



# FOOD TOXICOLOGY

## MCB 414

BY

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# INTRODUCTION

- ▶ Toxicology means the science of poisons.
- ▶ A toxicant or poison is a chemical substance which, after entering an organism, is capable of eliciting smaller or larger adverse changes in the functioning of cells, tissues, or even the whole organism, resulting in the most severe and untreated cases in the death of the organism.
- ▶ A similar term “toxin” usually refers to any proteinaceous poison produced by living organisms, particularly microorganisms such as bacteria in the body of a host.

# INTRODUCTION CONTN'D

- ▶ **Xenobiotic** is the general term that is used for a **foreign** substance taken into the body. Xenobiotics may produce beneficial effects (*such as a pharmaceuticals*) or they may be toxic (*such as lead*).
- ▶ As Paracelsus proposed centuries ago, dose differentiates whether a substance will be a remedy or a poison.
- ▶ A xenobiotic in small amounts may be non-toxic and even beneficial but when the dose is increased, toxic and lethal effects may result.

# Impact of toxic substances in foods on human health

## ▶ **Acute Toxicity:**

- ▶ Acute toxicity refers to the immediate or short-term effects of exposure to high doses of toxic substances in foods. Symptoms of acute food poisoning may include nausea, vomiting, diarrhea, abdominal pain, fever, and neurological symptoms.
- ▶ Examples of acute foodborne toxins include bacterial toxins (e.g., *Staphylococcus aureus* enterotoxin, *Bacillus cereus* toxin), fungal toxins (e.g., aflatoxins produced by *Aspergillus* species), marine biotoxins (e.g., ciguatoxin, saxitoxin), and chemical contaminants (e.g., heavy metals such as lead, mercury, arsenic, and pesticides).

## ▶ **Chronic Toxicity:**

- ▶ Chronic toxicity refers to the long-term effects of repeated or prolonged exposure to low doses of toxic substances in foods. Chronic exposure to certain foodborne toxins may lead to cumulative health effects and chronic diseases over time.
- ▶ Examples of chronic health effects associated with foodborne toxins include liver damage (e.g., aflatoxin-induced hepatocellular carcinoma), kidney damage (e.g., aristolochic acid nephropathy), neurological disorders (e.g., mercury poisoning), developmental disorders (e.g., lead poisoning in children), reproductive effects, and carcinogenesis.

# Impact of toxic substances in foods on human health cont'd

## ▶ **Allergic Reactions:**

- ▶ Some individuals may experience allergic reactions or hypersensitivity reactions to specific proteins or allergens present in foods.
- ▶ Food allergies can cause a range of symptoms, including skin rash, hives, itching, swelling of the lips, tongue, or throat, difficulty breathing, gastrointestinal symptoms, and anaphylaxis, a severe and potentially life-threatening allergic reaction.
- ▶ Allergic reactions to food allergens can occur even at very low levels of exposure and require strict avoidance of the allergenic food.
- ▶ Common food allergens include peanuts, tree nuts, milk, eggs, soy, wheat, fish, and shellfish.

## ▶ **Teratogenic effects:**

- ▶ Exposure to certain toxic substances in foods during pregnancy or early childhood may have adverse effects on fetal development, growth, and reproductive health.
- ▶ Examples of developmental and reproductive effects associated with foodborne toxins include birth defects, impaired cognitive development, growth retardation, infertility, and miscarriage.

# Impact of toxic substances in foods on human health contn'd

## ▶ **Carcinogenicity:**

- ▶ Some foodborne toxins have been classified as carcinogens, meaning they have the potential to cause cancer in humans.
- ▶ Chronic exposure to carcinogenic compounds in foods may increase the risk of developing certain types of cancer over time.
- ▶ Examples of carcinogenic compounds found in foods include
  - i. aflatoxins (associated with liver cancer),
  - ii. polycyclic aromatic hydrocarbons (PAHs) formed during food processing or cooking at high temperatures, and
  - iii. heterocyclic amines (HCAs) formed during cooking of meat at high temperatures.

