Chapter 7: Safe Food at Primary Production Stage

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Chapter 7: Safe Food at Primary Production Stage

In the last chapter you learnt about the different physical, biological and chemical contaminants which may enter the food chain. Primary production of food includes harvesting, slaughtering and milking of animals. Physical contaminants like dust, stones, metal/glass shards, seeds, straw, husk, etc. could enter the food during these processes. Bacteria, viruses, helminths, fungi and mycotoxins could contaminate the food when adequate sanitation is not maintained during the production process or if the growing conditions of food crops favoured microbial contamination. Good hygiene practices are essential for the handling of animals and animal products otherwise it can lead to serious food borne illnesses. Residues of pesticides, drugs administered to animals (veterinary drug residues), heavy metals, and toxic chemicals naturally present in plants and animals are likely to contaminate food at the primary production stage. Contamination can also occur at later stages of production, storage and transport of foods. Contaminant chemicals can leach out of utensils or packaging material in which food has been kept. Some chemicals may get formed during the process of cooking or processing. This chapter describes in detail how these contaminants enter our food, how severe the problem of contamination is, and the good practices needed to keep level of contaminants in check at the production level.

Pesticide residues

Pesticides are chemicals used to protect food from pests, such as insects, rodents, weeds, mold, and bacteria. The use of pesticides has increased several - fold in India over the years. Residues of these pesticides persist in the environment as well as in food. Runoff water from fields can contaminate the water bodies in which it falls or the soil and ground water if it penetrates the surface. Residues of pesticides detected in different foods like cereals, pulses, fruits, vegetables and in drinking water are a result of poor agricultural practices at the farm level.

Use of pesticides which do not dissipate very easily creates further problems. The most persistent pesticides are termed “persistent organic pollutants” (POPs). These tend to accumulate in the food-chain. They can biomagnify (concentrate) in marine and land animals, as well as humans building up chiefly in the adipose tissue, leading to toxic effects in the body. Examples of POPs include mainly organochlorine pesticides, namely, aldrin, endrin, dieldrin, chlordane, DDT, endosulfan, lindane, hexachlorobenzene, etc.

Examples of chronic poisoning effects due to build-up of pesticide residues in the body may include- carcinogenicity (ability to produce cancer), mutagenicity (ability to cause genetic changes), teratogenicity (ability to cause birth defects), oncogenicity (ability to induce tumour growth), liver damage, endocrine disruption resulting in hormonal disorders, reproductive disorders such as reduced sperm count, sterility, and miscarriage, neurotoxicity (nerve damage) or development of allergies to pesticides or chemicals used in formulation of pesticides.

Exposure of either parent to pesticides before conception, or of the mother during pregnancy, has been associated with increased risk of foetal death, spontaneous abortion and early childhood cancers. Exposure within the womb is also associated with increased risk of growth retardation, low birth weight and congenital anomalies.

Good Agricultural Practices (GAP)

People applying the pesticide in the field are not aware about concentrations to use, frequency with which to apply, sometimes applying more than needed amounts in the belief that their crops will be better protected. They also lack the knowledge about the safest pesticide to use, and land up purchasing substandard pesticides which they may need to apply more of to get the desired effect. Or, they may purchase the more toxic varieties even though safer and more effective substitutes are readily available. Another reason for high residue levels in foods is the post-harvest treatment of grains, fruits and vegetables, before they are marketed. This is mainly done to prevent spoilage due to insects and microbes. Thus, to ensure good agricultural practices, the farmers and other users of pesticides need to be trained and sensitized to adverse effects of misuse. Every packet of pesticide should carry the relevant information in the local language. In addition, efforts must be made to reduce the use of these chemicals in agriculture.

Integrated pest management

Pesticides even in small quantities can prove to be hazardous for us as our body finds it difficult to excrete them. Thus, even if these are judiciously used by the farmers, small amounts tend to accumulate in our bodies and have been known to cause adverse health effects. Research focus is thus on other forms of pest-control. Non-pesticide dependent agriculture and integrated pest management (IPM) is increasingly gaining popularity. The UN's Food and Agriculture Organisation (FAO) defines IPM as "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 minimize 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."

There are eight principles of integrated pest management according to the European Union (Figure 1). The first and foremost is to prevent or suppress pests by various techniques like crop rotation, balanced fertilizer use, adequate drainage and observing hygiene measures. The second principle is to monitor harmful pests using scientific tools. The monitoring data should be able to predict when food becomes vulnerable to pests. The system should have an inbuilt system to warn against pest infestations. The third principle is decision making which the professional needs to do about plant protection measures to apply when he receives a warning from the monitoring system. The fourth principle talks about using biological or physical methods of pest control where possible. The fifth principle states that if pesticides are to be used then the one selected should be the least harmful for the environment, humans and other animals. The sixth principle says that the quantity/frequency of pesticide used should be the minimal required to control the pest

problem. The seventh principle states that appropriate strategies are needed to ensure that resistance to a pesticide does not develop in the pest. This could be done by using a variety of pesticides with different modes of action. The eighth principle is that the success of plant protection measures should be regularly evaluated. This can be done by monitoring the pests and relating this to the pest control measure used.

