resources available for personal cleanliness
Water Quality	Water supply	Forms of water that come in contact with the product.
	Non-potable water	Non-potable water used in plant and for what purpose; distribution of non-potable water and how systems are identified.
	Reclaimed water	Reclaimed water used and from what system it comes from.
	Water treatment	Treatment done to control/reach the water quality; list of all water treatment chemicals used and the evidence that they are food compatible.
	Control of water quality	Controls done and against which reference (local/national legislation, WHO guidelines, etc.),
Maintenance	Equipment included in the maintenance programme	List of the equipment that should be in the maintenance programme.
	Hygiene during maintenance activities	Procedure in place to ensure that appropriate cleaning and tidying has been completed prior to recommencing activities in areas where maintenance or building works have been undertaken.
	Maintenance requests	Requests that affect feed safety and their priority; temporary repairs should not compromise feed safety.
	Release of maintained equipment	Procedure for releasing maintained equipment back to production should specify cleaning and pre-use inspection measures.
	Lubricants and other fluids	Lubricants and heat transfer fluids fit for purpose where there is potential for direct or indirect contact with materials.
Pest Control	Preventive measures for the access of pests	Buildings location, design and construction of premises should deter pests and restrict access by pests to a minimum.
	Infested materials	Handling of infested feed and feed ingredients as to prevent contamination of other materials, products or the establishment.
	Pest control service providers	Subcontractor hired for the control of pests shall have the necessary qualifications.
	Pest control program	Identification of target pests, control procedures and preventive measures applied; map of detectors and traps.
Waste Handling	Waste	Forms of waste and where they are produced.
	Waste containers	Collection and storage of waste; identification of bins or containers.
	Removal of waste from the plant	The way the waste is removed from the plant (collected by the municipality, collected by a subcontractor legally authorized).
Calibration	Equipment to be calibrated	List of all the equipment used in the process and labs that will need to be calibrated.
	Frequency of calibration	Frequency of equipment calibration or date to be calibrated.

- **PRINCIPLE 5:** Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
- **PRINCIPLE 6:** Establish procedures for verification to confirm that the HACCP system is working effectively.
- **PRINCIPLE 7:** Establish documentation concerning all procedures and records appropriate to these principles and their application.

HACCP principles can be considered throughout the feed/food chain, and their implementation should be guided by scientific evidence of risks to human health.

Application of the HACCP system

The development and implementation of HACCP requires that the sector operates according to well founded and controlled prerequisite programmes (as described before). In addition to elements related to GAPs, GMPs, prerequisite programmes may include systems such as control of non-conformities, traceability, documentation control, etc. The ability to implement the HACCP system depends on the degree of adherence to these practices.

During the hazard analysis step, the likelihood of occurrence of hazards is assessed with the expectation of consistent performance of the prerequisite programmes. If it is not possible to rely on a prerequisite programme for a hazard control, additional CCPs should be added to the HACCP plan, increasing its complexity.

The implementation, monitoring and effectiveness of prerequisite programmes should be periodically evaluated and the record of results, necessary actions and modifications should be available.

The successful application of HACCP requires the commitment and involvement of management and personnel, and the knowledge and/or training in its application for the particular type of feed business. It requires a multidisciplinary approach which should be appropriate to the feed business operation and may include expertise in primary production, microbiology, public health, animal nutrition, feed technology, environmental health, chemistry and engineering, according to the particular situation.

The application of HACCP principles consists in the implementation of the following 12 steps (five preliminary steps followed by the seven HACCP principles):

Assembling the HACCP team (step 1)

HACCP teams are formed, bringing together a group of people with roles that relate to feed safety. The following should be considered for the team building: management personnel, procurement and receipt of feed ingredients, quality, research and development, maintenance, production and sales, quality control, etc.

Records should be maintained that demonstrate that team members have sufficient knowledge and experience to develop and implement the feed safety system.

The feed safety team should have a coordinator appointed by management.

The composition of the feed safety team should be evidenced in an appropriate form.

The HACCP team should identify the scope of the HACCP system and applicable prerequisite programmes. The scope should describe which feed products and processes are covered.

Product description (step 2)

The feed safety team should describe and document the characteristics of products or group of products, including information on:

- product name or similar identification
- composition
- biological, physical and chemical characteristics important for feed safety
- intended shelf life and storage conditions
- packing
- feed safety information related to labelling and/or handling, preparation and use instructions, distribution methods
- feed safety regulatory requirements for end products
- feed ingredients and materials in contact with products
- composition of formulated ingredients, including additives and coadjuvants
- food safety regulatory requirements for feed ingredients and materials that come into contact with products.

Regulatory requirements are essential information for hazard analysis and should be kept up to date.

Intended use (step 3)

Intended use of the feed and its reasonably expected handling should be described.

Information on intended use is needed to help identifying acceptable hazard levels and to select the combinations of control measures that meet these levels.

User groups and, where appropriate, the consumer group should be identified for each product group. All links in the food chain that will use the product should be considered, as this information is important for the hazard analysis.

Attention should be given to groups that are vulnerable to certain hazards. This information will be used during the hazard analysis process. This information must be recorded and kept up to date.

Flow diagram (step 4)

Process flow diagram for products or group of products covered by the feed safety system should be designed to assess the occurrence, increase or introduction of feed safety hazards.

Flow diagrams should be clear, accurate and sufficiently detailed to enable the HACCP team to properly conduct the hazard analysis. Flow diagrams should include:

- the sequence and interaction of all process steps
- external processes
- outsourced processes
- where feed ingredients and intermediate products enter the process
- where rework and reprocessing happen
- where feed, intermediate products, by-products and waste come out.

Flow diagrams in block diagrams are the most commonly used technique. It is practical to number the flow steps, i.e. each of its blocks. It is also important to include feed ingredients, intermediates, reworks and reprocesses in the flow diagram and number them, as this numbering will facilitate the linking of information when working on the hazard analysis.

The flow diagram gives the sequence of operations and other information but does not contain all the details for the hazard analysis. It is necessary to detail what is the flow of materials and people movement in the factory so that it is possible to identify the cross-contamination routes and other possible hazards.

The HACCP team should detail, in the description of each step of the flow diagram, all control measures or procedures that are applied to ensure product safety. Details of equipment and auxiliary operations should also be added.

Regulatory or customer requirements that influence the choice of controls or procedures applied in the process steps should also be identified.

All information must be kept up to date.

Confirmation of the flow diagram in loco (step 5)

Once the flow diagram has been prepared, the feed safety team should confirm the accuracy of the information through an on-site verification. Verification should consider all activities performed and covered in the flow diagram, in different shifts and work teams, as there may be variations in procedures and in performing the steps of operations covered. The on-site verification record must be available either in the HACCP team meeting minutes or in the flow diagram form itself indicating when it was verified and who did the verification.

Hazard analysis (step 6 – principle 1)

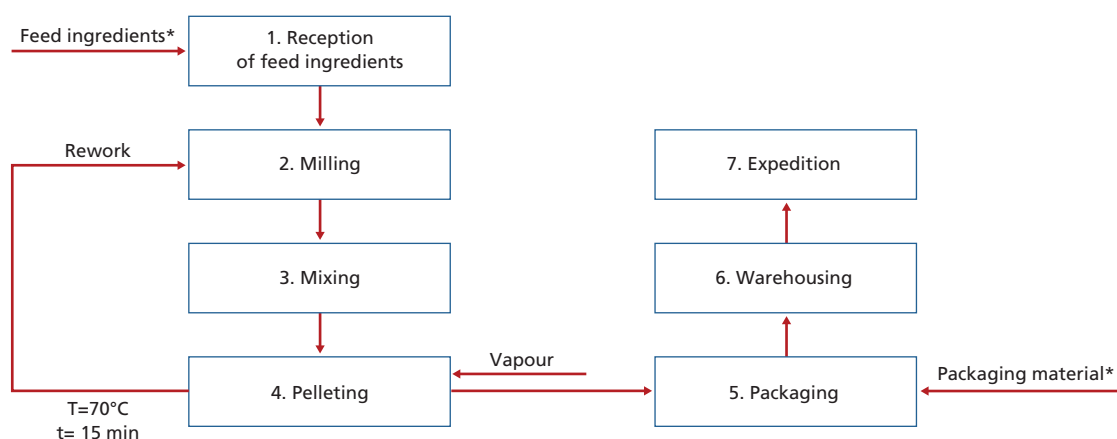
Hazard analysis should be a rigorous process for which the HACCP team must gather all the information from the previous steps, their experience, external information from other links in the chain, as well as specific hazards to decide which control measures are applicable. Such control measures will be included in the feed safety management system.

Thus, the following steps must be performed: hazard identification, their assessment and the determination of control measures.

Hazard identification and determination of acceptable levels

Feed safety hazards should be considered as any biological, chemical or physical hazards with the potential to have an adverse effect on human health. This information should

FIGURE 24
Simple example of a flow diagram for pellet feed



* All ingredients and materials can be listed separately
Source: Angela Pellegrino Missaglia

be documented for each process step identified in the flow diagram. The following must be considered in the hazard analysis to identify the likely occurrence of hazards:

- Feed ingredients - which can be addressed separately and information evaluated at the stage of receiving or in the step the feed ingredient is added.
- Environmental and equipment conditions - which will be addressed at each step identified in the flow diagram.
- The operations performed at each step - which will be addressed at each step identified in the flow diagram and as detailed in the description of the step.
- The steps preceding and following the one in analysis. A subsequent step may eliminate or reduce the hazard, or it is possible that recontamination occurs at a further step.
- The preceding and subsequent links in the feed chain.

Any reasonably expected feed safety hazard that may occur due to product type, process type, processing environment conditions shall be identified and recorded.

When competent authorities have established maximum limits, objectives, targets or criteria for the end product or process for a specific hazard/product combination, the hazard in question automatically becomes relevant to the product.

For each hazard identified, the acceptable level of this hazard in the end product should be determined, when possible. Acceptable level means the level of hazard in the end product that is required at the next step of the food chain to ensure a safe product.

The acceptable level should take into account:

- regulatory requirements
- customer requirements for feed safety
- intended use.

The justification for the acceptable level as the reference used and the value itself shall be recorded.

Thus, the feed safety team should determine the acceptable level of each hazard based on:

- objectives, maximum limits established by government authorities
- specifications or other customer reported information for the next step in the food chain.

Hazard analysis

Hazard analysis consists of identifying all potential hazards to determine which of them are significant for the specific situation and need to be controlled. In conducting the hazard analysis, the HACCP team should consider:

- Hazard source - where and how it may be introduced into the feed and/or its environment.
- Likelihood of hazard occurrence - qualitative and/or quantitative prevalence as well as frequency of occurrence and maximum possible levels and/or statistical distribution of these levels.

- Severity of adverse health effects that may be caused by the hazard.

The HACCP team will need to obtain the hazard information from scientific literature, databases, regulations and external experts and its own experience. The report of the Joint FAO/WHO expert meeting on Hazards associated with animal feed is a valuable source of information on hazards (FAO, WHO, 2019d).

When assessing the likelihood of occurrence of hazards, the HACCP team should consider the later and earlier steps of the process, equipment, services and environment as well as the previous (e.g. feed ingredient suppliers) and later steps of the chain (processing, transportation, distribution and consumers).

Hazard analysis may determine that it is not necessary to control a particular hazard. This can occur, for example, when the introduction or occurrence of a hazard is at an acceptable level without the need for intervention or when appropriate controls have been implemented at other stages of the food chain or the introduction of the hazard into the process is unlikely to occur or it is so low that the acceptable level is easily reached.

Each feed safety hazard shall be assessed according to the possible severity of adverse health effects and the likelihood of their occurrence. The methodology for this assessment and its results should be documented.

For this assessment, matrices may be used for the evaluation the significance of the hazard (see Figure 25)

The significance of the hazard determines whether elimination or reduction of the hazard to acceptable levels is essential and the types of control measures to be used. Hazards that have a grade 3 and 4 in the above matrix can be considered significant and may need specific control measures for their control and that are additional to the prerequisite programmes.

Identification of control measures

Depending on the results of the hazard analysis, the HACCP team should select a combination of control measures

FIGURE 25
Example of matrix for the evaluation
of the hazards' significance

Probability of occurrence	High	3	4	4
	Medium	2	3	4
	Low	1	2	3
		Low	Medium	High
Severity				

capable of preventing, eliminating or reducing hazards to the established acceptable levels.

Frequently, more than one control measure is required to control hazards and more than one hazard can be controlled by the same control measure, but not necessarily to the same extent.

Control measures should be evaluated for their effectiveness against the identified hazards. Therefore, and before the implementation of the control measures, they should be validated to obtain evidence that they are capable of controlling hazards to an acceptable level if properly implemented (FAO, WHO, 2013c).

Assessing the effect of a control measure includes:

- how hazards are affected by the control measure
- to what extent hazard levels are affected
- the step or location where the control measure should be applied.

Determination of CCPs (step 7 – principle 2)

The HACCP team should determine the critical control points – CCPs, based on the hazard analysis results. Potential hazards that should be included in the HACCP plan are those identified during hazard analysis that are significant and which may have an adverse effect on human health, if not effectively controlled.

Considering the control measures raised during hazard analysis, the HACCP team should identify the steps at which control measures can be applied. Each of these steps and their control measures should be evaluated and the CCPs determined. A CCP is a step at which a control measure or control measures, essential to control a significant hazard, is/are applied in an HACCP system.

The numbering of CCPs will facilitate their reference in the HACCP system.

Decision trees for CCP determination are helpful tools for this step and should be carefully chosen and used. The most common problem with using a decision tree is to apply it before completing the hazard analysis. By applying the decision tree to many potential hazards that are unlikely to have an adverse health effect and therefore may not be significant, CCPs that are not directly related to feed safety could be established. Experience also shows that strict application of the decision tree sometimes leads to a decision that contradicts common sense.

The decision tree proposed by Codex Alimentarius is given below (FAO, WHO, 2003).

Establish critical limits (step 8 – principle 3)

For each CCP, the critical limit should be established to ensure that the acceptable level of the hazard has not been exceeded and that the CCP remains under control.

If a critical limit is exceeded or violated, affected products are considered potentially unsafe.

The HACCP team should establish critical limits for monitoring each CCP controlling a significant hazard. For CCPs that control more than one hazard, critical limits should be established for the monitoring of each hazard.

An operational limit, which is more restrictive than the critical limit, can be also established. The operational limit acts as a safety factor that gives the opportunity to make the necessary adjustments and bring the process back to control before the product becomes potentially unsafe. Operational limits should take into account:

- the accuracy and precision of the measurement process
- product and process variations
- limits required to meet quality specifications.

Critical limit is a criterion, observable or measurable, relating to a control measure at a CCP which separates acceptability from unacceptability. When a critical limit is based on subjective data, such as a visual inspection, employees should be trained.

The HACCP team should document the reason for choosing the critical limits, which may have been established by regulatory requirements, by scientific literature, by agreed specifications, etc.

Establish a system to monitor control of CCP (step 9 – principle 4)

A monitoring system should be established for each CCP and that can demonstrate that this CCP is under control. This system should include all relevant procedures, instructions and records involving:

- measurements or observations that provide results within an appropriate timeframe
- the monitoring instruments used
- applicable calibration methods
- the frequency of monitoring
- the responsibility and authority for monitoring and evaluation of monitoring results
- records and method requirements.

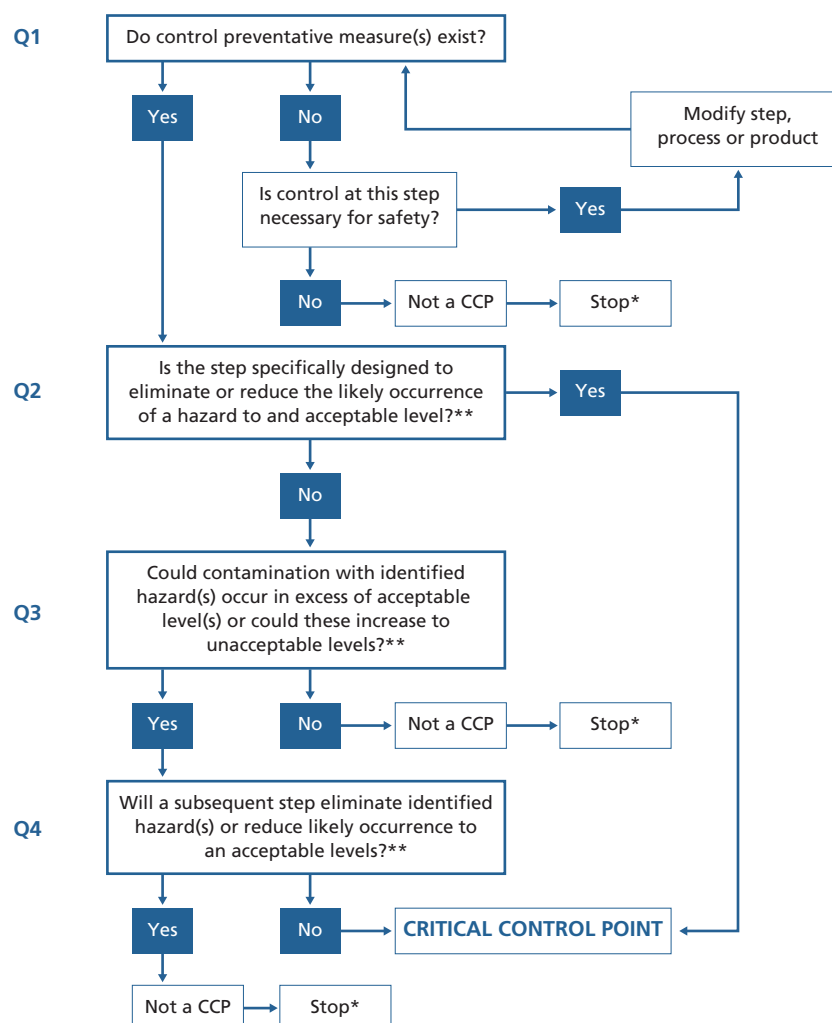
Monitoring methods and frequencies should be able to determine when critical limits have been exceeded in time to isolate the product before use.

As a rule, CCP monitoring procedures should provide real-time information. When this is not possible, monitoring should provide timely information for adjustments to be made to ensure process control and to prevent violation of critical limits and safety limits. Thus, there is no time to perform lengthy analysis and chemical analysis is preferred instead of microbiological determinations.

Establish the corrective actions to be taken when monitoring indicates that a particular CCP is not under control (step 10 – principle 5)

For each CCP, the HACCP system should include a set of planned corrections so that the CCP can be brought back

FIGURE 26
Decision tree to identify CCPs



* Proceed to the next identified hazard in the described process.

** Acceptable and unacceptable levels need to be defined within the overall objectives and identifying the CCPs of HACCP plan.

Source: FAO, WHO, 2003.

to control and corrective actions that will ensure that the cause of any non-compliance is identified and that recurrence is prevented.

Therefore, the HACCP team should plan actions that will be taken if monitoring results exceed the critical limits established for each CCP.

Initially, immediate action should be taken to eliminate the detected nonconformity, or else, a correction. Corrections may include process adjustments, reprocessing or product redirection for other appropriate use.