# The historical development of food toxicology as a scientific discipline

- ▶ The **historical development of toxicology** began with early cave dwellers who recognized poisonous plants and animals and used their extracts for hunting or in warfare.
- ▶ By 1500 BC, written recordings indicated that hemlock, opium, arrow poisons, and certain metals were used to poison enemies or for state executions.
- ▶ With time, poisons became widely used and with great sophistication.
- ▶ Notable poisoning victims include Socrates, Cleopatra, and Claudius.
- ▶ By the time of the Renaissance and Age of Enlightenment, certain concepts fundamental to toxicology began to take shape.
- ▶ The studies of Paracelsus (~1500AD) and Orfila (~1800 AD) are well known.
- ▶ **Paracelsus** determined that specific chemicals were actually responsible for the toxicity of a plant or animal poison. He also documented that the body's response to those chemicals depended on the dose received.
- ▶ His studies revealed that small doses of a substance might be harmless or beneficial whereas larger doses could be toxic. This is now known as the dose-response relationship, a major concept of toxicology. Paracelsus was one of the founders of modern toxicology.
- ▶ His best known quote: *All substances are poisons; it is the dose that makes the poison.*

# The historical development of food toxicology as a scientific discipline

- ▶ **Orfila**, a Spanish physician, is often referred to as the **founder of toxicology**.
- ▶ It was Orfila who first prepared a systematic correlation between the chemical and biological properties of poisons of the time.
- ▶ He demonstrated effects of poisons on specific organs by analyzing autopsy materials for poisons and their associated tissue damage.
- ▶ **18th and 19th Centuries:**
  - ▶ The development of modern chemistry and toxicology in the 18th and 19th centuries laid the foundation for the scientific study of food safety and toxic substances in foods. Chemists and toxicologists began to identify and characterize chemical compounds responsible for food poisoning and adulteration.
  - ▶ Landmark events, such as the 1858 publication of "The Jungle" by Upton Sinclair, exposed unsanitary and unsafe practices in the food industry, leading to increased public awareness and demands for food safety regulations.



# The historical development of food toxicology as a scientific discipline

## ▶ 20th Century:

- ▶ The 20th century saw significant advancements in food safety science, regulatory oversight, and public health initiatives. The establishment of government agencies, such as the U.S. Food and Drug Administration (FDA) and the World Health Organization (WHO), played a key role in regulating food safety and protecting public health.
- ▶ The 20th century is marked by an advanced level of understanding of toxicology. DNA (*the molecule of life*) and various biochemicals that maintain body functions were discovered.
- ▶ Our level of knowledge of toxic effects on organs and cells is now being revealed at the molecular level. It is recognized that virtually all toxic effects are caused by changes in specific cellular molecules and biochemicals.
  - ▶ Landmark events, such as the discovery of foodborne pathogens (e.g., Salmonella, Escherichia coli) and the development of microbiological methods for food testing, revolutionized our understanding of foodborne illnesses and the importance of microbiological safety in food production and processing.
  - ▶ The development of analytical techniques, such as chromatography and mass spectrometry, enabled the identification and quantification of chemical contaminants and food additives in foods, leading to improved monitoring and regulatory control of food safety.