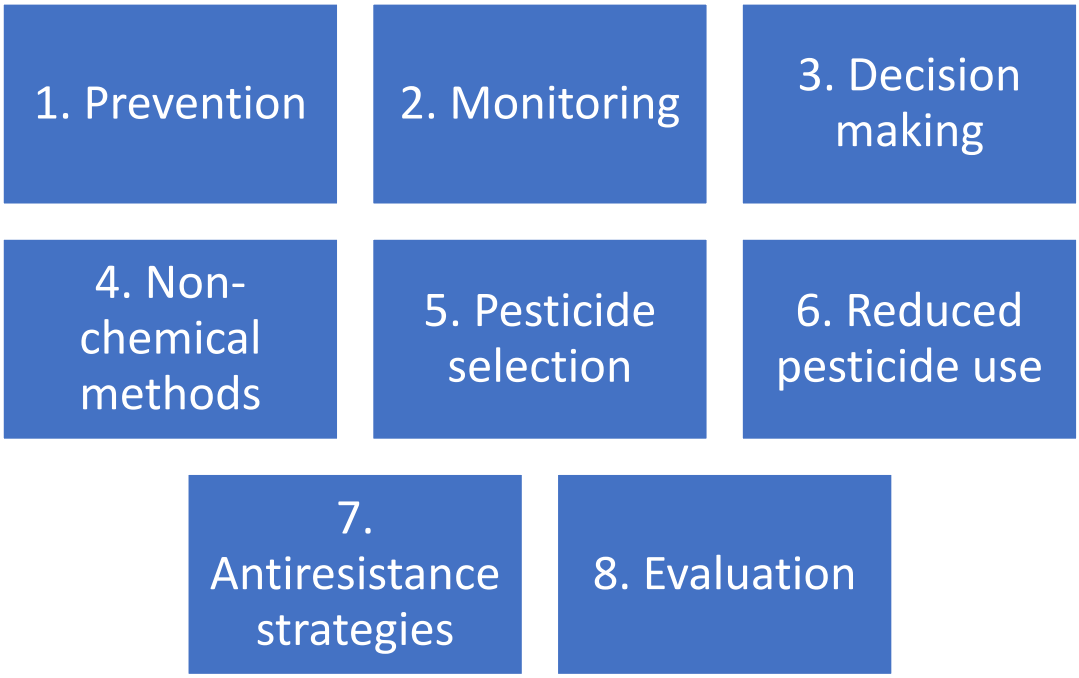

Figure 7. 1: Principles of integrated pest management

Biopesticides are living things or natural materials like animals, plants, bacteria and certain minerals or biochemicals which can be used for pest management. Biopesticides are less toxic than conventional pesticides. They don't affect the environment adversely as they don't persist in the environment and don't affect other organisms. Microbes like fungi have been used to control weeds and insects. Strains of *Bacillus thuringiensis* (Bt) have been used to control insect larvae. Certain genetically modified plants may have the ability to produce proteins which are pesticidal. Beneficial nematodes have also been used to control insect and slug pests. Animals can also be used as predators to control the population of pests. Such measures can contribute towards reducing contamination of foods and the environment.

National Pesticide Monitoring System

The Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare had started a central sector scheme, "**Monitoring of Pesticide Residues at National Level" (MPRNL)** in food commodities and environmental samples during 2005-06 with the participation of various laboratories representing Ministry of Agriculture, Indian Council of Agriculture Research, Ministry of Health and Family Welfare, Ministry of Environment and Forest, Council of Scientific and Industrial Research, Ministry of Chemical and Fertilizer, Ministry of Commerce and State Agricultural Universities across the country. The objectives of the scheme include:

- To identify crops and regions having preponderance of pesticide residues in order to focus extension efforts
- To strengthen infrastructure at Quarantine stations to prevent entry of foods which have pesticide residues above maximum residue limit (MRL)
- Testing / Certification of pesticide residues in export / import consignments
- To test pesticide residues and other contaminants in food commodities and environmental samples like soil and water.

Source: http://agricoop.nic.in/sites/default/files/MPRNL%20Guidelines_0.pdf

Veterinary drug residues

Various types of drugs are used while breeding animals, fowl and insects like bees which provide us with food. Some are injected into the animal while some others are given orally-mixed in the feed. Some chemicals may be sprayed or applied on the animals. Residues of these drugs show up in the food derived from these animals like meat, milk, eggs and honey. Acute poisoning outbreaks attributed to veterinary drug residues have been reported in several cases. Those who ate veal liver contaminated with a steroid like drug called clenbuterol developed symptoms of tremor, headaches, abnormally rapid heart rate and dizziness in Lyons, France (Pulce et al, 1991). Similar acute outbreaks were seen in 1996 in Caserta, Italy and in 1992 in Catalonia, Spain which affected 113 people. Hormones have been used by the beef and meat industry for several years to improve growth or milk yield. There have been serious concerns about environmental contamination, particularly of drinking water, from faecal and urinary excretion of hormones by millions of cattle. Hormones in food and water have been linked to endocrine disruption in humans with increased risk of breast cancer and early puberty in girls. Diethyl stilbesterol (DES) which was earlier used to promote growth of cattle, is now banned as it was found to be a potent carcinogen.

Antibiotic residues can be problematic for persons allergic to certain antibiotics. These may also cause a potential build-up of antibiotic resistant organisms in humans. Chloramphenicol has been shown to induce aplastic anaemia in sensitive individuals. Nitrofurans and some sulpha drugs have shown the potential to cause cancer in experiments conducted on laboratory animals. These drugs have been mostly banned for use in food producing animals. When the microflora of our gut is exposed to low doses of antibiotics in the form of residues in the food that we eat (viz. meat, milk and eggs of

contaminated animals), it starts changing. This alteration of gut microflora may lead to diseases and the development of resistant strains which cause failure of antibiotic therapy in case of an infection. Anthelmintics (which get rid of worms e.g. tapeworms) and antifungal medicines also cause a serious ecological problem with their residues being detected in the soil, besides the meat and milk.