Corrective actions should eliminate the cause of non-conformity detected, which requires the identification of the root cause to correct the source of the deviation to minimize the potential for the deviation to reoccur. Details of

the corrective actions, including the cause of the deviation and product disposition procedures should be documented in the HACCP records. Periodic review of corrective actions should be undertaken to identify trends and to ensure corrective actions are effective.

Establish procedures for verification to confirm that the HACCP system is working effectively (step 11 – principle 6)

Verification procedures should be established to confirm that the food safety management system is effective.

Verification procedures should confirm that:

- the HACCP plan is being followed and controlling hazards on an ongoing basis

- procedures show that the control measures are effectively controlling the hazards as intended.

Verification includes observations, internal and external audits, calibration, sampling and testing, and records review to determine if the HACCP is working correctly and as planned.

Examples of verification activities include:

- reviewing monitoring records to confirm that CCPs are kept under control
- reviewing corrective action records, including specific deviations, product disposition and any analysis to determine the root cause of the deviation
- calibrating or checking the accuracy of instruments used for monitoring and/or verification
- observing that control measures are being conducted in accordance with the HACCP plan
- reviewing the HACCP system, including the hazard analysis and the HACCP plan through internal and/or third-party audits.

The results of the checks must be recorded, and the food safety team kept informed.

Before the HACCP plan can be implemented, its validation is needed. This consists of making sure that the elements together are capable of ensuring control of the significant hazards relevant to the feed business: identifying the hazards, critical control points, critical limits, control measures, frequency and type of monitoring of CCPs, corrective actions, frequency and type of verification and the type of information recorded.

Establish documentation concerning all procedures and records appropriate to these principles and their application (step 12 – principle 7)

Efficient and accurate record keeping is essential to the application of a HACCP system. Documentation and record keeping should be appropriate to the nature and size of the operation and sufficient to assist the business to verify that the HACCP controls are in place and being maintained. Expertly developed HACCP guidance materials (e.g. sector-specific HACCP guides) may be utilized as part of the documentation, provided that those materials reflect the specific feed operations of the business.

Documentation examples are:

- HACCP team composition
- hazard analysis and the scientific support for the hazards included or excluded from the plan

- CCP determination
- critical limit determination and the scientific support for the limits set
- validation of control measures
- modifications made to the HACCP plan.

Record examples are:

- CCP monitoring activities
- deviations and associated corrective actions
- verification procedures performed.

A simple record-keeping system can be effective and easily communicated to employees. It may be integrated into existing operations and may use existing paperwork, such as receiving inspections and checklists to record, for example, product temperatures.

The HACCP team should draft, approve and document the HACCP plan, including for each identified CCP:

- the hazards to be controlled
- combination of control measures or specific control measures
- critical limits
- monitoring procedures
- corrections and corrective actions taken when critical limits set for the CCP have been exceeded
- responsibilities and authorities
- tracking records.

Updating preliminary information and documents specifying the prerequisite programmes and the HACCP plan

Developing a HACCP system is an iterative process; several steps must be repeated several times to ensure the effectiveness of the system and the accuracy of the documentation prepared. Upon completion of the hazard analysis, selection and classification of control measures and description of their attributes, it will be necessary to update regularly the information previously collected in the preliminary steps. This includes information regarding product development, product characteristics, intended use, flowcharts, process steps and control measures. These may have changed with new scientific publications, new regulations, changes in the manufacturing process, procedures, etc.

The inclusion of new information may require changes to the HACCP plan and the procedures specifying prerequisite programmes.

SECTION 4

On-farm production and use of feed and feed ingredients

This section provides guidance on the cultivation, manufacture, management and use of feed and feed ingredients on farms and in aquaculture.

This section should be used in conjunction with the applicable requirements of Sections 4 and 5 of the Code.

To help ensure the safety of food used for human consumption, good agricultural practices should be applied during all stages of on-farm production of pastures, cereal grain and forage crops used as feed or feed ingredients for food producing animals. For aquaculture the same principles should apply, where applicable.

Three types of contamination represent hazards at most stages of on-farm production of feed and feed ingredients, namely:

- Biological, such as bacteria, fungi, parasites and other microbial pathogens
- Chemical, such as residues of medication, pesticides, fertilizer or other agricultural substances; and
- Physical, such as broken needles, machinery and other foreign material.

Agricultural production of feed

Adherence to good agricultural practices is encouraged in the production of natural, improved and cultivated pastures and in the production of forage and cereal grain crops used as feed or feed ingredients for food producing animals. Following good agricultural practice standards will minimize the risk of biological, chemical and physical contaminants entering the food chain. If crop residuals and stubbles are grazed after harvest, or otherwise enter the food chain, they should also be considered as livestock feed. Most livestock will consume a portion of their bedding. Crops that produce bedding material or bedding materials such as straw or wood shavings should also be managed in the same manner as animal feed ingredients. Good pasture management practices, such as rotational grazing and dispersion of manure droppings, should be used to reduce cross-contamination between groups of animals.

Site selection

Land used for production of animal feed and feed ingredients should not be located in close proximity to industrial operations where industrial pollutants from air, ground water or runoff from adjacent land would be expected to result in the production of foods of animal origin that may present a food safety risk. Contaminants present in runoff from adjacent land and irrigation water should be below levels that present a food safety risk.

Fertilizers

Where manure fertilization of crops or pastures is practised, an appropriate handling and storage system should be in place and maintained to minimize environmental contamination, which could negatively impact on the safety of foods of animal origin.

There should be adequate time between applying the manure and grazing or forage harvesting (silage and hay making) to allow the manure to decompose and to minimize contamination.

Manure, compost and other plant nutrients should be properly used and applied to minimize biological, chemical and physical contamination of foods of animal origin which could adversely affect food safety.

Chemical fertilizers should be handled, stored and applied in a manner such that they do not have a negative impact on the safety of foods of animal origin.

Pesticides and other agricultural chemicals

Pesticides and other agricultural chemicals should be obtained from safe sources. Where a regulatory system is in place, any chemical used must comply with the requirements of that system.

Pesticides should be stored according to the manufacturer's instructions and used in accordance with Good Agricultural Practice in the Use of Pesticides (GAP). It is important that farmers carefully follow the manufacturer's instructions for use for all agricultural chemicals.

Pesticides and other agricultural chemicals should be disposed of responsibly in a manner that will not lead to contamination of any body of water, soil, feed or feed ingredients that may lead to the contamination of foods of animal origin which could adversely affect food safety.

Manufacturing of feed on-farm

Feed ingredients

On-farm feed manufacturers should follow the applicable guidelines established in sub-section 4.1 of the Code when sourcing feed ingredients off the farm.

Feed ingredients produced on the farm should meet the requirements established for feed ingredients sourced off the farm. For example, seed treated for planting should not be fed.

Mixing

On-farm feed manufacturers should follow the applicable guidelines established in Section 5 of the Code. Particular attention should be given to sub-section 5.6. of the Code.

In particular, feed should be mixed in a manner that will minimize the potential for cross-contamination between feed or feed ingredients that may have an effect on the safety or withholding period for the feed or feed ingredients.

Monitoring records

Appropriate records of feed manufacturing procedures followed by on-farm feed manufacturers should be maintained to assist in the investigations of possible feed-related intoxication, contamination or disease events.

Records should be kept of incoming feed ingredients, date of receipt and batches of feed produced in addition to other applicable records set out in sub-section 4.3 of the Code.

Good animal feeding practice

Good animal feeding practices include those practices that help to ensure the proper use of feed and feed ingredients on-farm while minimising biological, chemical and physical risks to consumers of foods of animal origin.

Water

Water for drinking or for aquaculture should be of appropriate quality for the animals being produced. Where there is reason to be concerned about contamination of animals from the water, measures should be taken to evaluate and minimize the hazards.

Pasture grazing

The grazing of pastures and crop lands should be managed in a way that minimizes the avoidable contamination of foods of animal origin by biological, chemical and physical food safety hazards.

Where appropriate, an adequate period should be observed before allowing livestock to graze on pasture, crops and crop residuals and between grazing rotations to minimize biological cross-contamination from manure. Where agricultural chemicals are used, operators should ensure that the required withholding periods are observed.

Feeding

It is important that the correct feed is fed to the right animal group and that the directions for use are followed. Contamination should be minimized during feeding. Information should be available of what is fed to animals and when, to ensure that food safety risks are managed.

Animals receiving medicated feed should be identified and managed appropriately until the correct withholding period (if any) has been reached and records of these procedures must be maintained.

Procedures to ensure that medicated feed are transported to the correct location and are fed to animals that require the medication should be followed. Feed transport vehicles and feeding equipment used to deliver and distribute medicated feed should be cleaned after use, if a different medicated feed or non-medicated feed or feed ingredient is to be transported next.

Stable feeding and lot/intensive feeding units

The animal production unit should be located in an area that does not result in the production of food of animal origin that poses a risk to the animal and food safety. Care should be taken to avoid animal access to contaminated land, and to facilities with potential sources of toxicity.

Hygiene

The animal production unit should be designed so that it can be adequately cleaned. The animal production unit and feeding equipment should be thoroughly cleaned regularly to prevent potential hazards to food safety. Chemicals used should be appropriate for cleaning and sanitizing feed manufacturing equipment and should be used according to instructions. These products should be properly labelled and stored away from feed manufacturing, feed storage and feeding areas.

A pest control system should be put in place to control the access of pests to the animal production unit to minimize potential hazards to food safety.

Operators and employees working in the animal production unit should observe appropriate hygiene requirements to minimize potential hazards to food safety from feed.

Aquaculture

Aquaculture. includes a wide range of species of finfish, molluscs, crustaceans, cephalopods, etc. The complexity of aquaculture is reflected in the wide range of culturing methods ranging from huge cages in open seas to culturing in small freshwater ponds. The diversity is further reflected by the range of stages from larvae to full grown size, requiring different feed as well as different culture methods. Nutritional approaches range from feeding only naturally occurring nutrients in the water to the use of sophisticated equipment and scientifically formulated compound feed.

To ensure food safety, necessary precautions should be taken regarding culturing methods, culturing sites, technologies, materials and feed used to minimize contamination in order to reduce food hazards.

Codex Alimentarius Code of Practice on Good Animal Feeding (CXC 54-2004)

AGRICULTURAL PRODUCTION OF FEED

GAPs apply to the primary production, including feed ingredients production and primary processing. Subsequently, feed ingredients are subject to feed production and processing where GMPs are applied.

GAPs minimise or reduce the risks of contamination, misuse of plant protection chemicals and deterioration during primary processing and storage. Therefore, it is important that feed and feed ingredients be provided by suppliers that follow GAPs and GMPs.

Site selection

Feed safety is ensured when production areas used are suitable and do not present risks for plant contamination. Knowledge of previous exposure of the site to any signif-

icant environmental event, such as flooding, gives further insight on the suitability of the site for farming. When irrigation is used, an adequate supply of water should be applied evenly to all plants. The water used should be of adequate quality (see Section 3). When wastewater is used, concentrations of chemicals and other information on water quality should be known. The WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater (WHO, 2006) provide information on water quality and explain the concepts and practices for the safe use of wastewater, including health-based targets and minimum procedures. It also covers approaches to ensuring the microbial safety of wastewater used in agriculture (see Box 6).

A risk assessment of the site to determine whether it is suitable for production should be conducted and should be

BOX 5

The use of integrated crop livestock forestry systems (ICFL)

ICFL is an agricultural production strategy that integrates different production systems — agricultural, livestock and forestry — within the same area. It can be implemented using mixed, rotating or succession crops, so that there is interaction between each component, thus generating mutual benefits for activities. ICFL can be implemented in different ways, with a wide range of crops and various animal species. It is adaptable to regional characteristics, climatic conditions, the local market, and can be adopted by small, medium, and large producers. This form of integrated system seeks to optimize land use, raising productivity levels, diversifying production and generating quality products (FAO, 2010; EMBRAPA, 2017).

The use of ICFL promotes:

- Improved physical, chemical and biological properties of soil thanks to increase of organic matter
- Lower incidence of diseases of plants and animals and the occurrence of weeds
- Improved use of natural resources through complementarity and synergy between animal and plant components
- Reduced use of agrochemicals to control insect pests, diseases, and weeds
- Improved water harvesting and quality
- Promotion of biodiversity and new niches and habitats for crop pollinizing agents' natural enemies of insect-pests and diseases and weeds
- Intensified nutrient cycle
- Increased soil bioremediation capacity
- Decreased feed and food losses
- Higher food production.

BOX 6

Irrigation practices

Irrigation practices with wastewater or with other water sources are similar and depend on the local conditions, including climate, physical and chemical soil properties, drainage conditions and the salt tolerances of the crops to be grown. Good irrigation practices may vary, but are based on:

- water quantity
- water quality
- soil characteristics (infiltration, drainage)
- crop selection
- irrigation techniques
- leaching
- management practices.

Guidelines for the Safe Use of Wastewater, Excreta and Greywater
– WHO, 2006

kept updated and reviewed when risks have changed or, at least, periodically.

Risk assessments of the site showing that it is suitable for production with regards to feed safety, environment and health of animals should consider:

- potential biological, chemical and physical hazards
- site history
- type of farm operation.

The most common factors and hazards to consider when carrying out a site risk assessment are (GlobalG.A.P., 2020):

- i) Regulation – local regulations should be verified for legal compliance.
- ii) Prior use of the land
 - Plants previously grown– some plants (e.g. cotton production) typically involve use of herbicides that can have long term effects on other plants subsequently grown.
 - Former use – Industrial or military use can cause contamination to land through residues, petroleum contamination, waste storage, etc. Landfill or mining sites may have unacceptable waste in their subsoil that can contaminate plants or harm livestock. Animal husbandry may create zones of high microbial content (e.g. manure deposit).
- iii) Soil
 - Soil structure – there should be structural suitability for the intended use and chemical/microbiological integrity.
 - Erosion – conditions that cause losses of topsoil by water/wind that may affect plant yield and/or affect land and water downstream.
 - Susceptibility to flooding – flood and probable contamination of the soil through the flood should be considered.
- iv) Water
 - Water availability – the amount of water supply shall at least match the consumption of the intended plants.
 - Water quality – the risk assessment should establish whether the water is of appropriate quality and according to the local regulations. The probability of upstream contamination (sewage,

animal farms) that may need treatment should be evaluated.

- Authorization to use water – rights or license to use the water may be needed and should be verified.
- v) Other impacts
 - Impacts from/on the neighbourhood – dust, smoke caused by the operation of agricultural machinery. Contamination from upstream and to downstream sites by silt-laden or chemical-laden runoffs. Contamination by spray drifts.
 - Impacts on the farm – types of adjacent farm operations should be verified such as smoke, fumes and dust from nearby industrial or transport installations, including roads with heavy traffic. Insects attracted by plants, waste products and/or operations using manure as well as depre-dations by pests from nearby natural or conserva-tion areas should be considered.

Pesticides and other agricultural chemicals

Pesticides and other agricultural chemicals should be obtained from reputable suppliers and be appropriately labelled. They should be stored safely in clearly labelled and secure containers, in clean and dry areas, separate from other materials and feed. Herbicides, pesticides, fertilizers and other agricultural chemicals should be used for the indicated purpose, applied according to the quantities and frequencies as indicated by manufacturers and national reg-ulations. Records of their application should be maintained, including the name and nature of the chemical used as well as all justifications for the application.

Withdrawal periods for harvesting, stocking, feeding or grazing should be strictly observed.

BOX 7

Integrated pest management

Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or mini-mize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

*International Code of Conduct on the Distribution of Pesticides –
FAO, 2003*

The use of antimicrobials in plant protection should be avoided or at least minimised. When antimicrobials are used, specific directions aiming at reducing the development of AMR should be strictly followed (FAO, WHO, 2011a).

Pesticides and other agricultural chemicals should be disposed responsibly in a manner that will not lead to con-tamination of any water body, soil, feed or feed ingredients that may lead to residues in food of animal origin, which could adversely affect food safety.

It should be ensured that expired or defective chemicals and empty containers are safely disposed of. Containers should go through a triple wash and the residual water should not be mixed with drinking and working waters. They should be broken or perforated so as not to be reused and, finally, kept in closed bags to be appropriately deliv-ered to collection centres designated for that purpose.

Use of fertilizers

Recommendations on the application of organic or inorganic fertilizers should be given by competent personnel that are technically responsible for determining the type and quantity of products to be used. Correct application is required to optimize use and storage procedures avoiding contamination.

Records should be kept of all fertilizer applications detail-ing the geographical area and the name and reference of the field, orchard, where the plant is located. The exact dates of the application of all fertilizers should be detailed, as well as the trade name, type of fertilizers and concentrations. The method and/or the equipment used should be detailed in the records of all applications. Stock inventory (type and amount of fertilizers stored) should be updated periodically. All this information will allow for the traceability in case of a non-compliance and/or feed emergency besides demonstrat-ing transparency of all operations conducted.

Fertilizers should be stored in a covered, clean and dry area separated from other products and in a manner that there is minimum risk of contamination. The covered area should be suitable to protect fertilizers in powders, granules or liquids from atmospheric agents. Spillage and leakage should be possible to be cleared away. Storage should be done in a way that poses the minimum risks to water sourc-es. Fertilizers should not be stored with harvested plants. Storage requirements in the safety data sheets should be followed.

Inorganic fertilizer should be purchased from a reliable source to have a guaranteed content of the plant nutrients and the absence of chemical contamination such as heavy metals and fluorine.

Manure and other natural fertilizers are potential sources of biological hazards. Use of manure or compost that has undergone a controlled composting process under an appro-priate time and temperature regime helps to reduce biolog-ical contamination. If manure or compost is purchased, the

supplier should guarantee that it was appropriately treated. Equipment such as tractors, trucks, transporters and tools previously used in areas treated with manure can contaminate plants. Therefore, all equipment that has come into contact with untreated manure should be cleaned prior to access to production areas (GlobalG.A.P., 2020).

Pre-harvest, harvest, drying and cleaning of grains before storage

Plants should be harvested when they are at low moisture content and full maturity. Delayed harvest of plants already infected by fungi of the *Fusarium* species may cause an increase in their mycotoxin content. All harvesting, drying, cleaning and storage equipment should be in a good working order, free as much as possible from plant residues, grains and dust. Damage of equipment during this critical period enhance the presence of mycotoxins and cause plant quality losses. If mechanical drying equipment is available, earlier harvest may be helpful in limiting mycotoxin production during the final stages of plant maturation. It is important to use proper drying techniques to avoid hazards such as PAH and dioxins (FAO, WHO, 2017).

Containers and conveyances (e.g. wagons, trucks) to be used for collecting and transporting the harvested plants from the field to drying facilities and to storage facilities after drying, should be clean, dry and free of plant residues, old grains, grain dust, insects and visible fungal growth before use and re-use.

During harvesting operation, the moisture content should be determined in several spots of each load of the harvested grain since the moisture content may vary considerably within the same field. As far as possible, the harvesting of grain with high moisture content should be avoided due to precipitation or morning dew or during late afternoon as it takes a longer time to dry. If possible, when pre-harvest monitoring or surveying of grain shows a field as having a higher *Fusarium* infection rate, harvest and store grain from such field(s) should be done separately from those fields with a lower infection rate.

During drying and cleaning before storage, it is very important to ensure that moisture levels in harvested grains are low enough to permit safe storage for even relatively short periods of time ranging from a few days to a few months. A maximum level of 15% moisture is generally considered to be low enough to prevent further growth of pre-harvest toxigenic fungi and germination of spores of fungi that typically infect grain and produce mycotoxins during storage, such as *Penicillium* (FAO, WHO, 2017).

Fungal growth in grain is closely related with water activity (aw), commonly defined as the water that is not bound to molecules (such as milled grain products) that can support the growth of bacteria, yeasts, and fungi. Although the appropriate moisture content for fungal growth on various

grains is different, the maximum aw to avoid fungal growth is basically the same. It is recognized that fungal growth is inhibited at aw of less than 0.70. The appropriate level of moisture content of grain should be determined based on plant variety, kernel size, grain quality, storage period and storage condition (e.g. temperature). Table 7 shows values of moisture content in relation to different aw at 25°C for some cereals.

Storage, distribution and transport of grains

Harvested plant should be stored in clean areas, free from residues of previous harvest. Where appropriate, storage facilities should be washed and insecticide treated prior to use, to prevent insect infestation.

For bagged commodities, bags should be clean and stacked on pallets or incorporate a water impermeable layer between the sacks and the floor.

The temperature for storage of harvested plants should best suit the control of insect and mould development without compromising physical or physiological integrity of the stored product. To more effectively monitor the condition of stored grain, it is advisable, if possible, to measure the temperature and humidity of the storage facilities and the stored grain at regular time intervals during storage. A grain temperature rise of 2-3°C may indicate microbial growth and/or insect infestation. If the temperature or moisture becomes unacceptably high, where possible, aerate the grain by circulation of air through the storage area to maintain proper and uniform temperature levels.

Use of a suitable authorized preservative such as organic acids (propionic acid) may be beneficial since such acids are effective in killing moulds and fungi and preventing the production of mycotoxins. If an organic acid is used, it is important that the amounts added are sufficient to prevent fungal growth and that they are used according to labelling instruction (FAO, WHO, 2017).

Transport containers should be dry and free from visible fungal growth, insects or any other contaminated material. As necessary, transport containers should be cleaned and disinfected before use and re-use and should be suitable for the intended cargo. The use of registered fumigants or insecticides may be useful. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate.

Shipments of grain should be protected from additional moisture by using covered or airtight containers or tarpaulins. Avoid temperature fluctuations and other measures that may cause condensation to form on the grain, which could lead to local moisture build-up and consequent fungal growth and mycotoxin formation.

Avoid insect, bird and rodent infestation during transport by the use of insect and rodent proof containers or insect and rodent repellent chemical treatments, if they are approved for the intended end use of the grain.

TABLE 7
Values of grain moisture content in relation to water activity at 25°C for some cereals

Cereal	Moisture content (%) at various aw			
aw	0.60	0.65	0.70	0.75
Rice	13.2	13.8	14.2	15.0
Oat	11.2	12.2	13.0	14.0
Rye	12.2	12.8	13.6	14.6
Barley	12.2	13.0	14.0	15.0
Maize	12.8	13.4	14.2	15.2
Sorghum	12.0	13.0	13.8	14.8
Wheat	13.0	13.6	14.6	15.8

Source: FAO, WHO, 2017

All machinery and equipment as well as trucks and trailers used to transport grains and other feed ingredients should be well cleaned. Cleaning operation of trailers that are used to transport different types of feed ingredients and medicated feed to prevent cross contamination, should be carefully conducted. Workers have to be aware of all necessary cleaning procedures and records to be kept. Do not load bulk feed, feed ingredients, or premixtures into equipment that is also used to haul pesticides, insecticides, glass or scrap metal.

Documentation and record keeping

Documentation of procedures and relevant farm practices ensure that producers have correctly developed, implemented and updated an effective feed production and management system.

The recording of practices established in the procedures allows the demonstration of compliance to the statutory, regulatory and client requirements. Record keeping will facilitate the traceability of products and information, observation of legal requirements, external inspections/ audits and the availability of data to the competent authorities.

Personnel health, safety and training

The health, safety and hygiene of workers should be ensured to guarantee the safe production of feed and feed ingredients in the farm. Training and education will guarantee that personnel are competent to perform their duties and have good knowledge of risks and conditions that can affect feed safety.

Training programmes are to be conducted on a regular basis and will help people understand production practices, handling of products and equipment as well as safety measures. Plant protection products, biocides and other chemicals that can be hazardous should only be handled by workers appropriately trained.

Personnel hygiene instructions are part of the workers training programme and can be provided verbally or through signs and pictures to ensure that:

- hands need to be clean
- skins cuts should be covered
- smoking, eating and drinking are permitted only in defined area
- sickness and infections should be informed
- protective clothing should be worn when required.

All people entering the production site should comply with the same safety and hygiene procedures applied to personnel.

Panels should clearly indicate chemicals and treated plant storages. In addition, panels should indicate the need to avoid storing protective clothing and equipment together with chemicals as well as and the importance of keeping protective clothing and equipment separated from personnel clothes at all times.

A place where personnel can store food and can eat should be available. Toilets, washing facilities and potable water should be accessible at all times. All personnel facilities should be well kept and clean.

Production planning

Planning enables control of purchases, storage, production and distribution of feed. It helps avoid the use of unauthorized feed ingredients and feed, which is improperly stored, contaminated, or past its expiry date. Planning of on-farm feed production should consider all production steps and components (see Figure 27).

Specification/purchase of feed ingredients

Safe feed can only be obtained from safe feed ingredients, which in turn should be obtained from safe sources. Monitoring of feed ingredients should include inspection and sampling and analysis for contaminants using risk-based protocols. Feed ingredients should meet acceptable and, if applicable, statutory standards for biological, chemical and physical hazards that may affect human health.

On-farm feed mixing and production

Feed produced on farm should meet the requirements established for feed sourced off farm. More specifically, feed and feed ingredients should be:

- wholesome
- kept free from contaminants and mould, insects, birds and other pests, dirt, stones and other debris
- mixed/added in the correct proportions
- from a known and reputable/reliable source
- stored separately and well identified.

In addition:

- mixing equipment should be clean and well-functioning; it should also ensure an even and uniform mixing of feed ingredients.
- personnel responsible for mixing feed ingredients should be able to ensure a homogeneous mixing.
- samples of feed and feed ingredients should be retained.
- all mixes should be recorded.

When adding ingredients:

- smaller ingredients should be added later with the mixer already full
- control ingredient weighing
- calibrate scales periodically
- record weights
- record order of ingredient addition
- check that the final weight is in accordance with the sum of the weight of the ingredients.

Receipt and inspection of feed ingredients

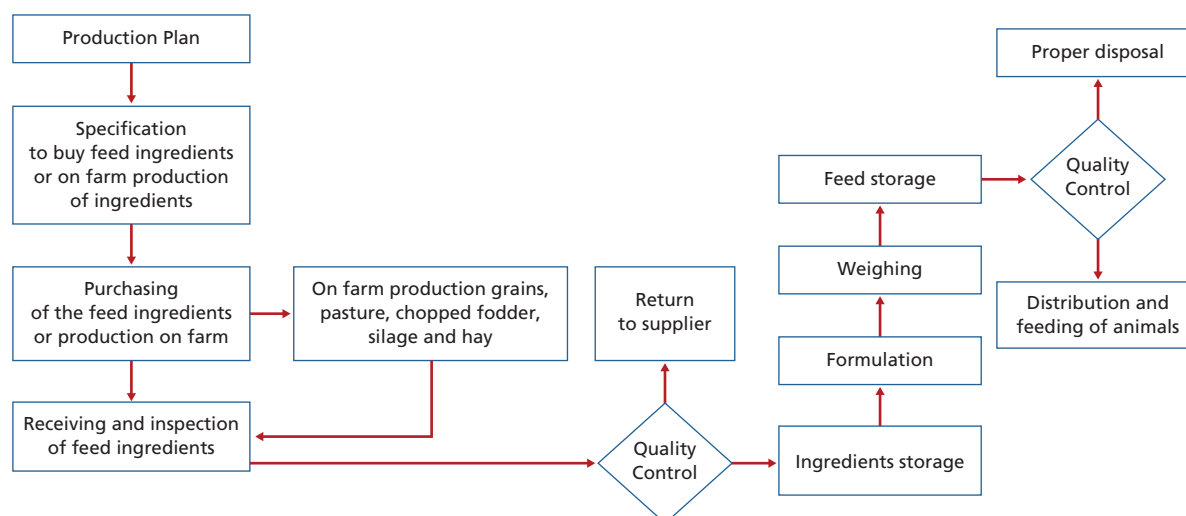
For purchased processed products, it should be verified what has been delivered and if it is in accordance with the order specifications, checking the conditions of transport (preserved tarpaulins, clean and intact packaging, absence of contaminants in the vehicle). Visual inspection before unloading should be carried out. In case of non-conformities, define the disposition of the load before unloading. Label verification, warranty levels, lot number, expiration date and manufacturer's indications should also be included in the receiving inspection. Record the receipt date, batch number, quantity, and manufacturing date. Preference should be given to products originating from farms that operate under GAP's. Record date of purchase and origin of the feed ingredients (Assured Food Standards Technical Advisory Committee, 2010).

Ingredients storage

The ingredients may be dry, wet or liquid and will require different types of storage. Facilities should be kept clean, disinfected and away from sources of contamination. The ingredients need to be stored in a way to be easily identified to prevent confusion that can lead to contamination. The use of ingredients should follow First In First Out (FIFO) or First Expires First Out (FEFO). The necessary measures to prevent worms, birds, pets and wild animals to contaminate feed ingredients should always be taken (Assured Food Standards Technical Advisory Committee, 2010).

Dry ingredients should be stored in a dry, cool, well-ventilated place away from sunlight. In grain silos, it is important

FIGURE 27
On farm feed production steps and components



Source: Avitech Animal Health Pvt. Ltd, adapted

to control humidity and temperature, date of entry and removal and record the use of insecticides and fungicides, checking the withdrawal period according to the manufacturer's indication.

Mixing and particle size

This operation can be as simple as mixing together two separate feed ingredients or the production of complex feed using dedicated machinery such as feeder wagons. Small numbers of animals can be adequately fed with mixtures made with a hoe (Parr, 1988). In this case the ingredients must be properly ground, in proportions not greater than 10%, and layered on top of each other and mixed together. Efficient mixing with hoe and mixing the ingredients at least 3 times yields acceptable mixtures (Parr, 1988). The quality of the mix is a major factor and depends on the type of equipment available. Farms typically use ready-made mixtures of micro minerals, vitamins and additives due to the difficulty in buying and mixing so many ingredients evenly and because most of them are used in low concentrations. The need for a homogeneous mixture is essential. It is necessary to control the homogeneity until the feed bunker. Wrong concentrations of some ingredients, due to inadequate mixing, may cause harm to animals and human health (e.g. selenium).

Factors which interfere with the quality of the mixture are (Axe, 1995):

- particle size
- particle shape
- density
- electrostatic charge
- hygroscopicity
- fluidity
- underfilling the mixer (less than 2/3 of volume)
- overfilling the mixer
- mixing time (varies with mixer type, follow manufacturer's instructions)
- worn bent ribbons, paddles, or screws
- build-up of molasses or animal fat, if used
- improper ribbon clearance.

It is also important to ensure that personnel have the appropriate skills to operate the scales used for weighing and that they understand the risks and complexity of the feed mixing operation.

Since segregation occurs primarily as result of differences in particle size, the difficulty of mixing multiple components can be reduced by making the sizes of the components as close as possible to each other and also by reducing the variation of size of the particles (Axe, 1995). It is important to have homogeneous distribution of feed additives and veterinary drugs in feed to avoid increasing the possibility of residues above the MRL of veterinary drugs and some feed additives in food. When veterinary drugs and feed additives are used, it is necessary to avoid

carryover during all the processes related to production and distribution of feed (FAO, WHO, 2019e).

Quality control

In general, the purpose of the feed quality control programme is to check the specifications of the feed ingredients and of final feed. A quality control plan should include periodic laboratory analysis of feed and feed ingredients using suitable methods of sampling and analysis (see Section on Sampling and Analysis).

A competent person should be given the responsibility for production and quality control. Their designated responsibilities should be listed and recorded. If responsibility is not designated, the farmer himself is the responsible individual.

The person with whom lies the responsibility should produce a written quality control plan, which should be implemented and reviewed when necessary.

Identification

Identification should describe the feed and provide instruction for use. Feed without identification may be used for the wrong animal species, after the expiry date, or not respecting the withdrawal period of medicated feed and daily consumption.

Storage

Feed and feed ingredients should be clearly identified and stored separately to preserve their identity and prevent cross-contamination, especially in the case of medicated feed. Feed ingredients that eventually may require analysis to ensure feed safety should be adequately identified and isolated until approval for their use is obtained.

Feed and feed ingredients should be stored in a manner so that stock occurs, observing expiration dates to avoid microbial growth, insect infestation, moulds, oxidation of vitamins and to ensure the proper activity of veterinary drugs and other additives. Veterinary drugs and feed additives have their own expiry date.

Storage areas should be kept clean, dry and at an appropriate temperature and humidity to minimize microbial growth. Where appropriate, pathogen control procedures should be carried out. Effective pest control regimes should be implemented. Access to storage areas by wildlife and other animals should be minimized.

Buildings and storage containers, such as silos and liquid tanks should be well ventilated and monitored to minimize contamination or deterioration of feed and feed ingredients.

Monitoring records

Appropriate records of feed manufacturing procedures should be maintained to assist in the investigations of possible feed-related contamination or disease events.

TABLE 8
Example of feed identification form

Date / Place:	
Product type:	
Product use:	
Ingredients:	
Origin:	
Lot number:	
Expiration date:	
Record of formula changes with date of formula changes:	

Records of incoming feed ingredients, date of receipt and batches of feed produced should be kept. A regular inventory of feed ingredients should be carried out to ensure that the correct feed ingredients have been used in the correct quantities and administered to the correct animals. In some production systems, general feeding plans may be more appropriate.

Records should also be maintained of master formulas and mixing instructions and the dates on which feed was mixed and used. Where veterinary drugs or feed additives are used, there should be records of the procedures used for their addition to prevent contamination of other feed. National legislation for the manufacturing of medicated feed should be followed.

Record keeping is an important element of traceability. Keep records of the information listed below in an accessible place and make them available when required. The names and addresses of the suppliers of all feed ingredients should be recorded. Most of the information is contained on the delivery invoice or feed label.

The following are examples of information to be recorded:

- Details of where feed and feed ingredients were stored.
- Detailed feed formulations of all mixes produced on the farm together with the date when each formulation started and ceased to be used.
- Records providing details of the feed that was produced and when. A 'barn sheet' or 'daybook' would usually fulfil this requirement.
- Batch number, where one exists.
- Where appropriate, the complementary mineral-vitamin mix used, how much was used, into which category of feed it was incorporated and the date that it was used.
- Date on which the feed was fed and to which animals.
- Use of pesticides and biocides, including name of product, date purchased, date used, and on which surfaces of which equipment/facility.
- Use of plant protection products (herbicides, fungicides and pesticides) on all growing or stored plants (including grass and forage plants) used for feed.

- Any occurrence of pests or diseases that may affect the safety of primary products.
- Results of any analysis carried out on samples taken from primary products or other samples taken for diagnostic purposes that have importance for feed safety.
- It is recommended to retain any additional documentation that demonstrates that specific hazards have been addressed. This might include, for example, documentation from contractors that a pest control system has been implemented or building work has been undertaken or materials have been purchased to protect supplies of feed.

Personnel training

All personnel should be aware of their roles and responsibilities in maintaining feed safety. Personnel should have the knowledge and skills necessary to enable them to handle feed hygienically. Those who handle cleaning chemicals or other potentially hazardous chemicals should be instructed in proper use to prevent contamination of feed. All training activities should be documented.

Managers and supervisors should have the necessary knowledge of feed hygiene principles and practices to be able to judge potential risks and take the necessary actions.

Elements to consider in determining the extent of training are the nature of hazards associated with the feed and the manner in which the feed is produced, processed, handled and packed, including the likelihood of contamination. Aspects related to literacy, education, language, culture and gender should also be taken into consideration and addressed as appropriate.

Topics to be considered for training programmes could include the following as appropriate to a person's duties:

- the principles of feed safety applicable to the feed business
- the measures relevant to the feed business that are used to prevent contaminants
- the importance of good personal hygiene, including proper hand washing and wearing, when needed, appropriate clothing for feed safety

- the good hygiene practices applicable to the feed business
- appropriate actions to take when feed safety problems are observed.

USE OF FEED

Feed distribution and feeding

The on-farm feed distribution system should ensure that the correct feed is provided to the right species and group of animals. During distribution and feeding, feed should be handled to avoid contamination from storage areas and equipment. Non-medicated feed should be handled separately from medicated feed to prevent cross-contamination.

Avoid overfilling the feeding troughs, adapting the quantity to the physiological requirements and remove any unused feed from the troughs before refilling. Clean the troughs and automatic feeders regularly.

Water supplies should be protected from unintentional contamination which includes pathogens and chemicals contaminants such as solvents, and nitrates.

Record for distribution:

- register feed label information (see section identification)
- delivery date
- quantity provided
- frequency of distribution according to consumption and product type
- distribution planning
- consumption control.

Record for feeders:

- status check
- establish schedule for frequent cleaning and maintenance
- suitability for quantity supplied and number of batch heads
- suitability of model and size for species and animal category.

To ensure safety of the feed, it is also necessary to:

- regularly clean all troughs and hoppers to minimize the risk of contamination from old feed
- maintain and regularly calibrate all dispensing equipment
- provide adequate trough space to ensure that animals can obtain sufficient feed intakes.

Medicated feed

Where medicated feed is used, veterinary drugs residues could transfer from feed to animal tissues and food of animal origin. Correct withdrawal periods should be followed and records kept. Feed transport vehicles and feeding equipment used to deliver and distribute medicated feed should be cleaned after use, if a different medicated feed or non-medicated feed is to be transported next.

Animals receiving medicated feed should be identified until the withdrawal period has expired.

Pasture grazing, preserved forages and fresh chopped fodder

Pasture, silage, hay and chopped fodder have potential to infect or contaminate animals and may represent a risk to feed and food safety. Feed can be contaminated by biological, chemical and physical hazards (see Section 1). Biological contamination by *Brucella* spp. or parasitic hazards such as the larvae form of *Taenia* spp., cysticercus, are well established. *Brucella* control in bovine population is fundamental to control pasture contamination by bacteria. Cysticercus also contaminates pasture and may be present in food. The main way to keep pasture and forage free of cysticercus is to control *Taenia* spp. in human population. Chemical hazards as heavy metals, physical hazards as particles of metal or glass and radionuclides, may be found on pasture and forages. Phytotoxins are eliminated by milk (Lopes *et al.*, 2019). However, it is important to know if contaminated pasture and forages are correlated or are responsible for contaminating food in naturally occurring situations. Information about the correlation of some contaminants in pasture and forage and correspondent levels in food are scarce.