Good veterinary practices

Numerous scientific bodies and regulatory agencies have looked at the issue of residues of hormones coming into the milk and meat meant for human consumption. Most of them have concluded that if good veterinary practices are followed, then drug residues wouldn't pose a significant risk to health. It is important therefore to consult a veterinarian before any drug is administered to livestock. This ensures that the appropriate drug is prescribed in the right dosage. The veterinarian can also advise about the appropriate time gap to be given between administering the drug and milking or slaughtering the animal to avoid high residue levels in the food products. This time gap is referred to as the withdrawal time or period during which the drug gets metabolized in the animal's body and the residues are excreted from the body so that these do not linger in the meat, milk or eggs of the animal when slaughtered for consumption. Due to mass production of milk, meat and eggs, use of drugs has become a necessity. Maintaining good hygiene and sanitary conditions in farms is of primary importance to reduce the use of these drugs to a minimum.

Monitoring

In India, the Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, which came in to force on 5th August, 2011, deals with compliance to standards set for various contaminants, toxins (microbial and naturally occurring) and residues (of pesticides, veterinary drugs and other pharmacologically active substances) in food. FSSAI specifies the tolerance limits for antibiotic residues in sea foods like shrimps, prawns, fish and fishery products. The responsibility for residue control is not solely that of the government. The responsibility should be shared by producers, marketing co-operatives, veterinarians, scientists and all those involved in the industry. Drug manufacturers are required to provide tissue residue and depletion rate data for all new drugs. They also need to provide a method to detect the residues in tissues so that monitoring can be done effectively.

Concerns over drug residues in food are not limited to public health. They can have serious economic consequences as well. Antibiotic residues present in milk intended to produce cheese or other fermented milk products, may interfere with the fermentation process by adversely affecting the bacterial or yeast cultures. This would result in subsequent economic losses to the food industry. Every year several consignments of seafood, honey, meat and meat products, etc. are rejected due to detection of veterinary drug residues by USA and the European Union. Hence it is in everyone's interest to address this problem and work towards a solution.

Heavy metals

Metals contaminate our foods when factories throw their waste products into the seas and rivers or bury their wastes before appropriately treating them. Smoke from industries as well as exhaust fumes from vehicles and machinery pollute the atmosphere with the particulate matter ultimately settling down on plants and soil not only in the vicinity but places further away as well due to widespread dispersion by wind. Food grown in contaminated soil or using contaminated water (especially raw sewage water/sludge), or even in the vicinity of polluting industries tends to be high in heavy metal content. Similarly, fish and other seafood from contaminated water bodies have heavy metals in them. The heavy metals in soil tend to contaminate the ground water as well.

Lead emissions are from road transport, cadmium emissions are mainly from tobacco smoke, fuel combustion and metallurgical operations, and mercury emissions are related to coal consumption. Metals may also enter food from metallic cans and other containers in which the food is cooked, stored or packaged, especially if the food is acidic in nature. Poor quality tin coating or improper tinning of brass vessels can result in tin and copper leaching into the food cooked or stored in the vessel.

Heavy metals like lead, cadmium, mercury and arsenic can cause a lot of damage to human health. Other heavy metals noted for their potential toxicity, include nickel, copper, zinc, silver, tin, and antimony. These metals are not readily excreted from our bodies and so keep getting deposited in different tissues and organs of the body. Concentrations of these heavy metals in blood, hair, nails and urine have been used as biomarkers of exposure. Contamination of drinking water with inorganic arsenic is a major problem in some parts of India especially States like West Bengal. Several surveys in India have detected high levels of lead in different foodstuffs, in drinking water and in seafood. The gastrointestinal uptake of lead from food is high. Also lead can easily cross the blood-brain barrier in children thus leading to neurotoxic effects. There may be a link between heavy metals (like lead, mercury, zinc, copper, arsenic) and autism, and aluminium and Alzheimer's disease as these heavy metals can be neurotoxic.

Bioaccumulation and Biomagnification

As it is difficult for the body to excrete heavy metals, these tend to over time, accumulate in the body tissues of not just humans but also animals (bioaccumulation). Contamination of fish with methyl mercury is a big problem due to industrial effluents being dumped into rivers, seas and oceans. In fact, fish consumption strongly predicts mercury levels in the body. Large old predators like sharks and pike, or scavengers like halibut, hold the greatest concentrations of mercury as they have fed on several contaminated fish which have in turn fed on contaminated plankton, krill etc. The higher the fish in the food chain, the more mercury it tends to have and this process is referred to as biomagnification (Figure 2). In plants, green leafy vegetables with large leaves tend to accumulate more heavy metals than the ones with smaller leaves. Certain plants tend to bio-accumulate heavy metals from the soil or water more than the others.

Figure 7. 2: Bioaccumulation and Biomagnification of Toxins

Ensuring safe waste disposal

Unlike organic pollutants, heavy metals do not decay and thus pose a different kind of challenge. Extensive research has shown that certain plants or microorganisms can be used to remove some heavy metals such as mercury. These plants can hyper- accumulate the heavy metals from soils by concentrating them in their bio matter.