Pasture

Pasture contamination is closely related to environmental contamination. Different areas will have different levels of risk. Cattle in extensive farming in Switzerland exhibited higher levels of dioxin-like PCB when compared with conventional farming (Zennegg, 2018.). The uptake of dioxins and PCBs in grazing animals resulted in elevated contaminant levels in suckler cows and calves. Residues of endosulfan were found on concentrates above the MRL and on alfalfa hay under MRL. No pesticide residues were found in wheat straw, shrubs and pasture or in milk samples. Another experiment showed that animals were not able to avoid contaminated pasture. Sheep grazing military training areas contained non-combusted fragments of various explosives, among which 2-methyl-1,3,5-trinitrobenzene (TNT), were not able to differentiate between contaminated pasture and clean pasture. No correlation was investigated between grazing contaminated areas and the presence of contaminants in milk or meat (Steinhein *et al.*, 2011).

Spreading manure onto pastures can play a role in transferring pathogens to livestock. The main risk is from spreading fresh, non-stored slurry. Risks can be reduced by storage and by using low application rates and leaving the pasture for as long as possible before allowing the animals to graze.

Consider the following points with respect to management of grazing lands (Assured Food Standards Technical Advisory Committee, 2010):

TABLE 9
Factors that may affect silage storage time

Oxygen	Levels greater than 5 percent allow the growth of aerobic bacteria. Oxygen infiltration is caused by poor compaction and/or inadequate sealing.
CO ₂	Levels greater than 20 percent prevent the growth of aerobic bacteria.
Inadequate sealing	Growth of fungi, yeast and aerobic bacteria during storage and decreased storage time.
Incomplete or inadequate fermentation	A high concentration of organic acids lowers the silage pH and inhibits the growth of aerobic microorganisms. Soluble carbohydrate residue is a nutrient source for pathogens.
Forage dry matter	Silages with high dry matter have a short storage period. They are difficult to compact and have lower acid levels.
Open silage control	The daily silage removed portion should consider loss due to oxygen exposure. Thus, the size of the silo should be appropriate for the daily amount to be used. Good compaction makes it difficult for oxygen to enter after silage has been opened.

Source: Jones *et al.*, 2004

- Manage grazing to minimize the possible contamination by physical, biological or chemical hazards (e.g. ensure that the area is free from microbial and chemical contamination and toxic plants).
- Observe withdrawal periods following applications of agricultural chemicals to the grazing area.
- Composts produced from organic materials originating off farm may be beneficial, but their application should be appropriate to the source of the compost, how it has been treated, the land to which it is applied and in accordance with national regulations.
- Carefully consider the grazing or conservation of plant grown near factories or other industrial facilities where harmful emissions could lead to elevated levels of certain environmental pollutants.
- Prevent livestock from accessing areas where redundant farm machinery is kept, avoiding ingestion of grass contaminated by leaking batteries, flaking paint, etc.
- If land other than your own is used for grazing livestock, seek assurances about the previous use of the land and that it is suitable for animal grazing.

Preserved forages and fresh chopped fodder

Attention should be given to the prevention of physical contaminants such as stones, metal objects, wood, sand, not only in silage production but also in the distribution of silages, hay and chopped fodder to animals. Prevention and control of the presence of toxic plants and seeds in the field to produce silage, hay and chopped fodder as well as monitoring the presence and levels of nitrates is important (Heinrichs and Roth, 2001).

The cleanliness of the site and equipment, both in production, processing and distribution, is fundamental for the control of contaminants.

Silage

Properly made and managed silage poses no health risks to humans or animals (Driehus *et al.*, 2018). Silage processes may reduce the amount of toxins in forages such as pyrrolizidine alkaloids (see Section 1). On the other hand, silage can be contaminated by microbial agents like *Clostridium botulinum*, *Bacillus cereus*, *Listeria monocytogenes*, Shiga toxin-producing *Escherichia coli*, *Mycobacterium bovis* and many mould species.

Silage can be made with different fodders and other plant products such as corn, sorghum, sugar cane, grass and others and should be produced in accordance with GAPs. The timing of harvest is important to obtain fodder with adequate moisture and maturity. A dry matter content of 65-70 percent is recommended for horizontal silos, 63-68 percent for tower silos, and 65 percent for silage preserved in bags. Simple techniques using microwaves can be used on farms to determine forage dry matter and decide on harvest time. Excess moisture in silages can release liquid effluents and contaminate the local water supply. Very dry silages make compaction difficult, causing fungal appearance and material loss.

The use of fungal control silage additives reduces the risk of mycotoxin production in silages. Silage additives may also be used to improve fermentation and to control some foodborne pathogens that occasionally infest silage (Queiroz *et al.*, 2018).

Particle size is important for proper compaction to reduce the presence of oxygen and to obtain adequate anaerobic fermentation and should be around 2 cm (Heinrichs and Roth, 2001; Romero and Castillo, 2013).

The supply of silage to animals should be controlled so that there is no feed waste and spoilage before ingestion. Unconsumed silage should be discarded.

The colour and smell are usually sufficient to identify poor quality silage, but assessing the pH, dry matter content and acid fermentation profile may be useful in determining the extent of improper fermentation.

Hay

Hay production should follow the principles of GAPs. Forage should have good stalk to leaf ratio (more leaves than stalks), thin stalks and thin cuticle. In general, grasses dry faster than legumes. Climatic conditions directly interfere with drying the forage. The ideal conditions are high temperatures and solar radiation, moderate wind and low relative humidity. These points are very important to prevent the presence of mould and fermentation. Harvesting at the right time directly interferes with the nutritional value of the hay. The appropriate moisture range at the time of hay baling should be 10-20 percent, i.e. dry matter between 80 and 90 percent (Romero *et al.*, 2015).

Toxic plants and seeds can contaminate hay in the field. Mycotoxins may be present in hay due to contamination during cultivation or after harvesting the forage at high moisture level.

Fresh chopped fodder

Fresh forage production must also follow the principles of GAPs. The time between harvest and the provision of fresh fodder to animals should be as short as possible to prevent undesirable fermentation of the fodder. Different fresh fodders are usually used, such as Camerum grass, *Leucaena leucocephala*, sorghum and pigeon pea. Contamination by agrochemicals during planting or growing can occur, for example, if a forage is planted for one purpose and is used for another, such as sugarcane produced for the alcohol or sugar industry when used as fresh chopped fodder. The withdrawal period maybe not be followed and pesticides levels in forage can be above the regulatory limit.

SECTION 5

Methods of sampling and analysis

Sampling

Sampling protocols should meet scientifically recognized principles and procedures

Analysis

Laboratory methods developed and validated using scientifically recognized principles and procedures should be used. When selecting methods, consideration should also be given to practicability, with preference given to those methods which are reliable and applicable for routine use. Laboratories conducting routine analyses of feed and feed ingredients should ensure their analytical competency with each method used and maintain appropriate documentation.

Codex Alimentarius Code of Practice on Good Animal Feeding (CXC 54-2004)

SAMPLING

Important factors that determine the design and implementation of a sampling programme involve the purpose of the sampling, type of analysis, analytical methods and laboratory accuracy, shipment size, cost of the assay, and the characteristics, variability and value of the feed and feed ingredient.

Sampling protocols should meet scientifically recognized principles and procedures. The use of recognized international sampling methods will ensure a standardized administrative and technical approach and will facilitate the interpretation of results of analysis related to lots or consignments of feed.

Purposes and conditions

When developing protocols, the objectives and purposes of the sampling should be clear. Correct sampling reduces the overall analytical error and enables adequate decisions on key objectives.

Examples of objectives that should be taken into consideration are the following:

- acceptance of consignments
- testing for batching release
- archive samples of feed until the expiry date
- control of feed ingredients
- control of in process feed
- feed controls
- release of non-conforming feed and feed ingredients
- obtaining of retention sample
- legal disputes
- inter-laboratory trials

- validation of analytical methods
- validation of cleaning efficacy
- validation of homogeneity of mixtures
- validation of control measures.

Sampling should be done in a well-defined area to avoid difficulties in the execution of procedures, reduce the risk of contamination and cross contamination, enable the proper execution of laboratory analysis and include all necessary safety and health precautions to the sampler and environment.

Personnel responsible for the sampling activities should be trained on the applicable procedures and have the necessary knowledge of products to be sampled, tools used in the sampling process, adequacy and cleanliness of the environment and sample storage container not to allow contamination or deterioration of the sample.

Sampling can be simple when the analyte to be determined is uniformly distributed in the lot to be sampled and when the material is homogeneous. One must consider that some contaminants are heterogeneously distributed in the lot such as mycotoxins, rye ergot and crotalaria. To choose an adequate sampling plan, knowledge of the distribution of the contaminated units within the bulk load is essential. Milling, comminuting and homogenizing steps are useful for the heterogeneous distribution of contaminants and to decrease sampling error. Several theories and techniques have also been used to overcome the problems of heterogeneity of materials which are related to geostatistics, spatial correlation and resampling techniques. For the homogeneously distributed analytes (e.g. dioxins), incremental samples must be taken at random throughout the

whole sampled portion in a regular interval and in approximately equal sizes (Fink-Gremmels, J., ed., 2012). For the non-homogeneously distributes analytes (e.g. mycotoxins, microorganisms) specific sampling methods should be used.

When sampling for the presence of contaminants such as in the case of mycotoxins, toxic metals, dioxins and dioxin-like PCBs, specific international or national standards should be followed.

Process and equipment

For the execution of the sampling procedures proper tools and materials need to be available to allow:

- opening of bags, packages, barrels, drums, containers, trucks, etc.
- re-closing of containers
- labelling to indicate that a sample has been removed
- storing, retaining and preservation of the sample
- labelling of the storage and retention container
- sampling precautions required by the chemical and microbiological methods of analysis.

All tools and auxiliary materials should be inert and cleaned before and after their use. In the same manner, sampling containers should be cleaned before sampling.

The feed industry uses a combination of tools for collecting samples. Bulk trucks and rail shipments of grains or soybean meal are frequently sampled using a hand probe. Bulk containers may be stratified and multiple samples collected if different portions of the grain are to be sampled.

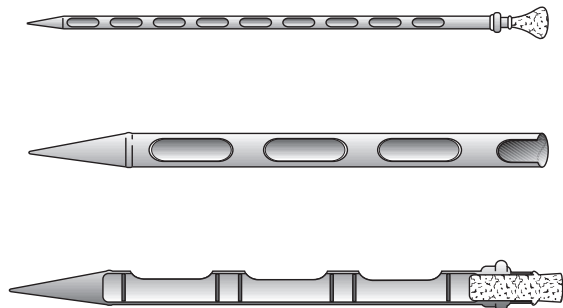
Slotted grain probes (see Figure 28) may be used to collect a representative sample from grain, soybean meal or feed. The grain probe should be long enough to penetrate at least $\frac{3}{4}$ of the depth of the feed. Grain samples are collected using a 4.13 cm diameter probe that consists of two tubes, one inside the other. The inner tube is divided into compartments that enable the individual collecting the sample to detect inconsistencies in grain quality across the

profile of the carrier. This procedure is more labour intensive since the contents of the probe must be emptied onto a tarp or trough and inspected before the grain is transferred into a container.

Open handled grain probes, in which the innertube is not divided into compartments, may be used for sampling feed ingredients including grain. The probe's contents are emptied from the handle and mixing will occur, making it difficult to perform a visual inspection for load inconsistencies by depth. An open handled spiral probe is designed such that openings on the inside tube rotate around, so it opens first at the bottom and then in gradual steps to the top. This assures a fair portion of the sample is collected across the profile of the material. However, incorrect use of this probe can result in the opposite effect if the inside tube is rotated in the opposite direction, resulting in a disproportionate amount of sample collected from the top. The probe should be inserted into the grain or feed ingredient at a 10-degree angle from the vertical, with the slots facing upward and completely closed. A 10-degree angle is used to obtain a cross section of the material, while placing the end of the probe as close to the bottom of the carrier as possible. The slots must be kept closed until the probe is inserted as far as it will go. If the probe's slots are open as it enters the grain, a disproportionate amount of material from the top will fill the probe. After the probe is fully inserted, the slots should be opened and the probe moved up and down quickly in two motions. The slots are then closed completely, the probe grasped by the outer tube and withdrawn from the grain.

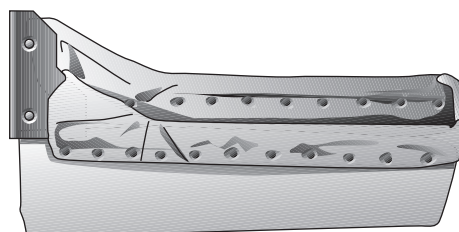
The Pelican grain probe (see Figure 29) is used for on-line grain sampling. The probe is a leather pouch, approximately 0.46 m long, with a band of iron inserted along the edge to hold the pouch open. The pouch is attached to a long pole. Pelicans are designed to catch grain as the pouch is swung or pulled through a falling stream of grain. The Pelican

FIGURE 28
Slotted grain probe



Source: Herrmann, T., 2001a

FIGURE 29
Pelican probe

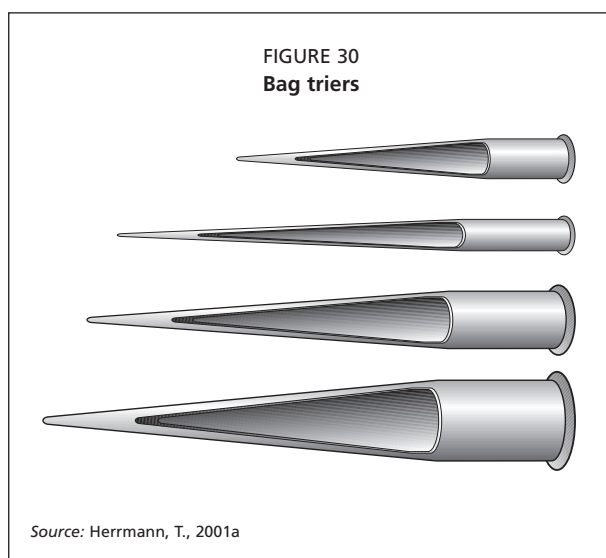


Source: Herrmann, T., 2001a

grain sampler is useful for sampling grain, soybean meal or complete feed samples while a truck is unloading.

Bag shipments of e.g. base mixes, premixtures and medicated feed should be sampled with bag triers (see Figure 30). Tapered bag triers are used to sample closed bags of powdered and granular commodities. Double-tube bag triers are usually constructed of stainless steel. These triers are available in various lengths and diameters, in both close ended and open-ended models and may be used to sample closed and opened bags of powdered and granular ingredients. Single tube, open ended bag triers are constructed of stainless-steel tubing and are used to sample opened bags of dry, powdery commodities when removal of a core material is desired.

Sampling may have different purposes as to verify the performance of the mixer and mixing process. In these cases, other alternatives to the simple sampling tools may be used (see Figure 31).



Fat, molasses and other liquid ingredients stored in drums or barrels can be sampled using a tube of glass or stainless steel. Bulk shipments of liquid ingredients may require a pump sampler. In all cases, the liquid should be subject to stirring prior to the withdrawal of the sample to ensure ingredient distribution.

Forage samples should contain substantial amount of material. The sampling procedure and sample preparation will vary depending on whether the material is a dry forage, silage, pasture, green chopped forage or forage in the field. Samples should be collected in twenty different locations using a core sampler. If this tool is not available, hand sampling can be used. Care should be taken to avoid leaf loss when using this latter procedure. Collecting silage samples should be performed by removing a column of 0.15 m deep by 0.30 m wide on the open face. Silage should be mixed, placed in a plastic bag, tightly packed and sealed to exclude the air (Herrmann, T., 2001a).

Pasture and field storage sampling are subject to variations in soil fertility and moisture content; therefore, sampling should be exercised with care. Eight to ten locations should be selected for sampling, removing approximately 0.1 square meters of forage at grazing height at each location. The composite of the sub samples should be mixed, and material reduced to 1 kg of working sample. Samples of green pasture should be immediately dried to prevent chemical changes.

Water samples may be collected directly into a clean sample container from ponds, lakes, tanks or other sources. The container should be immersed, holding its neck down to 0.30 m below the surface, then, turned mouth up to be filled with sample. Water after extended pumping should be sampled for two to four minutes to ensure it has not been standing in pipes. When bacterial examination is performed, a sterile container should be used for the water sampling.

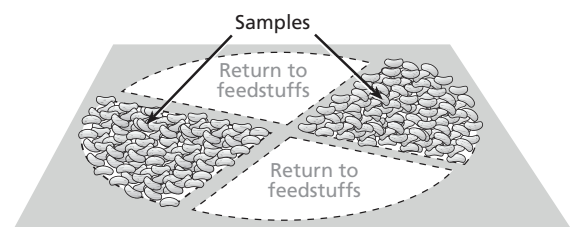
Feed can be sampled as it is transferred to the delivery vehicle if the feed is in the bulk form. In the case of cattle feed that is mixed during transport, collecting the sample from the feed bulk is an acceptable practice.

Any sign of heterogeneous material, which includes differences in shape, size or colour of particles in crystalline, granular or powdered solid substances, moist crust on hygroscopic substances, deposits of solid material or stratification in liquid products should be detected during the sampling procedure. Portions of the material that are heterogeneous should be sampled separately and a composite should not be created as it can mask safety problems.

Sample reduction

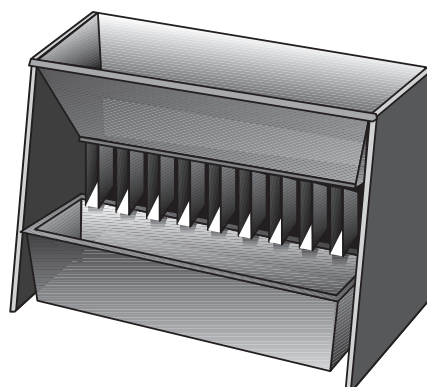
A representative sample is usually taken from a larger quantity of material, that is generally more representative. Most analysis will require smaller samples. Thus, the larger

FIGURE 32
Manual quartering



Source: Herrmann, T., 2001a

FIGURE 33
Riffler



Source: Herrmann, T., 2001a

sample should be divided in several parts to obtain the size required in the analytical method.

Sample reduction may be obtained by quartering the sample to a convenient quantity for analysis. The mixed composite sample should be spread on clean plastic or paper to form an even layer. The paper is marked into quarters and the two opposite quarters are taken and mixed (see Figure 32). The process is repeated until the two quarters selected give the desired sample size.

Complete feed and feed ingredients may be partitioned into uniform sub samples using a riffler (see Figure 33). The sample is poured into the hopper, which is divided into equal portions by two series of chutes that discharge alternately in opposite directions into separate pans.

Heavy plastic bags, zip lock bags, plastic bags or plastic containers make excellent sample containers for dry feed ingredients or feed. The container should protect the sample from light, air, moisture as required by the storage conditions or the intended laboratory analysis.

Sample storage room

In many countries samples of finished products should be archived until the expiry date. Normally, the expiry date is engraved on the product bags and samples are kept in a storage room in each factory (see Figure 34). The conditions of the sample storage room in terms of temperature, humidity and light should be similar to those mentioned for storage on the product labels.

Frequency and retention

With few exceptions, all incoming ingredients should be sampled upon arrival and inspected for identity, physical purity and compared with a reference sample and standard specifications. The sampling procedure should include inspection of the carrier's paperwork to ensure the correct material is being delivered and documentation of receipt of

FIGURE 34
Sample storage room in a well design factory



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the ingredients, which may include a certificate of analysis. When receiving bulk materials, the shipping documents should be inspected for identification of mill, supplier and the name of the individual hauling the cargo. A receiving report that documents receipt of feed ingredients will further support a sampling programme. This receiving report should include the date, feed ingredient name and lot, supplier name, carrier name, bill of lading, purchase order, invoice number, time of receiving, weight, bin number where the ingredient was placed, number of the supplier certificate of analysis, sensory and physical properties verified on the receipt of goods and signature of the person responsible for the receiving inspection.

Commercial feedmills should collect and retain a sample of complete feed for each lot of a given product. Medicated feed may require:

- sampling and evaluation according to regulatory requirements, as the medication added has to be strictly controlled.

BOX 8

Recommendations for the selection of sampling plans

The following enumerates the essential points that users should address for the selection of appropriate sampling plans

1. Existence (or not) of international reference documents on sampling of the considered products.
2. Nature of the control
 - characteristic applicable to each individual item of the lot
 - characteristic applicable to the whole lot (statistical approach).
3. Nature of characteristic to control
 - qualitative characteristic (characteristic measured on a pass/failed or similar basis, i.e. presence of pathogen micro-organism);
 - quantitative characteristic (characteristic measured on a continuous scale, for example a compositional characteristic).
4. Choice of the quality level (acceptance quality limit - AQL or limiting quality - LQ)
 - in accordance with the principles laid down in the Codex manual of procedures and with the type of risk: critical/non-critical non-conformities.
5. Nature of the lot
 - bulk or pre-packed commodities;
 - size, homogeneity and distribution concerning the characteristic to control.
6. Composition of the sample
 - sample composed of a single sampling unit;
 - sample composed of more than one unit (including the composite sample).
7. Choice of the type of sampling plan
 - acceptance sampling plans for statistical quality control;
 - for the control of the average of the characteristic;
 - for the control of per cent non-conforming items in the lot;
 - definition and enumeration of non-conforming items in the sample (attribute plans);
 - comparison of the mean value of the items forming the sample with regards to an algebraic formula (variable plans).

Codex Alimentarius Guidelines on Sampling
(CXC 54-2004)

- concentration (that are sometimes very small) according to the veterinary prescription, allow traceability and mass balance of quantities used.

Samples should be retained until all feed has been consumed by the animal or for liability reasons.

Sampling plans for feed and feed ingredients

International methods of sampling should be used to ensure that valid sampling procedures are applied when feed is being tested for compliance to a standard or objective. The Codex Alimentarius General Guidelines on Sampling (FAO, WHO, 2004) provides information and guidance to facilitate the development of specific sampling procedures for conformity assessment.

Numerous sampling plans are available and none can ensure that every item in a lot conforms to the studied parameters. They are nevertheless useful for guaranteeing an acceptable quality level agreed by the parties for the specified controls.

A sampling procedure should stipulate the conditions on which a lot should be inspected and classified. These conditions include the inspection procedures (normal, tightened or reduced inspection), switching procedures (normal to tightened, tightened to normal and normal to reduced) inspection level (I, II and III, S-1, S-2, S-3, S-4), acceptance quality levels (AQLs), number of items to be randomly selected from the lot and that will comprise the sample, acceptance and rejection numbers.

The International Standardization Organization (ISO) provides a number of standards related to sampling.

- **ISO 2854:1976:** Statistical interpretation of data - techniques of estimation and tests relating to means and variances (ISO, 2006a).
- **ISO 2859-1:1999:** Sampling procedures for inspection by attributes - part 1: sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection (ISO, 1999).
- **ISO 2859-2:2020:** sampling procedures for inspection by attributes - part 2: sampling plans indexed by limiting quality (LQ) for isolated lot inspection (ISO, 2020).
- **ISO 2859-3:2005:** sampling procedures for inspection by attributes - part 3: skip-lot sampling procedures (ISO, 2019b).
- **ISO 2859-4:2002:** sampling procedures for inspection by attributes - part 4: procedures for assessment of declared quality level (ISO, 2008).
- **ISO 2859-5:2005:** sampling procedures for inspection by attributes - part 5: system of sequential sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection (ISO, 2019c).
- **ISO 28590:2017:** sampling procedures for inspection by attributes - part 10: introduction to the ISO 2859

series of standards for sampling for inspection by attributes (ISO, 2017b).

- **ISO 3494:1976:** statistical interpretation of data - power of tests relating to means and variances (ISO, 2015).
- **ISO 3951-1:2013:** sampling procedures for inspection by variables - part 1: specification for single sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection for a single quality characteristic and a single AQL (ISO, 2013).
- **ISO 3951-2:2013:** sampling procedures for inspection by variables - part 2: general specification for single sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection of independent quality characteristics (ISO, 2018a).
- **ISO 3951-3:2007:** sampling procedures for inspection by variables - part 3: double sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection (ISO, 2016b).
- **ISO 3951-4:2011:** sampling procedures for inspection by variables - part 4: procedures for assessment of declared quality levels (ISO, 2017a).
- **ISO 3951-5:2006:** sampling procedures for inspection by variables - part 5: sequential sampling plans indexed by acceptance quality limit (AQL) for inspection by variables (known standard deviation) (ISO, 2006b).
- **ISO 5725-1:1994:** accuracy (trueness and precision) of measurement methods and results - part 1: general principles and definitions (ISO, 2018b).
- **ISO 7002:1986:** agricultural food products - layout for a standard method of sampling from a lot (ISO, 2018c).
- **ISO /TR 8550-1:2007:** guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots - part 1: acceptance sampling (ISO, 2017c).

- **ISO /TR 8550-2:2007:** guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots - part 2: sampling by attributes (ISO, 2017d).
- **ISO /TR 8550-3:2007:** guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots - part 3: sampling by variables (ISO, 2017e).
- **ISO 10725:2000:** acceptance sampling plans and procedures for the inspection of bulk materials (ISO, 2016c).
- **ISO 11648-1:2003:** statistical aspects of sampling from bulk materials - part 1: general principles (ISO, 2019d).
- **ISO 11648-2:2001:** statistical aspects of sampling from bulk materials - part 2: sampling of particulate materials (ISO, 2018d).
- **ISO 28597:2017:** acceptance sampling procedures by attributes - specified quality levels in nonconforming items per million (ISO, 2017f).
- **ISO 24333:2009:** cereals and cereal products - sampling (ISO, 2018e).

ANALYSIS

Feed and feed ingredients should be submitted for routine analysis as part of a feed safety programme. Knowledge of feed and feed ingredients and composition is of utmost importance for managing feed safety. Laboratory methods should be developed and validated according to scientifically recognized principles.

To control, approve and reject feed and feed ingredients, well written specifications are necessary. They will be used in the communications and agreements with suppliers, in formulation and to comply with customers' requirements. In the specification sheets, safety parameters of feed and feed ingredients shall be defined.

TABLE 10
Commonly used determinations for feed and feed ingredients safety

Properties	Motivation
Sensory and physical properties	Inspection of colour, odour, texture, moisture, temperature and visualization of impurities such as foreign material and insect infestation. Identification of product identity.
Bulk density	Important for inventory control and determination of feed ingredient performance during batching and blending. A nonhomogeneous mixture can result in a safety problem as components, especially veterinary drugs, may not be present in equal proportions throughout the mixture.
Purity	Verification of absence of contaminant: physical (e.g. glass, foreign material, etc); chemical (e.g. toxic metals, dioxins, mycotoxins, pesticides, etc); biological (e.g. <i>Salmonella</i> , <i>E. coli</i> , etc).
Moisture	Moisture can be related to microorganism's development growth of fungi and production of mycotoxin.
Microscopy	Materials are examined and identified based on physical characteristics such as shape, colour, particle size, softness, hardness, and texture. Feed microscopy is a useful method for identifying impurities/contaminants and evaluating the safety of feed ingredients. It also serves as a useful method for identifying missing or fraudulent ingredients in feed.

Source: Herrman, T. 2001b

Methods of analysis

Accuracy, precision, specificity, sensitivity, dependability and practicality should be considered when choosing the most appropriate method. Furthermore, the selection of methods must consider matters other than the listed attributes. Depending on their purpose, methods can be classified as (Garfield, F.M., 1994):

- Official methods - required by legislation and used in regulatory analyses by competent authorities.
- Reference/Standard methods - developed and validated by organizations or groups through collaborative studies.
- Screening or rapid methods - used as expedient means to determine, for many samples, whether any of them should be subjected to additional testing by a more accurate method or else, a confirmatory method.
- Routine methods - used on routine analysis and can be official or standard or even modified to be more convenient when many samples need to be processed.
- Automated methods - use automated equipment and may be official or screening methods.
- Modified methods - usually official or standards methods that were modified for simplification, to remove interfering substances or to be applicable to different types of samples.

When choosing the method, the analyst should consider those that are applied to the matrix of interest, those that have been tested and validated over the concentration range of interest and methods documented by published inter-laboratory validation data. Preference should be given to methods for which reliability has been established in collaborative studies in several laboratories.

The characteristics of the different methods and their application must be considered when working on an analytical programme.

Screening methods

There are various reasons to use screening methods. The most important is that many of these methods neither require a laboratory environment nor highly educated personnel. Moreover, the screening methods are less expensive and often the duration of the analysis is shorter compared to conventional methods.

These methods are typically used in situations, where a high number of samples needs to be analyzed and there are some indications that most samples are below the target level. Screening tests are designed to identify samples exceeding this target level. Negative samples are accepted as such. Positive samples need to be subjected to confirmatory analysis for official control, as screening methods may lead to false positive results. In other situations, for

instance for quality control or when advanced methods are not available, a positive result may directly trigger an action without further measurements.

The impact of false positive results on the measurement exercise needs to be evaluated case-by-case also considering other factors. For instance, if there is very high cost reduction by using screening tests compared to conventional methods, an increased rate of false positive results can be accepted.

It should be noted that when these methods are used for complex products such as compound feed, the performance may be worse. For this reason, screening methods should always be validated for each product of concern to see if the method is fit for the purpose (FAO, WHO, 2019d).

Confirmatory methods

Samples giving a positive result with screening methods could undergo a confirmatory test to check for compliance with the target level. Confirmatory tests require the use of more sophisticated methods that have been thoroughly validated, for instance by conducting a collaborative trial. However, the latter requires considerable planning in terms of design of the trial, the type of matrix or matrices to be analyzed, the level of hazard and the number of samples (FAO, WHO, 2019d).

Multi-analyte methods

Multi-analyte assays are methods enabling the detection of multiple analytes in one test. The objectives for the development of multi-analyte assays are simple: quick sample pre-treatment alternatives with high-throughput screening settings for the analysis of large numbers of samples at low cost. To date, there have been increased efforts toward the development of multi-analyte assays focused on different analytes, such as enzyme-linked immunoassays, fluorescence immunoassays and other immunoassays. They are based on different solid supports or biosensors for the detection of pesticides; electroanalytical sensors and devices for the detection and identification of pathogen microorganisms; polymerase chain reaction techniques for the detection of viruses; bacteria and other pathogen microorganisms; liquid chromatography-tandem mass spectrometry for the determination of mycotoxins; photoinitiators and amine synergists in food. These rapid and sensitive assays could satisfy the requirements of other environmental materials detection and quantification.

New developments in analytical methods

Mass spectrometry (MS)-based detection methods have replaced the formerly applied HPLC-ultraviolet (LC-UV) and HPLC-fluorescence methods and the GC-flame ionization detection (GC-FID) and GC-electron capture detection (GC-ECD) methods for many applications.

For potentially toxic elements (arsenic, cadmium, lead and mercury) most laboratories apply atomic absorption spectroscopy (AAS) in different formats for the various compounds. Single-analyte methods for feed, feed ingredients, premixtures and feed additives are well established and standardized. Multi-analytes methods based on inductively coupled plasma (ICP) - atomic emission spectrometry (ICP-AES) that are primarily focused on minerals and trace elements, may also be used for lead and cadmium, but only for higher levels of mineral products. The trend is towards the use of ICP-MS multi-analyte methods where potentially toxic elements can be determined together with minerals and trace elements.

Technologies for the detection and enumeration of biological hazards are emerging; these include the use of chromogenic and fluorogenic growth media as well as more rapid bacteriophage-based and impedance-based techniques. Nonetheless, the need for rapid and accurate detection in parallel remains (Okelo, P.O., Fink-Gremmels, J., 2012).

As advances in real time microbiology continue, it may be expected that detection and enumeration that are based on all existing methods will become more amenable to automation and better adapted to computer technology to control process, analyses and the reporting of results. Real time microbiological detection and enumeration results

TABLE 11
Screening and confirmatory methods

Group of hazards	Screening methods		Confirmatory methods	
	Methods available	Remarks	Methods available	Remarks
Dioxins + dlPCBS	Bio-assays (Calux) (Hoogenboom <i>et al.</i> , 2006)	Multi-analyte	GC/HRMS, GC-MS/M (European Commission, 2017)	Multi-analyte
Mycotoxins	Dipsticks, ELISA (Maragos <i>et al.</i> , 2010, von Holst et Stroka, 2014)	Also multi-analyte	LC-MS/MS, LCFLUO (Stroka <i>et al.</i> , 2003, Mol <i>et al.</i> , 2008)	Also multi-class together with Plant toxins
Heavy metals			AAS, ICP-MS (EN 15510, 2017)	LC-ICP-MS for inorganic arsenic and methylmercury; AAS for inorganic arsenic after SPE pre-separation
Veterinary drugs	Dipsticks, ELISA (Borràs <i>et al.</i> , 2011)	Also multianalyte	LC-MS/MS (Kaklamanos <i>et al.</i> , 2013)	
Organochlorine Pesticides	GC-ECD		GC-MS	
Plant toxins	Dipsticks (tropane alkaloids), Mulder <i>et al.</i> , 2014) ELISA (pyrrolizidine alkaloids) (Oplatowska <i>et al.</i> , 2014)	Also multianalyte; for many plant toxins screening methods are not yet available	LC-MS/MS (Mol <i>et al.</i> , 2008)	Also multi-class together with mycotoxins; for some of the emerging plant toxins no methods are available
Brominated flame retardants			GC-MS/MS, LC-MS/MS (for PBDES) (Lankova <i>et al.</i> , 2013)	GC-MS/MS: also together with dlPCBS, ndl-PCBs, PAHs
Pathogens	Conventional PCR (Jarquin <i>et al.</i> , 2009)		Culture-based assays (MPN), real-time PCR and qPCR (Okelo and Fink-Gremmels, 2012)	Disadvantage of qPCR: preenrichment necessary to distinguish between viable and non-viable counts
Parasites			Microscopy	
Packaging materials			Visually, microscopy (Raamsdonk <i>et al.</i> , 2012)	
Microplastics			Microscopy (Raamsdonk <i>et al.</i> , 2012)	
Radionuclides			Gamma-ray, spectrometry measurements (Desideri <i>et al.</i> , 2014)	
Nanomaterials	Not available yet		Not available yet	

Abbreviations: AAS: Atomic Absorption Spectroscopy; ECD: Electron Capture Detection; GC: Gas Chromatography; ELISA: Enzyme-linked immunosorbent assay; LC: Liquid Chromatography; ICP: Inductively Coupled Plasma; HRMS: High Resolution MS; MPN: Most Probable Number; MS: Mass Spectrometry; MS/MS: tandem MS; NIR: Near Infrared; PCR: Polymerase chain reaction; qPCR: quantitative PCR; SPE: Solid-phase Extraction

Source: FAO, WHO, 2019d

for target organisms can be used as input data to control mechanisms that regulate critical operating conditions of process equipment during the manufacture of feed and feed ingredients (Fink Gremmels J., 2012).

Whole Genome Sequencing (WGS), sometimes referred to as DNA fingerprinting, can identify microorganisms with previously unknown accuracy. The technology can detect organisms in better detail as it is rapid, cost-effective, easy-to-use and universally applicable. WGS offers high-resolution subtyping of different bacterial, viral, fungal and parasitic hazards. This capability can be used for retrospective comparison of microorganisms associated with epidemiologically suspected outbreaks or for prospective laboratory surveillance of high-burden diseases.

Table 11 lists both screening and confirmatory methods that are used in practice for each of the potential hazards. It should be stressed that most of these methods have not been validated for all relevant feed and feed ingredients.

Most of the hazards, especially chemical, will require the most sophisticated techniques, a better equipped laboratory and a highly skilled staff.

As shown in Table 11, no reliable methods are available for several hazards, notably for nanomaterials. This indicates the strong need for development of these methods.

Industry and institutional associations, through different group of experts, have published guidelines with methods to be applied for process and products evaluation and safety controls (Laboratory Methods and Services Committee of the American Association of Feed Control Officials – AAFCO, Laboratory Committee of the Brazilian Association of Feed Manufacturers – Sindirações, Laboratory Committee of the American Association of Feed Industry – AFIA). These routine

evaluations of feed and feed ingredients will require different equipment and a relatively simple setup. Lab personnel should always be trained.

Tables 12 and 13 summarise references for accessible methods that can be implemented in the feedmill laboratories and that use basic equipment, materials and reagents.

LABORATORY QUALITY ASSURANCE PROGRAMMES

One of the main goals of the laboratory is the production of high-quality analytical data obtained through analytical measurements that are accurate, reliable and adequate for the intended purpose. This can be achieved with the implementation of a well-established quality assurance programme ensuring analytical competency and maintenance of proper documentation.

Quality assurance programmes will require the implementation of elements such as: management quality policy statement, programme objectives, control of samples and records, equipment maintenance, methods validation, measurement principles, training, methods selection, intra and inter-laboratory testing, proficiency testing, reference standards, field and lab sampling, statistical considerations, audits, corrective actions, programme revision and update.