Use of lead in petrol has decreased over the last few decades, phasing out of the remaining uses of lead additives in motor fuels should be encouraged. Similarly use of lead in paints, food containers, glazing should be banned to reduce exposure to this toxic heavy metal.

Exposure to arsenic is mainly via intake of food and drinking water. According to a study, folic acid (a type of B vitamin) supplementation may reduce the risk of arsenic-related

adverse health outcomes (Gamble et al, 2006). Folic acid helped in the methylation of arsenic and decreased excretion of the inorganic form which has been linked to skin and bladder cancers and peripheral vascular disease. A study in Bangladesh (Freeman, 2009) has indicated that improved nutritional status could constitute a key strategy for reducing the risk of arsenic-related diseases especially in children. Itai Itai disease in which cadmium accumulates in the bones is also seen more in people who in addition to being exposed to excessive cadmium, consume a diet low in calcium and have poor vitamin D status. Thus, having a nutritious diet can protect us from the toxic effects of heavy metals.

Avoiding farm produce grown in contaminated soil, choosing smaller fish to consume and green leafy vegetables with small leaves can also help to reduce our exposure. Utensils made of only good quality alloys should be used. Cheap alloys may leach out more metals when in contact with food materials being stored or cooked in it. Other measures of reducing exposure would include a crackdown on polluting industries, treatment of sewage/sludge to decrease the load of heavy metals, safe and responsible disposal of electronics and batteries, etc. which have heavy metal components and vigilance in monitoring heavy metal levels in the food and water of the population. Contaminated ground water should be treated before consumption. Scientists have been working on low cost technologies to decontaminate water at the household level, especially in rural areas.

FSSAI, the regulatory authority, specifies the maximum amount of heavy metals permissible in food. It is the work of the State Food Safety Departments to monitor levels in foods. For instance, lead in milk should be below 0.02 ppm, whereas in turmeric up to 10 ppm is permissible. Methyl mercury in any food should not be more than 0.25 ppm.

Mycotoxins

Fungi growing on food may produce toxins which are harmful to health. These are called mycotoxins. Diseases caused by the growth of fungus on a host are termed as mycoses (like athlete's foot, ringworm, etc.) while diseases caused due to exposure to toxic fungal metabolites or mycotoxins is called mycotoxicoses.

Types of mycotoxins and crops affected

Mold growth is supported by a number of foods and hence mycotoxins have been detected in a variety of foods for human consumption, particularly cereals and nuts. Consumption of mycotoxin contaminated feed by animals can result in tainting of meat, eggs and milk. Some examples of mycotoxins are aflatoxins produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*, ergot alkaloids produced by the *Claviceps sp*., Trichothecenes, Fumonisin and Zearalenone produced by the *Fusaria sp.* and Ochratoxin by *Aspergillus ochraceus* and *Penicillium* species. The crops may get contaminated with the fungus while still in the field or after harvest during the storage period. For instance, *Claviceps* affects cereals during the pre-harvest stages; *Fusarium* contamination generally occurs under the field conditions and persists during early storage; and, *Aspergillus* and *Penicillium* are typical storage fungi, infecting agricultural commodities due to improper storage. Infection with *A. flavus* can also occur in the field. Currently there are more than 300 known types of mycotoxins but the attention is usually focussed on the ones which are very toxic to us or those that are carcinogenic.

Adverse effects

Aflatoxin is one of the most commonly detected mycotoxins in peanuts and products made from peanuts as well as a variety of cereal grains. It is toxic to the liver and has been recognised as a hepatocarcinogen (causing liver cancer). Consumption of cereal grains containing ergot alkaloids leads to symptoms of gangrene and convulsions. Deoxynivalenol and other trichothecenes found in cereal grains and some vegetables and other crops have been shown to inhibit protein synthesis in the body, haemorrhaging in the digestive tract and decreased bone marrow and immune function. In case of skin contact they have also caused dermatitis. Zearalenone has been toxic to the reproductive tract of animals, causing oestrogenic effects in farm animals. Ochratoxin A found in cereals, coffee, spices and dried fruits is a possible carcinogen. It has been shown to be toxic to kidneys. Patulin, found in apples, apple juice, cider, and other fruits, is an irritant to the stomach, causing nausea, vomiting and even ulceration in severe cases. It is genotoxic, neurotoxic, and known to cause reproductive toxicity. These are only some examples of the adverse health effects of mycotoxins.

Aflatoxin M1 detected in Milk in India

The National Milk Safety and Quality Survey 2018 conducted by FSSAI revealed Aflatoxin M1 residues beyond permissible limits in 368 (out of 6,432) samples, that is 5.7% of the samples. Aflatoxin M1 comes in the milk through feed and fodder. Amongst the top three States with highest levels of Aflatoxin M1 residues are Tamil Nadu, Delhi and Kerala.

Control and prevention

The world over, mycotoxin contamination of foods and feeds has led to significant health and economic impacts - loss of human life, cost of health care and in addition the losses incurred when farm animals or livestock are affected. This is especially a problem in India where farmers can lose their source of livelihood if their cattle or other livestock succumb to the toxic effects of mycotoxin contaminated feeds. High levels of contamination have been seen in certain food crops as well as feed due to poor agricultural and storage practices. In addition, the country has had to deal with huge financial losses due to rejection of shipments of foods by importing nations, due to unacceptable levels of mycotoxins.