Laboratories operating under a recognized quality management standard can seek independent approval of their quality assurance arrangements preferably by accreditation which will allow them to demonstrate competence and reliability. Quality standards are available such as ISO/IEC 17025 – General Requirements for the Competence of Testing and Calibration Equipment (ISO, 2017h) and applied by the accreditation organizations on the evaluation of

TABLE 12
Physico-chemical methods

Scope	Determination	Reference methods	Equipment required
Maize, peanuts, wheat, triticale, barley, oat, meals, feed	Mycotoxins	Rodriguez-Amaya, D. B., Soares, L. V., 1985. Rodriguez-Amaya, D. B., Soares, L. V., 1989.	Analytical scale Water bath Dark chamber UV 366 nm UV/VIS spectrophotometer Blender Ultrasound
Minerals and mixtures	Inorganic contaminants	AOAC Method 968.08, 2016.	Analytical scale Atomic absorption spectrophotometer Muffle furnace Thermal plate
Minerals and mixtures	Inorganic contaminants	AOAC Method 985.01, 2016.	Analytical scale ICP/OES spectrophotometer Muffle furnace Thermal plate

TABLE 13
Microbiological methods

Scope	Determination	Reference methods	Equipment required
Feed and feed ingredients	<i>Bacillus cereus</i>	Bennet, R.W., Behy, N., 2001.	Analytical scale Autoclave Incubation ovens Bunsen burner or microwave oven
Feed and feed ingredients	Yeasts and moulds	Tournas, V., Stack, M.E., Mislivec, P.B., Koch, H.A.; Bandler, R., 2001.	Analytical scale Autoclave Incubation oven Bunsen burner or microwave oven Water bath Laminar flow Incubator (25 +/- 1°C)
Feed and feed ingredients	<i>Clostridium perfringens</i>	Rhodehamel, E.J., Harmon, S.M. 2001. Labbe, R.G., 2001.	Analytical scale Autoclave Incubation oven Bunsen burner or microwave oven Water bath (with agitation) Laminar flow Incubator (25+/- 1°C) Stomacher
Feed and feed ingredients	<i>Salmonella</i>	Andrews, W.H., Flowers, R.S.; Silliker, J.; Bailey, J.S., 2001. Andrews, W.H., Wang, H., Jacobson, A., Hammack, T.S. 2020. Bennett, A.R.; Macphee, S.; Betts, R.; Post, D., 1999. International Standardization Organization, 2017g.	Analytical scale Autoclave Bunsen burner or microwave oven Water bath (with agitation) Stomacher
Feed and feed ingredients	<i>E. coli</i>	Davidson, P.M., Roth, L.A., Gambrel-Lenarz, S.A., 2004. Baird, R.B. et al., 2017. Feng, P.C.S., Hartman, P.A., 1982.	Analytical scale Autoclave Incubation oven Bunsen burner or microwave oven Water bath (with agitation) Stomacher

the competence of the laboratory. This is important to be observed specially when contracting an external laboratory. As alternatives to accreditation, adoption of validated methods, proficiency tests, intra or inter laboratory trials can ensure analytical competence.

Measures of uncertainties

When choosing a contracted laboratory, it is important to discuss the purposes of the analysis to be done, the method the laboratory will use to perform the analytical determinations and in particular the expressed uncertainty of the results.

Uncertainty is a measure of the quality of laboratory results. Analytical results vary due to several conditions of the laboratory system and many important decisions are based on the values obtained in quantitative analyses. Results are decision elements for acceptance or rejection of products and shipments when compared to specifications

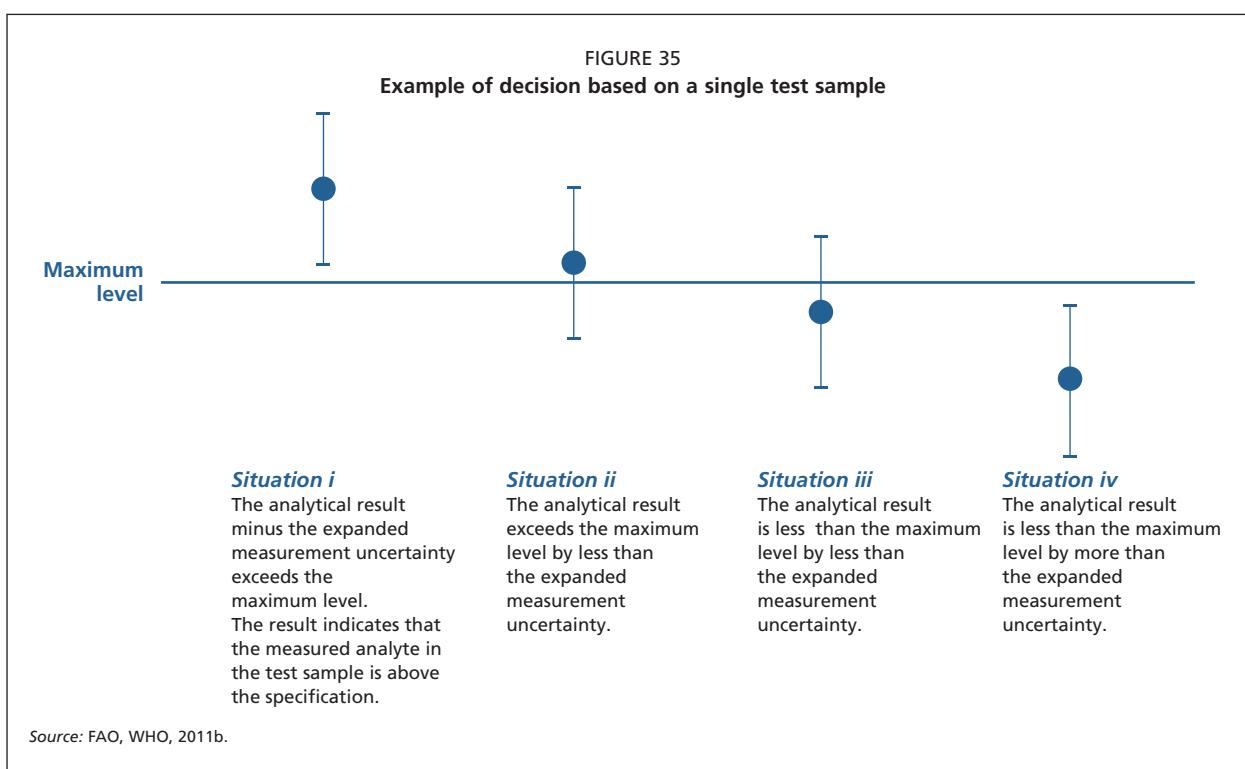
or legislation, in estimating process performance and for business transactions involving monetary values. Regardless of the decision taken based on analytical results, it is very important to have an indication of the quality of the analysis, i.e. the extent to which results can support the decision to be taken. For this reason, uncertainty is calculated.

The concept of uncertainty as a quantifiable attribute is relatively new, although it has always been part of the measurement practice. But, just as the use of the International System of Units has brought coherence to scientific and technological measures, an internationally shared concept of the measurement uncertainty assessment and expression should result in a broader meaning of a wide range of measurement results in all areas and enable a better understanding and interpretation of statutory and regulatory aspects. In some areas of analytical chemistry, such as those involved in international trade, laboratories are already required to implement quality assurance measures to ensure that they

TABLE 14

Practical recommendations for sampling and analyzing

When defining the sampling procedures, one should consider the purpose of sampling, the laboratory analysis to be performed on the samples and the characteristics of the feed and feed ingredients.
The objectives and sampling purposes to be achieved should be clear when developing the sampling procedures to be adopted.
Sampling should be done in a well-defined area to avoid difficulties in the executing of procedures, reduce the risk of contamination and cross contamination, enable the proper execution of laboratory analysis and include all necessary safety and health precautions for the sampler and environment.
Personnel responsible for the sampling activities should be trained on the applicable procedures.
All tools and auxiliary materials should be inert, and in a clean condition before and after their use.
Portions of the material that are not homogeneous should be sampled separately and a composite should not be made as it can mask safety problems.
With few exceptions, all incoming ingredients should be sampled upon arrival and inspected for identity, physical purity and compared with a reference sample and standard specifications.
International methods of sampling should be used to ensure that valid sampling procedures are applied when feed is being tested for compliance to a particular standard or objective.
A sampling procedure should stipulate the conditions on which a lot should be inspected and classified.
Accuracy, precision, specificity, sensitivity, dependability and practicality should be considered when choosing the most appropriate method of analysis.
Laboratories operating under a recognized quality standard can seek independent approval of their quality assurance arrangements, preferably by accreditation which will allow them to demonstrate competency and reliability.



are capable of delivering the required quality results. That is, with acceptable uncertainty, for decision making and risk assessment. In addition to reporting how good results can be considered, uncertainty also makes it possible to compare results from different laboratories.

It is very important to define clear guidelines to allow unambiguous interpretation of analytical result with respect to their measurement uncertainties. The significance of this can be illustrated by an example (see Figure 35), which

shows the simplest case when decisions are made based on a single test sample. (FAO, WHO, 2011b).

Practically, in situation i, the interpretation would be that the sample is nonconforming, as it does not meet the specification. For situation ii, one could consider having no reason to suppose that the limit was exceeded and, therefore, no action would be taken. On the other hand, others could take measures, without considering the uncertainty and the sample would be considered non-complaint and

above the limit. Of course, when dealing with biological hazards, the criterion would necessarily be the most restrictive. In the case of chemicals, additives and others, the criterion could vary from one interpretation to another. Considering situation iii, the sample would be accepted, but it is important to note that the reported value is close to the specified maximum and future samples are likely to be

closely monitored. In the case of pathogens, as described in the previous case, some would consider that there would be a risk, even remote that the sample contained such organisms and would consider it non-complaint. The reported value, for situation iv, is below the specified limit, considering or not the uncertainty value. Thus, the sample would be considered as complaint.

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Appendices

APPENDIX 1

Codex Alimentarius Code of Practice on Good Animal Feeding

(CXC 54-2004. Amendment 2008)

SECTION 1. INTRODUCTION

1. This Code is to establish a feed safety system for food producing animals which covers the whole food chain, taking into account relevant aspects of animal health and the environment in order to minimize risks to consumers' health. This Code applies in addition to the principles of food hygiene already established by the Codex Alimentarius Commission¹, taking into account the special aspects of animal feeding.

SECTION 2. PURPOSE AND SCOPE

2. The objective of this Code is to help ensure the safety of food for human consumption through adherence to good animal feeding practice at the farm level and good manufacturing practices (GMPs) during the procurement, handling, storage, processing and distribution of animal feed and feed ingredients for food producing animals.

3. This Code of Practice applies to the production and use of all materials destined for animal feed and feed ingredients at all levels whether produced industrially or on farm. It also includes grazing or free-range feeding, forage crop production and aquaculture.

4. Those issues of animal welfare other than food safety related animal health are not covered. Environmental contaminants should be considered where the level of such substances in the feed and feed ingredients could present a risk to consumers' health from the consumption of foods of animal origin.

5. While recognizing that, in its totality, a feed safety system would address animal health and environmental issues, in addition to consumers' health, this Code of Practice, in fulfilling the Codex mandate of consumer protection, only addresses food safety. Notwithstanding this, best efforts have been made to ensure that the recommendations and practices in this Code of Practice will not be detrimental to the more general animal health and environmental aspects of animal feeding.

¹ *Recommended International Code of Practice – General Principles of Food Hygiene* (CAC/RCP 1-1969)

SECTION 3. DEFINITIONS

6. For the purpose of this Code:

Feed (Feedingstuff): Any single or multiple materials, whether processed, semi-processed or raw, which is intended to be fed directly to food producing animals.

Feed Ingredient: A component part or constituent of any combination or mixture making up a feed, whether or not it has a nutritional value in the animal's diet, including feed additives. Ingredients are of plant, animal or aquatic origin, or other organic or inorganic substances.

Feed Additive²: Any intentionally added ingredient not normally consumed as feed by itself, whether or not it has nutritional value, which affects the characteristics of feed or animal products.

Medicated Feed: Any feed which contains veterinary drugs as defined in the Codex Alimentarius Commission Procedural Manual.

Undesirable Substances: Contaminants and other substances which are present in and/or on feed and feed ingredients and which constitute a risk to consumers' health, including food safety related animal health issues.

SECTION 4. GENERAL PRINCIPLES AND REQUIREMENTS

7. Feed and feed ingredients should be obtained and maintained in a stable condition so as to protect feed and feed ingredients from contamination by pests, or by chemical, physical or microbiological contaminants or other objectionable substances during production, handling, storage and transport. Feed should be in good condition and meet generally accepted quality standards. Where appropriate, good agricultural practices, good manufacturing practices (GMPs) and, where applicable, Hazard Analysis and Critical Control Point (HACCP) principles³ should be followed to control hazards that may occur in food. Potential sources of contamination from the environment should be considered.

² Micro-organisms, enzymes, acidity regulators, trace elements, vitamins and other products fall within the scope of this definition depending on the purpose of use and method of administration.

³ Hazard Analysis and Critical Control Point, as defined in the Annex to the *General Principles of Food Hygiene* (CXC 1-1969).

8. Parties that produce feed or feed ingredients, those that rear animals for use as food and those that produce such animal products need to collaborate to identify potential hazards and their levels of risk to consumers' health. Such collaboration will enable the development and maintenance of appropriate risk management options and safe feeding practices.

4.1 Feed ingredients

9. Feed ingredients should be obtained from safe sources and be subject to a risk analysis where the ingredients are derived from processes or technologies not hitherto evaluated from a food safety point of view. The procedure used should be consistent with the *Working Principles for Risk Analysis for Application in the Framework of the Codex Alimentarius*⁴. Manufacturers of feed additives in particular should provide clear information to the user to permit correct and safe use. Monitoring of feed ingredients should include inspection and sampling and analysis for undesirable substances using risk-based protocols. Feed ingredients should meet acceptable and, if applicable, statutory standards for levels of pathogens, mycotoxins, pesticides and undesirable substances that may give rise to consumers' health hazards.

4.2 Labelling

10. Labelling should be clear and informative as to how the user should handle, store and use feed and feed ingredients. Labelling should be consistent with any statutory requirements and should describe the feed and provide instructions for use. Labelling or the accompanying documents should contain, where appropriate:

- information about the species or category of animals for which the feed is intended;
- the purpose for which the feed is intended;
- a list of feed ingredients, including appropriate reference to additives, in descending order of proportion;
- contact information of manufacturer or registrant;
- registration number if available;
- directions and precautions for use;
- lot identification;
- manufacturing date; and
- "use before" or expiry date.

11. This sub-section does not apply to labelling of feed and feed ingredients derived from modern biotechnology.⁵

4.3 Traceability/product tracing and record keeping of feed and feed ingredients

12. Traceability/product tracing of feed and feed ingredients, including additives, should be enabled by proper record keeping for timely and effective withdrawal or recall of products if known or probable adverse effects on consumers' health are identified. Records should be maintained and readily available regarding the production, distribution and use of feed and feed ingredients to facilitate the prompt trace-back of feed and feed ingredients to the immediate previous source and trace-forward to the next subsequent recipients if known or probable adverse effects on consumers' health are identified.⁶

4.3.1 Special conditions applicable to emergency situations

13. Operators should, as soon as reasonable, inform the competent authorities in the country if they consider that a feed or feed ingredient does not satisfy the feed safety requirements established in this Code. The information should be as detailed as possible and should at least contain a description of the nature of the problem, a description of the feed or feed ingredients, the species for which it is intended, the lot identifier, the name of the manufacturer and the place of origin. The competent authorities and operators should immediately take effective measures to ensure that those feed or feed ingredients do not pose any danger to consumers' health.

14. As soon as it becomes likely that a particular feed or feed ingredient is to be traded internationally and may pose a danger to consumers' health, the competent authorities of the exporting countries should notify, at least, the competent authorities of the relevant importing countries. The notification should be as detailed as possible and should at least contain the particulars indicated in the previous paragraph.

4.4 Inspection and control procedures

15. Feed and feed ingredients manufacturers and other relevant parts of industry should practice self-regulation/auto-control to secure compliance with required standards for production, storage and transport. It will also be necessary for risk-based official regulatory programmes to be established to check that feed and feed ingredients are produced, distributed and used in such a way that foods of animal origin for human consumption are both safe and suitable. Inspection and control procedures should be used to verify that feed and feed ingredients meet requirements

⁴ Procedural Manual of the Codex Alimentarius Commission.

⁵ Whether and how to label animal feed and feed ingredients derived from modern biotechnology awaits developments on food labelling, being considered by the Codex Committee on Food Labelling

⁶ Development of detailed measures on traceability/product tracing should take into the account: *Principles for Traceability/Product Tracing as a tool within a Food Inspection and Certification System* (CXG 60-2006).

in order to protect consumers against food-borne hazards.⁷ Inspection systems should be designed and operated on the basis of objective risk assessment appropriate to the circumstances.⁸ Preferably the risk assessment methodology employed should be consistent with internationally accepted approaches. Risk assessment should be based on current available scientific evidence.

16. Monitoring of feed and feed ingredients, whether by industry or official inspection bodies, should include inspection and sampling and analysis to detect unacceptable levels of undesirable substances.

4.5 Health hazards associated with animal feed

17. All feed and feed ingredients should meet minimum safety standards. It is essential that levels of undesirable substances are sufficiently low in feed and feed ingredients that their concentration in food for human consumption is consistently below the level of concern. Codex Maximum Residue Limits and Extraneous Maximum Residue Levels set for feed should be applied. Maximum residue limits set for food, such as those established by the Codex Alimentarius Commission, may be useful in determining minimum safety standards for feed.

4.5.1 Feed additives and veterinary drugs used in medicated feed

18. Feed additives and veterinary drugs used in medicated feed should be assessed for safety and used under stated conditions of use as pre-approved by the competent authorities.

19. Veterinary drugs used in medicated feed should comply with the provisions of the *Guidelines for the Design and Implementation of National Regulatory Food Safety Assurance Programmes Associated with the Use of Veterinary Drugs in Food Producing Animals*.⁹

20. Borderlines between feed additives and veterinary drugs used in medicated feed may be set to avoid misuse.

21. Feed additives should be received, handled and stored to maintain their integrity and to minimise misuse or unsafe contamination. Feed containing them should be used in strict accordance with clearly defined instructions for use.

22. Antibiotics should not be used in feed for growth promoting purposes in the absence of a public health safety assessment.¹⁰

4.5.2 Feed and feed ingredients

23. Feed and feed ingredients should only be produced, marketed, stored and used if they are safe and suitable, and, when used as intended, should not represent in any way an unacceptable risk to consumers' health. In particular, feed and feed ingredients contaminated with unacceptable levels of undesirable substances should be clearly identified as unsuitable for animal feed and not be marketed or used.

24. Feed and feed ingredients should not be presented or marketed in a manner liable to mislead the user.

4.5.3 Undesirable substances

25. The presence in feed and feed ingredients of undesirable substances such as industrial and environmental contaminants, pesticides, radionuclides, persistent organic pollutants, pathogenic agents and toxins such as mycotoxins should be identified, controlled and minimised. Animal products that could be a source of the Bovine Spongiform Encephalopathy (BSE) agent¹¹ should not be used for feeding directly to, or for feed manufacturing for, ruminants. Control measures applied to reduce unacceptable level of undesirable substances should be assessed in terms of their impact on food safety.

26. The risks of each undesirable substance to consumers' health should be assessed and such assessment may lead to the setting of maximum limits for feed and feed ingredients or the prohibition of certain materials from animal feeding.

SECTION 5. PRODUCTION, PROCESSING, STORAGE, TRANSPORT AND DISTRIBUTION OF FEED AND FEED INGREDIENTS

27. The production, processing, storage, transport and distribution of safe and suitable feed and feed ingredients is the responsibility of all participants in the feed chain, including farmers, feed ingredient manufacturers, feed compounders, truckers, etc. Each participant in the feed chain is responsible for all activities that are under their direct control, including compliance with any applicable statutory requirements.

28. Feed and feed ingredients should not be produced, processed, stored, transported or distributed in facilities or using equipment where incompatible operations may affect

⁷ *Principles for Food Import and Export Inspection and Certification* (CXG 20-1995).

⁸ *Guidelines for the Design, Operation, Assessment and Accreditation of Food Import and Export Inspection and Certification Systems* (CXG 26-1997).

⁹ CXG 71-2009

¹⁰ *WHO Global Principles for the Containment of Antimicrobial Resistance in Animals Intended for Food*, June 2000, Geneva, Switzerland.

¹¹ Joint WHO/FAO/OIE Technical Consultation on BSE: public health, animal health and trade, OIE Headquarters, Paris, 11–14 June 2001.

their safety and lead to adverse effects on consumers' health. Due to the unique characteristics of aquaculture, the application of these general principles must consider the differences between aquaculture and terrestrial-based production.

29. Where appropriate, operators should follow GMPs and, where applicable, HACCP principles to control hazards that may affect food safety. The aim is to ensure feed safety and in particular to prevent contamination of animal feed and food of animal origin as far as this is reasonably achievable, recognising that total elimination of hazards is often not possible.

30. The effective implementation of GMPs and, where applicable, HACCP-based approaches should ensure, in particular, that the following areas are addressed.

5.1 Premises

31. Buildings and equipment used to process feed and feed ingredients should be constructed in a manner that permits ease of operation, maintenance and cleaning and minimises feed contamination. Process flow within the manufacturing facility should also be designed to minimise feed contamination.

32. Water used in feed manufacture should meet hygienic standards and be of suitable quality for animals. Tanks, pipes and other equipment used to store and convey water should be of appropriate materials which do not produce unsafe levels of contamination.

33. Sewage, waste and rain water should be disposed of in a manner which avoids contamination of equipment, feed and feed ingredients.

5.2 Receiving, storage and transportation

34. Chemical fertilizers, pesticides and other materials not intended for use in feed and feed ingredients should be stored separately from feed and feed ingredients to avoid the potential for manufacturing errors and contamination of feed and feed ingredients.

35. Processed feed and feed ingredients should be stored separately from unprocessed feed ingredients and appropriate packaging materials should be used. Feed and feed ingredients should be received, stored and transported in such a way so as to minimize the potential for any cross-contamination to occur at a level likely to have a negative impact on food safety.

36. The presence of undesirable substances in feed and feed ingredients should be monitored and controlled.

37. Feed and feed ingredients should be delivered and used as soon as possible. All feed and feed ingredients should be stored and transported in a manner which minimizes deterioration and contamination and enables the correct feed to be sent to the right animal group.

38. Care should be taken to minimize deterioration and spoilage at all stages of handling, storage and transport of feed and feed ingredients. Special precautions should be taken to limit fungal and bacterial growth in moist and semi-moist feed. Condensation should be minimized in feed and feed ingredient manufacturing and processing facilities. Dry feed and feed ingredients should be kept dry in order to limit fungal and bacterial growth.

39. Waste feed and feed ingredients and other material containing unsafe levels of undesirable substances or any other hazards should not be used as feed, but, should be disposed of in an appropriate manner including compliance with any applicable statutory requirements.

5.3 Personnel training

40. All personnel involved in the manufacture, storage and handling of feed and feed ingredients should be adequately trained and aware of their role and responsibility in protecting food safety.

5.4 Sanitation and pest control

41. Feed and feed ingredients, processing plants, storage facilities and their immediate surroundings should be kept clean and effective pest control programmes should be implemented.

42. Containers and equipment used for manufacturing, processing, transport, storage, conveying, handling and weighing should be kept clean. Cleaning programmes should be effective and minimise residues of detergents and disinfectants.

43. Machinery coming into contact with dry feed or feed ingredients should be dried following any wet cleaning process.

44. Special precautions should be taken when cleaning machinery used for moist and semi-moist feed and feed ingredients to avoid fungal and bacterial growth.

5.5 Equipment performance and maintenance

45. All scales and metering devices used in the manufacture of feed and feed ingredients should be appropriate for the range of weights and volumes to be measured, and be tested regularly for accuracy.

46. All mixers used in the manufacture of feed and feed ingredients should be appropriate for the range of weights or volumes being mixed and be capable of manufacturing suitable homogeneous mixtures and homogeneous dilutions, and be tested regularly to verify their performance.

47. All other equipment used in the manufacture of feed and feed ingredients should be appropriate for the range of weights or volumes being processed, and be monitored regularly.

5.6 Manufacturing controls

48. Manufacturing procedures should be used to avoid cross-contamination (for example flushing, sequencing and physical clean-out) between batches of feed and feed ingredients containing restricted or otherwise potentially harmful materials (such as certain animal by-product meals, veterinary drugs). These procedures should also be used to minimise cross-contamination between medicated and non-medicated feed and other incompatible feed. In cases where the food safety risk associated with cross-contamination is high and the use of proper flushing and cleaning methods is deemed insufficient, consideration should be given to the use of completely separate production lines, transfer, storage and delivery equipment.

49. Pathogen control procedures, such as heat treatment or the addition of authorised chemicals, should be used where appropriate, and monitored at the applicable steps in the manufacturing process.

5.7 Recalls

50. Records and other information should be maintained as indicated in sub-section 4.3 of this Code to include the identity and distribution of feed and feed ingredients so that any feed or feed ingredient considered to pose a threat to consumers' health can be rapidly removed from the market and that animals exposed to the relevant feed can be identified.

SECTION 6. ON-FARM PRODUCTION AND USE OF FEED AND FEED INGREDIENTS

51. This section provides guidance on the cultivation, manufacture, management and use of feed and feed ingredients on farms and in aquaculture.

52. This section should be used in conjunction with the applicable requirements of Sections 4 and 5 of this Code.

53. To help ensure the safety of food used for human consumption, good agricultural practices¹² should be applied

during all stages of on-farm production of pastures, cereal grain and forage crops used as feed or feed ingredients for food producing animals. For aquaculture the same principles should apply, where applicable. Three types of contamination represent hazards at most stages of on-farm production of feed and feed ingredients, namely:

- Biological, such as bacteria, fungi and other microbial pathogens;
- Chemical, such as residues of medication, pesticides, fertilizer or other agricultural substances; and
- Physical, such as broken needles, machinery and other foreign material.

6.1 Agricultural production of feed

54. Adherence to good agricultural practices is encouraged in the production of natural, improved and cultivated pastures and in the production of forage and cereal grain crops used as feed or feed ingredients for food producing animals. Following good agricultural practice standards will minimize the risk of biological, chemical and physical contaminants entering the food chain. If crop residuals and stubbles are grazed after harvest, or otherwise enter the food chain, they should also be considered as live-stock feed. Most livestock will consume a portion of their bedding. Crops that produce bedding material or bedding materials such as straw or wood shavings should also be managed in the same manner as animal feed ingredients. Good pasture management practices, such as rotational grazing and dispersion of manure droppings, should be used to reduce cross-contamination between groups of animals.

6.1.1 Site selection

55. Land used for production of animal feed and feed ingredients should not be located in close proximity to industrial operations where industrial pollutants from air, ground water or runoff from adjacent land would be expected to result in the production of foods of animal origin that may present a food safety risk. Contaminants present in runoff from adjacent land and irrigation water should be below levels that present a food safety risk.

6.1.2 Fertilizers

56. Where manure fertilization of crops or pastures is practiced, an appropriate handling and storage system should be in place and maintained to minimize environmental contamination, which could negatively impact on the safety of foods of animal origin. There should be adequate time between applying the manure and grazing or forage harvesting (silage and hay making) to allow the manure to decompose and to minimize contamination.

¹² Guidelines on this definition are under development by FAO.

57. Manure, compost and other plant nutrients should be properly used and applied to minimize biological, chemical and physical contamination of foods of animal origin which could adversely affect food safety.

58. Chemical fertilizers should be handled, stored and applied in a manner such that they do not have a negative impact on the safety of foods of animal origin.

6.1.3 Pesticides and other agricultural chemicals

59. Pesticides and other agricultural chemicals should be obtained from safe sources. Where a regulatory system is in place, any chemical used must comply with the requirements of that system.

60. Pesticides should be stored according to the manufacturer's instructions and used in accordance with Good Agricultural Practice in the Use of Pesticides (GAP)¹³. It is important that farmers carefully follow the manufacturer's instructions for use for all agricultural chemicals.

61. Pesticides and other agricultural chemicals should be disposed of responsibly in a manner that will not lead to contamination of any body of water, soil, feed or feed ingredients that may lead to the contamination of foods of animal origin which could adversely affect food safety.

6.2 Manufacturing of feed on-farm

6.2.1 Feed ingredients

62. On-farm feed manufacturers should follow the applicable guidelines established in sub-section 4.1 of this Code when sourcing feed ingredients off the farm.

63. Feed ingredients produced on the farm should meet the requirements established for feed ingredients sourced off the farm. For example, seed treated for planting should not be fed.

6.2.2 Mixing

64. On-farm feed manufacturers should follow the applicable guidelines established in Section 5 of this Code. Particular attention should be given to sub-section 5.6 of this Code.

65. In particular, feed should be mixed in a manner that will minimize the potential for cross-contamination between feed or feed ingredients that may have an effect on the safety or withholding period for the feed or feed ingredients.

6.2.3 Monitoring records

66. Appropriate records of feed manufacturing procedures followed by on-farm feed manufacturers should be maintained to assist in the investigations of possible feed-related contamination or disease events.

67. Records should be kept of incoming feed ingredients, date of receipt and batches of feed produced in addition to other applicable records set out in sub-section 4.3 of the Code.

6.3 Good animal feeding practice

68. Good animal feeding practices include those practices that help to ensure the proper use of feed and feed ingredients on-farm while minimising biological, chemical and physical risks to consumers of foods of animal origin.

6.3.1 Water

69. Water for drinking or for aquaculture should be of appropriate quality for the animals being produced. Where there is reason to be concerned about contamination of animals from the water, measures should be taken to evaluate and minimise the hazards.

6.3.2 Pasture grazing

70. The grazing of pastures and crop lands should be managed in a way that minimises the avoidable contamination of foods of animal origin by biological, chemical and physical food safety hazards.

71. Where appropriate, an adequate period should be observed before allowing livestock to graze on pasture, crops and crop residuals and between grazing rotations to minimise biological cross-contamination from manure.

72. Where agricultural chemicals are used, operators should ensure that the required withholding periods are observed.

6.3.3 Feeding

73. It is important that the correct feed is fed to the right animal group and that the directions for use are followed. Contamination should be minimised during feeding. Information should be available of what is fed to animals and when, to ensure that food safety risks are managed.

74. Animals receiving medicated feed should be identified and managed appropriately until the correct withholding period (if any) has been reached and records of these procedures must be maintained. Procedures to ensure that medicated feed are transported to the correct location and are fed to animals that require the medication should be followed. Feed transport vehicles and feeding equipment used to deliver and distribute medicated feed should be cleaned after use,

¹³ See Definitions for the Purposes of the Codex Alimentarius (Procedural Manual of the Codex Alimentarius Commission).

if a different medicated feed or non-medicated feed or feed ingredient is to be transported next.

6.4 Stable feeding and lot/intensive feeding units

75. The animal production unit should be located in an area that does not result in the production of food of animal origin that poses a risk to food safety. Care should be taken to avoid animal access to contaminated land, and to facilities with potential sources of toxicity.

6.4.1 Hygiene

76. The animal production unit should be designed so that it can be adequately cleaned. The animal production unit and feeding equipment should be thoroughly cleaned regularly to prevent potential hazards to food safety. Chemicals used should be appropriate for cleaning and sanitising feed manufacturing equipment and should be used according to instructions. These products should be properly labelled and stored away from feed manufacturing, feed storage and feeding areas.

77. A pest control system should be put in place to control the access of pests to the animal production unit to minimise potential hazards to food safety.

78. Operators and employees working in the animal production unit should observe appropriate hygiene requirements to minimise potential hazards to food safety from feed.

6.5 Aquaculture¹⁴

79. Aquaculture includes a wide range of species of finfish, molluscs, crustaceans, cephalopods, etc. The complexity of aquaculture is reflected in the wide range of culturing methods ranging from huge cages in open seas to culturing in small freshwater ponds. The diversity is further reflected by the range of stages from larvae to full grown size, requiring different feed as well as different culture methods. Nutritional approaches range from feeding only naturally occurring nutrients in the water to the use of sophisticated equipment and scientifically formulated compound feed.

80. To ensure food safety, necessary precautions should be taken regarding culturing methods, culturing sites, technologies, materials and feed used to minimize contamination in order to reduce food hazards.

SECTION 7. METHODS OF SAMPLING AND ANALYSIS

7.1 Sampling

81. Sampling protocols should meet scientifically recognized principles and procedures.

7.2 Analysis

82. Laboratory methods developed and validated using scientifically recognized principles and procedures should be used.¹⁵ When selecting methods, consideration should also be given to practicability, with preference given to those methods which are reliable and applicable for routine use. Laboratories conducting routine analyses of feed and feed ingredients should ensure their analytical competency with each method used and maintain appropriate documentation.¹⁶

¹⁴ Aquaculture producers should refer to relevant sections of the Code of Practice for Fish and Fishery Products for additional information (CXC 52-2003).

¹⁵ *General Criteria for the Selection of Methods of Analysis Using the Criteria Approach* (Procedural Manual of the Codex Alimentarius Commission).

¹⁶ For example, through quality assurance systems such as ISO 17025

APPENDIX 2

Relevant Codex Alimentarius texts

(as of June 2020)

Standards

(<http://www.fao.org/fao-who-codexalimentarius/codex-texts/list-standards/en/>)

General Standard for Contaminants in Food and Feed (CXS 193-1995)

General Standard for Methods of Analysis and Sampling (CXS 234-1999)

Codes of Practice

(<http://www.fao.org/fao-who-codexalimentarius/codex-texts/codes-of-practice/en/>)

Animal feeding

Code of Practice on Good Animal Feeding (CXC 54-2004)

Antimicrobial resistance

Code of Practice to Minimise and Contain Foodborne Antimicrobial Resistance (CXC 61-2005)

Contaminants

Code of Practice for the Reduction of Aflatoxin B₁ in Raw Materials and Supplemental Feedingstuffs for Milk-Producing Animals (CXC 45-1997)

Code of Practice for Source Directed Measures to Reduce Contamination of Food with Chemicals (CXC 49-2001)

Code of Practice for the Prevention and Reduction of Mycotoxin Contamination in Cereals (CXC 51-2003)

Code of Practice for the Prevention and Reduction of Dioxins, Dioxin-like PCBs and non-Dioxin-like PCBs in Food and Feed (CXC 62-2006)

Code of Practice for Weed Control for the Prevention and Reduction of Pyrrolizidine Alkaloid Contamination in Food and Feed (CXC 74-2014)

Hygiene

General Principles of Food Hygiene (CXC 1-1969)

Guidelines

(<http://www.fao.org/fao-who-codexalimentarius/codex-texts/guidelines/en/>)

Animal Feeding

Guidelines on the Application of Risk Assessment for Feed (CXG 80-2013)

Guidance for Governments on Prioritizing Hazards in Feed (CXG 81-2013)

Inspection and certification systems

Principles and Guidelines for the Exchange of Information in Food Safety Emergency Situations (CXG 19-1995)

Guidelines for the Exchange of Information Between Countries on Rejections of Imported Foods (CXG 25-1997)

Principles for Traceability/Product Tracing as a Tool within a Food Inspection and Certification System (CXG 60-2006)

Principles and Guidelines for the Exchange of Information between Importing and Exporting Countries to support Trade in Food (CXG 89-2016)

Organic production

Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (CXG 32-1999)

Pesticides

Methods of Sampling for the Determination of Pesticide Residues for Compliance with Maximum Residue Limits (CXG 33-1999)

Guidelines on Good Laboratory Practice in Pesticide Residue Analysis (CXG 40-1999)

Guidelines on Performance Criteria for Methods of Analysis for the Determination of Pesticide Residues in Food and Feed (CXG 90-2017)

Veterinary drugs

Guidelines for the Design and Implementation of National Regulatory Food Safety Assurance Programmes Associated with the Use of Veterinary Drugs in Food Producing Animals (CXG 71-2009)

Maximum Residue Limits and Risk Management Recommendations

(<http://www.fao.org/fao-who-codexalimentarius/codex-texts/maximum-residue-limits/en/>)

MRLs and RMRs for Veterinary Drugs in Foods (CXM 2)

MRLs for Veterinary Drugs in Foods
(online database: <http://www.codexalimentarius.org/standards/veterinary-drugs-mrls/en/>)

MRLs for Pesticides in Food and Feed
(online database: <http://www.codexalimentarius.org/standards/pesticide-mrls/en/>)

Miscellaneous texts

(<http://www.fao.org/fao-who-codexalimentarius/codex-texts/miscellaneous/en/>)

Pesticides (the two texts below should be read in conjunction with)

Classification of Food and Feed (CXA 4-1989)

Principles and Guidance on the Selection of Representative Commodities for the Extrapolation of Maximum Residue Limits for Pesticides to Commodity Groups (CXG 84-2012)

Other texts that may be relevant to feed

Other texts developed primarily for food safety that may also be applicable to feed can be found on the Codex webpage: <http://www.fao.org/fao-who-codexalimentarius/codex-texts/en/> or on the dedicated pages of subsidiary bodies of the Codex Alimentarius Commission (related standards): <http://www.fao.org/fao-who-codexalimentarius/committees/general-subject-committees/en/>

APPENDIX 3

Relevant FAO publications

Balanced feeding for improving livestock productivity. Increase in milk production and nutrient use efficiency and decrease in methane emission

<https://home.fao.org/3/i3014e/,DanalInfo=www.fao.org+i3014e00.htm>

Conducting national feed assessments

<https://home.fao.org/3/i3043e/,DanalInfo=www.fao.org+i3043e00.htm>

Crop residue based densified total mixed ration. A user-friendly approach to utilize food crop by-products for ruminant production

<https://home.fao.org/3/i2728e/,DanalInfo=www.fao.org+i2728e00.htm>

Enhancing animal welfare and farmer income through strategic animal feeding. Some case studies

<https://home.fao.org/3/i3164e/,DanalInfo=www.fao.org+i3164e00.htm>

Estimation des bilans fourragers dans la région du Sahel d'Afrique de l'Ouest et Centrale

<http://www.fao.org/3/ca9111fr/CA9111FR.pdf>

Greenhouse gas emissions from ruminant supply chains. A global life cycle assessment

<https://home.fao.org/3/i3461e/,DanalInfo=www.fao.org+i3461e00.htm>

On-farm mycotoxin control in food and feed grain

<https://home.fao.org/3/a1416e/,DanalInfo=www.fao.org+a1416e00.htm>

Optimization of feed use efficiency in ruminant production systems

<https://home.fao.org/3/i3331e/,DanalInfo=www.fao.org+i3331e00.htm>

Protein sources for the animal feed industry.