As it is not always economically feasible to reject mycotoxin contaminated foods, maximum permissible levels are declared by regulatory authorities of countries. Levels of mycotoxins falling below these are unlikely to cause harm even if consumed for a long period of time. These levels however need to be monitored regularly to ensure that they do not exceed safe levels. Spread of awareness regarding harmful effects of mycotoxins as well as ways to prevent and reduce levels in food and feed is very important. FSSAI in India puts the limit for aflatoxin in different foods for human consumption between 10-15 ppb. For Ochratoxin A the limit is 20 ppb in wheat, rye and barley, 50 ppb for Patulin in apple juice and a 1000 ppb for DON in wheat. The European Union has the strictest maximum acceptable limit in the world (of 4 ppb) for aflatoxins in food for human consumption.

For reducing the amount of the mycotoxin in our food, simple measures like separating visibly mouldy grains, seeds and fruits from healthy ones, as well as washing before

consuming or processing them into food products, can go a long way. Processing and cooking of food seem to lower the level of mycotoxins in food for example, milling and cooking reduces aflatoxin levels in foods. However, processing and pasteurisation of milk does not completely destroy aflatoxin. Filtering unrefined oils also reduces mycotoxin levels especially if passed through adsorbents which bind toxins like aflatoxin. Binding agents like bentonite and aluminosilicate clays are also added to feeds to bind aflatoxin so that it is not available for absorption.

Good nutrition tackles adverse effects of mycotoxins

Some nutrients and phytochemicals have shown the potential to reduce the toxic effects of mycotoxins. These include - antioxidants like selenium, vitamins A, E and C, and fructose, phenolic compounds, chlorophyll and coumarins.

However, preventing the growth of the fungi by good agricultural practices and proper storage seems to be the more logical way of reducing the mycotoxin content of foods. Harvesting the crop early is known to protect crop from fungus which is known to attack standing ready crop especially if the weather is unpredictable. Deep ploughing of fields after harvesting and then planting a different crop not susceptible to the same fungus also helps in getting rid of infestations. Sorting, winnowing, washing, crushing combined with de-hulling of grains is effective in reducing mycotoxin levels.

Maintaining absolute cleanliness and sanitation of the storage area and controlling storage conditions go a long way in reducing contamination levels. Maintaining moisture levels below 10%, keeping temperatures low and or maintaining an inert gas environment helps as it discourages fungal growth. Mycotoxin levels could also be kept low by use of chemicals to control growth of fungi and insect infestation. A number of fungicides are used by the agricultural sector, although, there are several concerns with regard to pesticide residues in feeds and food as well as damage to the environment.

Feed control

From the discussion above it can be seen that several contaminants may enter the food chain through feed given to animals. Feed contaminants have been detected in the animal products like meat, milk, eggs, etc. Thus, it is important to look at the quality of feed that is given to livestock.

Sources of contamination

Environmental, agricultural, industrial, or other sources can contaminate animal feed and feed ingredients, causing serious adverse effects to animal and human health. Contamination can happen at any stage of the animal feed production system – harvest, manufacture, storage, or transportation. Mycotoxins, naturally occurring chemical hazards, heavy metals, pesticides and veterinary drug residues are the different types of contaminants detected in feeds. These may enter as a result of feed of animals being

treated with pesticides, low doses of veterinary drugs being mixed with feed to support growth of animals, feed grown on soil or using water contaminated with heavy metals and, other additives being mixed in feeds. Feed additives are products used in animal nutrition for purposes of improving the quality of feed and the quality of food from animal origin, or to improve the animals' health. Feed if improperly stored can develop fungal and pest infestation.

Transmissible Spongiform Encephalopathies (TSEs) are a group of progressive degenerative conditions that affect the brain and nervous system of some animals and humans. TSEs are also referred to as prion diseases. Scrapie is a degenerative disease afflicting the nervous system of sheep and goats. In 1986, scientists first learnt that the disease was transmissible to another species. Cattle were being fed offal (intestine and internal organs), meat and bone meal from sheep and goats to increase the amount of protein in their diet. This probably resulted in the transfer of the infective agent causing cattle to develop Bovine spongiform encephalopathy (BSE) or 'mad cow disease'. The disease was first reported in United Kingdom, and by 2006 the disease spread across international boundaries to more than 24 countries. The export of animal feed products made in UK to other countries had apparently resulted in the spread of the disease.

Quality control

The Feed Hygiene Regulation of the European Commission ensures that feed safety is considered at all stages. This has an impact on feed and food safety, including primary production. The registration of all feed business operators by the competent authority is compulsory. The Regulation tries to ensure that all feed businesses operate in accordance with harmonised hygiene requirements and apply good hygiene practices at all levels of agriculture production and use of feed. Hazard Analysis and Critical Control Point (HACCP) principles are used by feed business operators other than at the level of primary production. There are community and national guidelines for good practices in feed production.

In India, a new Regulation for Animal feed, Feed Additives and Pre-mixtures under FSS Act, 2006, has been formulated. It covers feed standards and hygiene requirements for feed ingredients, medicated feed, feed additives and pre-mixtures as well as specifies sampling and testing methods. Training content under FoSTaC has also been developed for training of feed safety supervisors working in processing establishments and for feed safety officers. Also, there is a module for third party audit of feed business operators.

Other hazards

Some toxins occur naturally in food stuffs. Several may be formed because of the way we process and package the foods during secondary and tertiary processing. Cooking normally destroys or decreases the amount of toxicants in foods. However, in some cases it may introduce new chemicals which are harmful for our health. Some of these have been discussed here highlighting the need to reduce human exposure to these toxic chemicals which can be carcinogenic.