<https://home.fao.org/3/y5019e/,DanalInfo=www.fao.org+y5019e00.htm>

Quality assurance for microbiology in feed analysis laboratories

<https://home.fao.org/3/i3287e/,DanalInfo=www.fao.org+i3287e00.htm>

Successes and failures with animal nutrition practices and technologies in developing countries

<https://home.fao.org/3/i2270e/,DanalInfo=www.fao.org+i2270e00.htm>

Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities

<https://home.fao.org/3/i3437e/,DanalInfo=www.fao.org+i3437e00.htm>

The feed analysis laboratory: Establishment and quality control

<https://home.fao.org/3/i3535e/,DanalInfo=www.fao.org+i3535e00.htm>

Use of lesser-known plants and plant parts as animal feed resources in tropical regions

<https://home.fao.org/3/i2629e/,DanalInfo=www.fao.org+i2629e00.htm>

World mapping of animal feeding systems in the dairy sector

<https://home.fao.org/3/,DanalInfo=www.fao.org+a-i3913e.pdf>

APPENDIX 4

National codes of practice

AFRICA

South Africa

Animal Feed Manufacturers Association (AFMA)

AFMA Code of Conduct

<https://www.afma.co.za/afma-code-conduct/>

AFMA Transport Protocol

<https://www.afma.co.za/afma-transport-protocol/>

AFMA Early Warning System

<https://www.afma.co.za/afma-early-warning-system/>

Codes of Practice and Guidelines

<https://www.afma.co.za/codes-of-practice-guidelines/>

ASIA AND PACIFIC

Australia

Australian Code of Good Manufacturing Practice for the Feed Milling Industry

<http://www.sfmca.com.au/items/943/Q1.3ver4CodeofGMP.doc>

FAMIqs v6 Code of Practice

<https://fiaaa.com.au/fami-qs/> and <https://fami-qs.org/code-6-0.html>

Japan

Establishment of the Guidelines of Good Manufacturing Practice (GMP) for Feed

www.famic.go.jp/ffis/feed/obj/Guidelines_of_GMP_for_Feed.pdf

EUROPE

European Feed Manufacturers Federation (FEFAC)

European Feed Manufacturers' Guide – EFMC

<https://www.fefac.eu/our-publications/good-practices/265/>

FAMI-QS

Quality and Feed Safety System for Specialty Feed Ingredients - Certification System

www.fami-qs.org/documents.htm

Austria

Agrarmarkt Austria Marketing GesmbH

Einzelfuttermittelherstellung

Mischfuttermittelherstellung Handel Lagerung und Umschlag Fahrbare Mahl- und Mischanlagen Transport

https://b2b.ama.info.at/fileadmin/user_upload/Dokumente/Alle_Dokumente/Futtermittel/AMA-Futtermittelrichtlinie_pastus_Version_2016_%C3%84nderungen_2020.pdf

Czech Republic

Codex of principles of good practice and HACCP for the production, storage, and transport of additives, premixtures and feed for food producing animals

https://spkk.cz/image.ashx?i=879003.pdf&fn=2007_Codex_of_principles.pdf

Denmark

DAKOFO

God produktionspraksis for fremstilling og transport af fjerkræfoder

https://www.dakofo.dk/media/1059/foderregelsaet_27maj2014.pdf

France

OQUALIM

OQUALIM's Certification Programs

<https://www.oqualim.com/en/certifications/oqualim-s-certification-programs>

Germany

QS

QS Leitfaden für die Futtermittelwirtschaft

https://www.q-s.de/services/files/downloadcenter/4_leitfaeden/futtermittelwirtschaft/lf_fumi_frei_01012020_d.pdf

Luxembourg

OVOCOM

Feed Chain Alliance Standard

https://ovocom.be/FCAAAdvantages.aspx?__sys=1

Portugal

Associação Portuguesa dos Alimentos Compostos para Animais (IACA)

Guia de Boas Práticas para os Industriais de Pré-Misturas e de Alimentos Compostos para Animais Destinados à Produção de Géneros Alimentícios

https://issuu.com/alimentacao_animal/docs/guia_boas_pr_ticas_fabrico_aca_2007

Slovakia

AFPWTC Slovak Feed Manufacturers Code

<https://www.uksup.sk/okvz-spravna-vyrobn-prax-haccp>

Slovenia

Gospodarska Zbornica Slovenije (GZC)

Slovenian Feed Manufacturers Code

https://www.kgzs.si/uploads/dokumenti/strokovna_gradiva/nacionalne_smernice-krma_2007.pdf

Spain

Fundación CESFAC

Marca de garantía - Alimentación Animal Certificada

<https://cesfac.es/media/attachments/2019/08/05/marca-de-garantia2.pdf>

United Kingdom

Agricultural Industries Confederation (AIC)

Universal Feed Assurance Scheme

www.agindustries.org.uk/content.output/93/93/Trade%20Assurance/Trade%20Assurance%20Schemes/UFAS.msp

LATIN AMERICA

Brazil

SINDIRAÇÕES

Feed and Food Safety Program

<https://sindiracoes.org.br/programa-feed-food/o-programa/>

Colombia

Instituto Colombiano Agropecuario (ICA)

Anexo Técnico Buenas Prácticas de Manufactura de Alimentos para Animales – BPMAA de la Resolución No. 61252 del 3 de febrero de 2020, por medio de la cual se establecen los requisitos y el procedimiento para el registro de los fabricantes e importadores de alimentos para animales, así como los requisitos y el procedimiento para el registro de alimentos para animales y se dictan otras disposiciones.

<https://www.ica.gov.co/getattachment/f7b59ff6-7bfc-477a-8110-40a14b80bd4e/2020R61252.aspx>

APPENDIX 5

The role of national feed associations and setting up a feed association

INTRODUCTION

Every country, or region, with a sizable feed industry usually has a feed association. These associations are created by the industry to cooperate on many issues for and on behalf of the industry. The associations serve in many roles. Most associations are organized to respond to government inquiries and pressures. The associations provide the opportunities for the industry to speak to the governments in a single voice so that its issues and needs are more clearly understood. Many associations have education and training as an objective, thus allowing industry experts the opportunity to teach the entire feed sector.

THE ROLE OF NATIONAL FEED ASSOCIATIONS IN FEED/FOOD SAFETY, AUDITING AND REGULATIONS

Feed associations worldwide, along with governments, have assumed the role of leading their industry in developing feed/food safety programmes. These feed/food safety programmes may include government regulations and self or third-party audits.

Consumers everywhere are entitled to a safe food supply. The animal protein sector has in recent years been called upon to prove its ability to produce safe feed to make safe food. The BSE outbreak of the late 1980s and 1990s brought to the forefront the issue that safe feed produces safe food. Additional issues such as dioxin, *Salmonella* and GMOs all focused the public attention on the feed industry and its ability to produce safe feed to make safe food.

Feed trade associations have worked with their governments to develop regulations and auditing programmes to give consumers the confidence they need to eat products of animal origin.

Trade associations are formed to serve their members' political, educational and social or public relations needs in ways that individuals or single companies cannot. The feed industry has been served by trade associations for almost 100 years. The mission and purpose of the associations is to collectively accomplish things together more effectively than individually.

Principle goals and objectives for feed associations should include:

- establish a forum to promote industry dialogue
- establish political influence
- craft policies which are beneficial to the industry

- create industry standards to gain customer and consumer confidence
- provide industry specific education opportunities
- present networking opportunities for companies or individuals
- collaborate on public relations messages to influence public opinion
- pool resources to find new products or markets
- liaise with government officials
- mediate industry disputes
- coordinate research projects
- organize conferences and for a for discussions and dialogue
- offer opportunities to put buyers and sellers together.

To create a feed association, leader representatives must come together at a non-threatening, neutral site to discuss the needs and benefits of forming such an association.

Writing a 'mission statement' for the new association is usually the best way to achieve consensus. The 'mission statement' should be short, clear and concise. For example, the 'mission statement' for a new feed association could be: "The mission of this feed association is to establish a dialogue of feed industry entities so that their common interests can be served."

After there is agreement on the need to establish a feed association, the formation process begins.

The formation process includes creating a corporate legal entity, probably determined by the legal system. The association may be a 'not-for-profit' entity, which usually has a specific legal status.

Once the mission and purpose have been established, more specific goals and objectives need to be written, agreed and clearly understood by all prospective members. It is best to keep the goals or objectives of the new association very simple and limited. As with all new entities, over burdening them with high expectations may prove to be their downfall.

A new feed association will require bylaws and organizational structure. The bylaws should include the following sections:

- name
- objectives and purpose
- membership
- authorization of committees
- dues structure

- meeting requirements
- election of directors and officers
- duties, powers and terms of the directors and office holders
- voting or corporate decision provisions
- indemnification
- amendments.

Suggested details for each of the sections:

Name - The name should be descriptive of the industry and the scope, such as Feed Association of (name of country, group or region). Consideration should be given to what the acronym would be as most associations are labelled and known for their acronym.

Objectives and purpose - The objectives should be understandable, simple and achievable. For example: "The objectives of the Association shall be to provide industry representation to government agencies, to develop and present industry positions to consumers and customers. It will also be an objective to provide industry specific education opportunities."

Membership - The membership can be as broad or as narrow as necessary to achieve the objectives. If the membership base is very broad the political influence and dues base is greater but consensus may be harder to achieve. If the membership base is narrow, the political influence is less, the dues base is less but agreement of industry policy will likely come easier.

A narrow membership base may be an association that allows as members only feed manufacturers that sell feed. A broad membership base is an association with membership that makes feed for sale and private use and suppliers of macro and micro feed ingredients, equipment manufacturers and service providers.

Authorization of committees - The bylaws should allow for the establishment of committees. The committees can be for single specific purposes or for long term technical purposes. The bylaws should give authority to form, fill and disband the committee.

Dues structure - The dues structure will need to be determined after the membership base is established. Fairness and equitability are keys in any dues structure. Large members should be expected to carry a larger share of the needed dues than small members; however, small members should expect to contribute a fair and equitable portion of the dues and all members must take ownership in the association through their active involvement, beyond their dues contribution. Suppliers to the feed industry should be treated with the same fairness and equitability.

Meeting requirements - Meeting requirements are frequently determined by corporate laws. If an annual meeting is necessary, this bylaw provision must set forth those provisions. Time, place, frequency and who has the authority to call meetings are all part of this bylaw section.

Election of directors and office holders - This section sets forth the number of directors, how they are selected and their length of board term. Depending on the membership, there may need to be provisions on equal representation of membership segments, such as feed manufacturers, ingredients suppliers, equipment suppliers, etc. This Bylaw section should establish what officers are necessary (Chairperson, President, Secretary, Treasurer, etc) and how they are selected, elected and replaced.

Duties and powers of directors and office holders - This section states who has the authority to call meetings, preside over meetings, record the actions, hire staff, open bank accounts, sign checks, etc. This section should also set forth quorum requirements.

Voting or corporate decision provisions - This section should address how members can vote, by mail, email, telephone, in person or by proxy etc. If more than a majority vote is necessary for any decisions, this section should state those instances.

Indemnification - This section should state the provision whereby the association will indemnify any director, officers, staff or member-to-member legal disputes, including the legal fees.

Amendments - Conditions on how the bylaws can be amended or changed. Once the feed association has been established, business can be conducted. Most feed associations are initially run and operated by volunteers from the membership. Keeping the membership informed about what and how the association is serving the membership is important. The association should consider having written policies and procedures for each of the following:

Policy making - Who and how the official policies are made and communicated. This is usually done by the Board of Directors.

Government action plan - This plan would state what issues are important to the industry and how the association should communicate and attempt to influence the government.

Membership plan - Written plans to attract, recruit, and retain prospective members. The plan would state how and when and by whom dues billing is conducted.

Communications plan - A written plan for communication with the membership, the government and consumers. The plan would include who is to write, and send the communication and how often these should be done. This may be included in the Membership Plan. This plan would include provisions for a membership directory, annual report, web site and leadership listings, etc.

Corporate governance - This plan would detail the bylaw provisions as to whom, how and when the leadership of the association is elected, where and when the meetings are held and how the leadership is responsive to the industry.

Employee manual - An employee manual would give employees the rules as well as the benefits of employment.

A feed association offers the feed and feed ingredient industry many opportunities to advance the purpose of the industry. Developing an influential feed association is hard work but also very rewarding for the leadership and the prospective membership. Lifelong friendships will be established, consumer confidence in the feed industry will be gained and the safety of meat, milk and eggs for consumers are all benefits of a feed association.

In addition, feed trade associations can be established on a regional or multi-nation basis, particularly when the countries or the feed industry or feed ingredient industry readily crosses borders. Most of the decision making processes for establishing a multi-nation feed association are the same as for a national feed association. However, additional factors need to be considered. They include:

- language
- country of domicile
- legal and corporate structure
- communication issues – postal, phone, email, etc.
- meeting locations to prevent dominant country appearances
- cost of international travel
- dues structure with different currencies
- units of measures for comparative base lines
- political differences between countries.

The mission, purpose and objectives of the multi-nation association needs to be very clearly established because the assumed norms may well be different between the countries. It is important that no countries feed sector is given disproportionate influence as this will create an imbalance of power and the effectiveness and harmony the association that was intended will be lost.

Transparency and communication are most important when establishing a multi-nation association. The complexities of starting a multi-nation association are numerous and the time to deal with the unique issues are during creation. However, the benefits to the industry of having a multi-nation association are enormous.

DRAFT BYLAWS FOR A NATIONAL FEED ASSOCIATION

Introduction and bylaws

The recall of feed raw ingredients or feeds for safety reasons can often be most efficiently carried out via a trade association. For this reason all countries should be encouraged to establish a suitable association.

Bylaws of a National Feed Association (NFA) must abide by relevant laws or regulations within a country. Below is an outline of bylaws that may be useful when setting up a National Feed Association.

Article 1: Name

Section 1. The name of the association will be the (country name) _____ National Feed Association (NFA). The Association shall be incorporated under the laws of (your country).

Article 2: Mission, objective and purpose

Section 1. The mission of the National Feed Association is: The mission of the National Feed Association is to establish a dialogue of feed industry entities, so that their common interests can be served and feed safety issues addressed.

Section 2. The objectives and purpose of the National Feed Association shall be:

- a) present to the industry a forum for dialogue and discussion
- b) to provide industry representation to government agencies
- c) to develop and present industry positions to consumers and customers
- d) to give industry specific education opportunities
- e) to give the authorities a route for dissemination of feed safety information to industry.

Article 3: Membership

Section 1. Eligibility: Any company, who manufactures feed or feed ingredients, distributes feed or feed ingredients, or supplies the livestock, poultry or aquaculture feed industry, is eligible.

Section 2. Voting: Each member shall be eligible to one vote. Each member shall designate to the NFA corporate secretary the official voting representative.

Section 3. The membership shall by a fixed date each year, elect a Board of Directors. A simple majority vote will win the election.

Section 4. Duration of membership: Membership of NFA will continue as long as the member continues to pay the authorised dues as approved by the Board of Directors

Article 4: Directors and Officers

Section 1. The membership of NFA shall elect a Board of Directors to govern the Association.

Section 2. The Board of Directors shall be specified in number (at least three).

Section 3. The Board terms will be for three years. Board members can serve more than one term, but normally not more than two successive terms.

Section 4. Officers: The NFA will have a President, a Secretary and a Treasurer. A single individual may hold more than one position but the President and the Secretary cannot be the same person.

Section 5. The Board of Directors will elect the officers.

Section 6. The Board of Directors may from time to time add additional officers.

Article 5: Duties and Powers of the Board and Officers

Section 1. Duties of the Board of Directors: The Board of Directors shall be the governing body of the NFA. The Board of Directors shall be responsible for the property, business affairs and policies of the association. The Board shall authorise the creation of Committees. The Board shall hire and discharge the staff and officers.

Section 2. Board meetings: The Board of Directors shall meet at least once a year in a place agreed to by majority vote of the Board. The Board meeting shall be convened by the President. The meeting of the Board of Directors shall be called by either the President, the secretary or by any other two members of the Board of Directors

Section 3. Quorum: A majority of the board will constitute a quorum. A quorum can be achieved by in-person votes or by proxy.

Section 4. Duties of President: The President or designated deputy shall preside over board meetings.

Section 5. Duties of the Secretary: The secretary shall keep the official records of the Association including but not limited to, Board Minutes, membership roster and corporate documents. The Secretary shall perform additional duties as assigned by the President.

Section 6. Duties of the Treasurer: The Treasurer shall be responsible for the funds received by the association. The Treasurer shall make a periodic and full accounting of all income and expenditures. The Treasurer shall perform additional duties as assigned.

Section 7. Duties of other Officers. Any other duly elected officers shall perform such duties as assigned by the President or the Board of Directors.

Note: All sections below need simplifying in order to account for countries with small numbers of companies in the trade and do not need a large formal structure.

Article 6 - Committees and Meetings

Section 1. There shall be a Board and Officer Nominating Committee. The Board and Officer Nominating committee shall consist of at least three and not more than seven members. The majority of the Nominating Committee members shall be individuals who are not currently serving on the Board or as an officer of the Association.

Section 2. The Board and Officer Nominating Committee shall nominate members to serve on the Board of Directors and shall provide the slate of nominees 15 days prior to the election.

Section 3. Independent nominations for the Board of Directors will be taken, however, these nominations must be submitted 10 days prior to the election.

Section 4. Any other committee approved by the Board of Directors shall also be given the authority to serve the Association.

Section 5. The Chairman of the Board or the President will select the Chairman of the Committees and initial committee members.

Section 6. Committees shall meet at a time and place agreeable to the majority of the committee.

Section 7. There will be an annual meeting convened at a time and place approved by the Board of Directors. The membership shall have at least 30 days notice of its time and place.

Section 8. Mail, email, fax or phone messages will constitute notice of meetings.

Section 9. Ten percent of the total membership will constitute a quorum.

Article 7: Dues

Section 1. The rate and basis of dues for each member class shall be determined by the Board of Directors.

Section 2. A member who fails to pay its dues will be given written notice of delinquency 60 days after they are due. If the delinquency is not satisfied in the next 60 days, they will be terminated from the membership roles.

Article 8: Indemnification

Section 1. The Association shall indemnify any Board, officer or staff who is party or threaten to be made party to a suit as long as that person was speaking for, or acting for the Association and authorised by the Board.

Section 2. The Association shall defend or pay for the legal defence for the person as described in Section 1 above.

Article 9 - Miscellaneous

Section 1. Seal: The Association may have a seal of such design by or for the Board of Directors. The seal shall be used to identify the Association as necessary.

Section 2. Year: The year of the Association will be January 1 - December 31.

Section 3. Amendments: These bylaws may be amended, repealed or altered by a two-thirds vote of the Board of Directors. A 20-day notice must be given to all Board member prior to any changed, amendment or alternation of the Bylaws.

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This Manual provides comprehensive information and practical guidelines to assist farmers, producers and all stakeholders along the feed value chain to comply with the requirements of the Codex Alimentarius Code of Practice on Good Animal Feeding. The application of the Code is an important step for the expansion of international trade of feed and products of animal origin. Both feed/food exporting and importing countries can benefit from a greater and safer trade of feed and products of animal origins. This Manual is intended to guide managers of feedmills, the feed industry as a whole and on-farm feed mixers and producers. It will also be of value to national competent authorities, in particular those engaged in feed inspection, in their supervisory roles. It can also serve as a training manual and a guide to setting up national feed associations.

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