Naturally occurring toxicants

Foods also contain a wide range of natural chemical compounds which may act as toxicants or anti-nutritional factors which interfere with the way our body utilizes nutrients. The harmful effects of consuming these range from mild symptoms of gastric distress to even death. Some examples of naturally occurring toxicants are seafood toxins, biogenic amines, alkaloids and toxic amino acids. Shellfish poisoning (due to toxins present in shellfish), epidemic dropsy (due to consumption of Argemone seeds or oil) and Lathyrism (due to a toxic amino acid in *Khesari dal*) are some of the disease conditions arising out of consuming foods containing these natural toxins. Some of the chemicals which act as anti-nutritional factors are trypsin inhibitors, phytates, oxalates, tannins and cyanogenic glycosides. They interfere with the absorption or utilization of nutrients by our body.

Produced during processing

A number of toxic chemicals are produced during cooking and processing of foods. Advanced Glycation End Products (AGEs) are produced when animal fats are cooked at high temperatures. They are also produced when plant foods are cooked to the point of browning or crisping. Animal-derived foods that are high in fat and protein are generally AGE-rich. These have been implicated in atherosclerosis as they increase oxidative stress and inflammation, and in aging of the skin (formation of wrinkles). Acrylamide is formed whenever foods that contain the amino acid asparagine and any reactive carbohydrate are heated at temperatures greater than 120 °C. Starch based foods like potato, bread, bakery products and breakfast cereals, cocoa based products and coffee are especially likely to contain acrylamide. Acrylamide causes DNA damage, neurological and reproductive damage, and is a probable carcinogen.

Heterocyclic Amines are formed from pyrolysis of amino acids and proteins at high temperature or when creatine and amino acids present in muscle tissues of animals are heated to high temperatures like during cooking of meat. They may also be formed during the Maillard reaction in which amino acids react with carbohydrates. These are mutagenic and carcinogenic. These may also be formed in plant-based foods when they are browned or charred. Nitrosamines are formed when nitrates or nitrites (preservatives added to processed meat/ fertilizers added to vegetables) combine with amino acids on exposure to high temperatures during cooking (e.g. grilling or frying). These preservatives are used a lot in processed meat products like sausages, bacon, ham, salami, etc. and hence it is undesirable to eat these foods as a part of the regular diet. Nitrosamines have also been detected in alcoholic beverages like beer, cheese, soyabean oil and canned fruit. Drying, kilning, salting, smoking or curing of food also promotes formation of nitrosamines. Nitrosamines have been shown to produce cancer in experimental animals. Polycyclic Aromatic Hydrocarbons (PAHs), are formed during grilling or charring of food especially meats. Food exposed to fumes of cooking oil or to smoke from the fossil fuels (wood, coal and oil) used for cooking may also contain these toxins. Cooking directly in contact with the flame also increases the PAH content.

Safe Cooking Practices Lower Levels of Contaminants

It is better to reduce consumption of foods cooked at high temperatures (e.g. by frying, grilling, and baking). One should refrain from eating foods that are cooked to a crisp, smoked, charred, or blackened, to reduce exposure to harmful chemical products like AGEs, acrylamide, heterocyclic amines, nitrosamines, and polycyclic aromatic hydrocarbons.

Cooking foods at lower temperatures (boiling, steaming temperatures) or eating some vegetables in the raw form will reduce exposure to most of these chemicals formed at high cooking temperatures.

Packaging and Storage conditions

Toxic chemicals may also migrate from the packaging/ holding container to the food. Hence it is very important that the best quality materials be used for cooking, storing and packaging food. Several studies show that storing water and food in plastic results in migration of chemicals. Additives like plasticizers, antioxidants, catalysts, suspension and emulsifying agents, stabilizers and polymerization inhibitors, pigments, fillers, etc. are regularly used in the manufacturer of different types of plastics. These may leach into food and water stored in plastic containers. Bisphenol A (BPA) a component of polycarbonate used to make plastic bottles and also the epoxy-resin lining of metal cans, is a chemical which has been detected even in plain water stored in plastic bottles. BPA is an endocrine disruptor and its use has been banned in many countries especially in baby bottles and cups for children. Phthalates which make plastics more supple and bendable have also been known to leach out into food and beverages in contact with plastics. Food packaging material, tubing and other parts of processing equipment may all have phthalates which can leach out into the food products. Phthalates have also been identified as potential carcinogens and endocrine disruptors.

Tin, aluminium, iron/steel cans and containers may also leach metals into foods stored in them. Acidic foods generally react with metals. Inks used on the packaging for branding, printing the label information and barcoding may also leach out into the food product. Sterilization while food is there in the packaging using gamma radiation, steam, or ethylene oxide treatments, can cause leaching. Gamma radiation can break the carbon-chlorine bonds found in PVC plastics and some additives, forming breakdown products that can then percolate into food. Highly processed foods are likely to contain higher amounts of most of these chemicals. NHANES data from USA indicates that higher the consumption of fast foods by participants, the higher is the concentration of phthalate metabolites in their urine.

Some chemicals are also intentionally added to foods for a technological purpose like to impart colour and flavour to the food, to increase the shelf life of the food or to impart desirable texture to the finished food product. These chemicals are known as food additives and these can turn problematic when they are consumed in large quantities as some additives like preservatives and colouring agents have been associated with allergic reactions in sensitive people. These chemicals may become further problematic and produce other symptoms if misused like adding more than permitted. When additives are added in excess or to foods in which they aren't permitted, it becomes a case of food adulteration.

Food adulteration

Buying food from reliable sources is also an important step towards ensuring that we consume safe food. This reduces the chances of the food being adulterated. Unscrupulous vendors may add inferior quality material or extract valuable ingredients from a food for economic gains. This not only decreases the quality of the food but can lead to serious health consequences if non-edible harmful ingredients are added to food.

According to the Food Safety and Standards Act, 2006 an **adulterant** is defined as "any material which is or could be employed for making the food unsafe or sub-standard or mis-branded or containing extraneous matter"

Foods commonly adulterated

Adulterants have been detected in almost all kinds of foods - food grains and pulses, edible oils and fats, spices, milk and milk products, meat and meat products, beverages (both alcoholic and non-alcoholic), tea, coffee, sweetening agents like sugar, honey, jaggery and items made from these like *mithai*. Foods which are more likely to be adulterated include:

- Foods which are expensive - like edible oils, spices, etc.
- Foods which sell more like wheat flour, oil, milk etc. are foods consumed daily
- Foods which are perishable like milk and milk products
- Foods sold loose like milk, spices, etc.
- Foods in which it is easy to mix an adulterant like those in the form of powder, paste or mince.

Foods which are in a powder, minced or paste form are also more likely to be adulterated, as it is more difficult for the naked eye to detect adulteration in these foodstuffs. For instance, when buying minced mutton, it is difficult to tell which animal meat is being sold as goat meat, or similarly whether starch dyed yellow has been added to turmeric powder. Adulteration of foods sold loose by the retailer is also more common as compared to packaged foods as labels carry the name and address of the manufacturer or distributor and they can be caught by the regulatory authority if their food stuff is found sub-standard. Consumers should avoid buying foodstuffs sold loose even though these are cheaper.

Selecting Pure Spices

Ground spices are at a high risk of adulteration with coloured starch, straw, chalk powder etc. It is important to keep certain points in mind while purchasing these spices- Do not purchase loosely sold powdered spices as they are at a higher risk of being adulterated. Packets should be sealed properly and carry FSSAI license number and preferably AGMARK logo. Check the best before date. Do not purchase if the spices are too brightly coloured or have an extra shine.

https://fssai.gov.in/upload/uploadfiles/files/Guidance_Note_Safe_Ground_Spices_30_07_2018(1).pd

Health effects of adulterants

Adulteration not only lowers the quality but may also lead to adverse health effects. There have been instances of death due to toxic substances added as adulterants to food. Chemicals like urea, sodium carbonate (washing soda, soda), sodium hydroxide (caustic soda), formaldehyde and hydrogen peroxide added to increase the shelf-life of milk, can damage the intestinal lining by irritating it. Use of the *Lathyrus* pulse to adulterate lentils (*masoor)* or *toor dal* or *besan*, can prove to be harmful. This pulse has a toxic factor, which is a neurotoxin leading to the crippling disease lathyrism. Mustard oil has been found to be adulterated with argemone oil which leads to symptoms of oedema, gastrointestinal disturbances, increased permeability of blood vessels, glaucoma, respiratory symptoms and congestive heart failure. Mineral oil (liquid paraffin) and castor oil, cheap inedible oils used as adulterants, may have a laxative effect with nausea, vomiting and possible damage to the lining of the intestine if consumed in excessive amounts or for a long period of time. Similarly, industrial dyes (like metanil yellow, sudan dyes, auramine, etc.) being used to colour food products have led to food poisoning outbreaks.

Prevention and Control

The Food Safety and Standards Authority of India (FSSAI) has been established for laying down science-based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption. FSSAI has also developed a simple, illustrated manual to detect common adulterants at home called DART- Detect Adulterants with Rapid Tests. This manual can be accessed from the weblink provided in the references. The simple tests include physical inspection of food as well as chemical reactions. For instance, artificially coloured pulse grains will leave a colour trail when immersed in a glass of water. Pure silver leaves will crumble to a powder when crushed between fingers whereas aluminium used as an adulterant on *mithai* (sweetmeats) is not that delicate and will leave shreds. If powdered spices are sprinkled on the water surface, pure spices will not leave any saw dust/powdered bran on the surface of water. In case one finds that any food item is adulterated, one must stop using the food product and report this to the authorities. State Food Authorities in addition regularly pick up samples and analyse them for quality and presence of adulterants. Food vendors selling adulterated food items are prosecuted as per the provisions of the FSS Act.

An efficient monitoring and surveillance system can help in ensuring that all food produced and sold for human consumption is safe from contamination and willful adulteration. Methods for reducing contamination of foods at the primary production stage should be actively used. It is also important to prevent contamination and production of hazardous chemicals in food during secondary and tertiary stages of production.

Summary

- Residues of pesticides, drugs administered to animals (veterinary drug residues), heavy metals, mycotoxins and toxic chemicals naturally present in plants and animals are likely to contaminate food at the primary production stage.
- Residues of pesticides detected in different foods like cereals, pulses, fruits, vegetables and in drinking water are a result of poor agricultural practices at the farm level.
- Pesticides even in small quantities can prove to be hazardous for us as our body finds it difficult to excrete them. Non-pesticide dependent agriculture and integrated pest management (IPM) is thus increasingly gaining popularity. Biopesticides i.e. natural materials like animals, plants, bacteria and certain minerals or biochemicals are being used for pest management.
- Various types of drugs are used for animals, fowl and insects like bees which provide us with food like meat, milk, eggs and honey. Residues of these drugs show up in the food leading to acute food poisoning outbreaks, increased risk of antimicrobial resistance and economic loss to the food industry which uses live cultures for production of fermented products. Hormones in food and water have been linked to endocrine disruption in humans with increased risk of breast cancer and early puberty in girls.
- Good veterinary practices need to be followed and appropriate withdrawal time period given before milking or slaughtering animals for consumption.
- Food grown in contaminated soil or using contaminated water (especially raw sewage water/sludge), or even in the vicinity of polluting industries tends to be high in heavy metal content. Similarly, fish and other seafood from contaminated water bodies have heavy metals in them. Metals may also enter food from metallic cans and other containers in which the food is cooked, stored or packaged, especially if the food is acidic in nature.
- Heavy metals like lead, cadmium, mercury and arsenic can cause a lot of damage to human health as it is difficult for the body to excrete them. Bioaccumulation and biomagnification are a serious issue. Higher the animal in the food chain, greater the heavy metal concentration in body and higher the risk of adverse effects. Safe waste disposal is the key to reducing contamination of air, soil and water.
- Fungi growing on food may produce toxins (mycotoxins) which are harmful to health. Some of these are potential carcinogens. Some examples of mycotoxins are aflatoxins, ergot alkaloids, trichothecenes, fumonisin, zearalenone, patulin and ochratoxin.
- Proper hygienic and controlled storage conditions and certain processing activities can reduce mycotoxin levels in food and feed.

- Environmental, agricultural, industrial, or other sources can contaminate animal feed and feed ingredients, causing serious adverse effects to animal and human health. Contamination can happen at any stage of the animal feed production system – harvest, manufacture, storage, or transportation.
- Transmissible Spongiform Encephalopathies (TSEs) are a group of progressive degenerative conditions that affect the brain and nervous system of some animals and humans. The spread of TSEs has been linked to offal from affected animals being used as feed for other animals. Quality and safety of animal feed hence needs to be monitored.
- Some toxins and anti-nutritional factors occur naturally in food stuffs while others may be formed because of the way we process and package the foods.
- Shellfish poisoning, epidemic dropsy and lathyrism are some conditions which develop as a result of naturally occurring toxic substances in foods. Some of the chemicals which act as anti-nutritional factors interfering with the utilization of nutrients by our body are trypsin inhibitors, phytates, oxalates, tannins and cyanogenic glycosides.
- Advanced Glycation End Products (AGEs), acrylamide, heterocyclic amines, polycyclic aromatic hydrocarbons and nitrosamines are formed when certain foods are cooked at high temperatures. One should refrain from eating foods that are cooked to a crisp, smoked, charred, or blackened, to reduce exposure to harmful chemical products.
- Toxic chemicals (like BPA, phthalates, inks, etc.) and metals may also migrate from the packaging/ holding container to the food. Hence it is very important that the best quality materials be used for cooking, storing and packaging food.
- Unscrupulous vendors may add inferior quality material or extract valuable ingredients from a food for economic gains thus not only decreasing the quality of the food but also leading to adverse health consequences especially if non-edible harmful ingredients are used as adulterants.
- Foods which are expensive**,** have high sale value, are perishable, sold loose or sold in powdered, minced or paste form are more likely to be adulterated. One needs to be vigilant about the quality of food that is procured for consumption.
- The Food Safety and Standards Authority of India (FSSAI) has been established for laying down science-based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption.

Key Terms

Bioaccumulation – is the gradual accumulation of a substance in the body over time resulting from faster absorption in comparison to the rate of excretion.

Biomagnification – also known as bioamplification is the concentration of toxins (like pesticides, heavy metals, etc.) in an organism at successively higher levels in the food chain.

Biopesticides - are natural materials like animals, plants, bacteria and certain minerals or biochemicals which can be used for pest management.

Carcinogenicity - ability to produce cancer.

Endocrine disruptors – are chemicals which interfere with the normal functioning of the hormones of the body producing adverse health effects consequently.

Mutagenicity - ability to cause genetic changes.

Oncogenicity - ability to induce tumour growth.

Persistent Organic Pollutants – are chemicals which are organic in nature and tend to persist in the environment as they do not dissipate easily. They have adverse health consequences.

Teratogenicity - ability to cause birth defects.

Exercises

1. Discuss why pesticide residues in food and feed are health hazards.
2. How do veterinary drug residues in food affect us? How will good veterinary practices help to reduce our exposure?
3. What do you understand by bioaccumulation and biomagnification? Discuss with reference to mercury levels in fish.
4. What are mycotoxins? Explain how we can reduce our exposure to mycotoxins.
5. Why is it important to monitor the quality of feed given to animals used for production of food for humans?
6. List some toxic chemicals which are produced during cooking/processing. How can exposure to these be reduced?
7. How can packaging introduce contaminants in our food?
8. What is food adulteration? Which foods are more likely to be adulterated?

Activity

Visit your local market or use the food stuffs in your kitchen for this activity. Download the DART book for testing adulterants in food. Select some basic spices like pepper corns, turmeric and red chilli powder, as well as milk and cooking oil. Perform the simple tests described in the manual to check the purity of the food items.

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