# The historical development of food toxicology as a scientific discipline

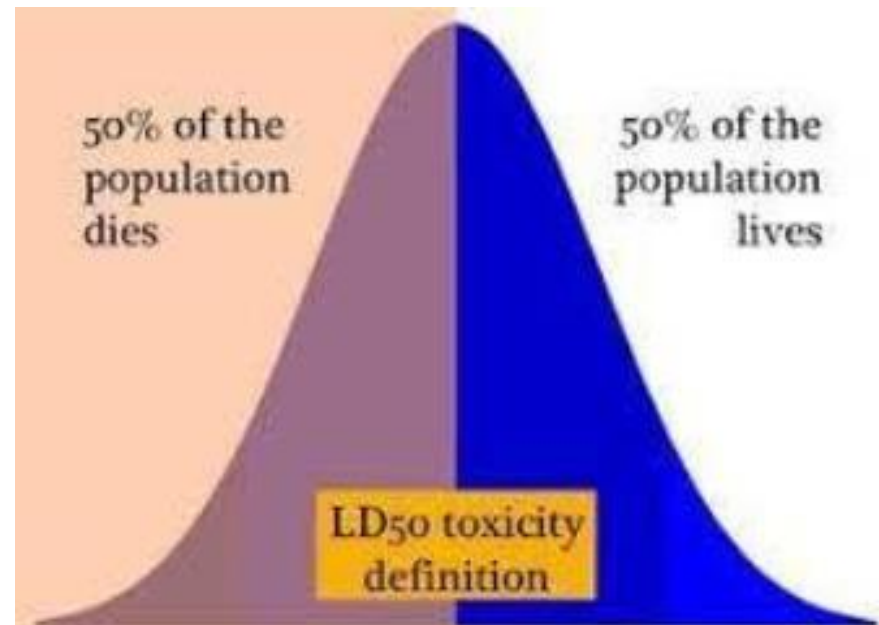
- ▶ The establishment of international standards, such as the Codex Alimentarius Commission, provided guidelines and regulations for food safety, quality, and trade on a global scale.
- ▶ **21st Century:**
  - ▶ In the 21st century, advancements in technology, globalization of the food supply chain, and emerging food safety challenges have shaped the field of food toxicology. Rapid methods for detecting foodborne pathogens and chemical contaminants have been developed, allowing for faster and more accurate risk assessment and management.
  - ▶ The emergence of novel food production technologies, such as genetic engineering, nanotechnology, and alternative protein sources, has raised new questions and concerns regarding the safety and regulation of novel foods and food ingredients.
  - ▶ Increasing awareness of foodborne illnesses, food allergies, and food fraud has led to greater consumer demand for transparency, traceability, and authenticity in the food supply chain. Regulatory agencies and food industry stakeholders continue to collaborate on initiatives to enhance food safety, prevent foodborne illnesses, and promote public health.

# Acute toxicity

- ▶ Acute toxicity refers to those adverse effects occurring following oral or dermal administration of a single dose of a substance, or multiple doses given within 24 hours, or an inhalation exposure of 4 hours.
- ▶ A parameter used to evaluate acute toxicity (short-term poisoning potential) is the median lethal dose (LD<sub>50</sub>).
- ▶ LD<sub>50</sub> represents the dose of a substance that is lethal to 50% of the test animals exposed to it under specific experimental conditions in the absence of antidotes or treatment.
- ▶ The LD<sub>50</sub> value is quantitative and is expressed in terms of milligrams of substance per kilogram of body weight (mg/kg) of the test animal.
- ▶ The LD<sub>50</sub> is determined through experimental studies conducted in laboratory animals, such as rodents (e.g., rats, mice) or non-rodents (e.g., rabbits, guinea pigs), following established protocols and guidelines for acute toxicity testing

# Acute toxicity contn'd

- ▶ The smaller the LD50 value, the more toxic is chemical. The opposite is also true: the larger the LD50 value, the lower the toxicity.



# Acute toxicity contn'd

- ▶ Absolute (LD100) and minimal (LDmin) toxicity can be measured.
- ▶ LD100 belongs to the most durable, and LDmin to the weakest animal.
- ▶ Instead of doses, concentrations can be used—the respective parameters will be LC50, LC100, and LCmin (mmol/L,  $\mu\text{g}/\text{m}^3$  ).
- ▶ The classical LD50 test, which requires torture and sacrifice of a large number of test animals and which had caused long scientific and social debates, was finally canceled by the end of 2002.
- ▶ The alternative animal acute-oral toxicity tests, such as the fixed-dose procedure (FDP), acute toxic class (ATC) method, and up-and-down procedure (UDP), have been developed.
- ▶ LD50 does not provide information about chronic health effects from long-term exposure to a substance.
- ▶ LD50 values are used in:
  - ▶ **Classifying the acute toxicity of chemicals** for regulatory purposes (e.g., labeling requirements)
  - ▶ **Risk assessment** to estimate the potential hazards associated with exposure to a substance
  - ▶ **Guiding safety procedures** when handling hazardous materials

# How are LD/LC<sub>50</sub> tests done?

- ▶ In nearly all cases, LD<sub>50</sub> tests are performed using a pure form of the chemical. Mixtures are rarely studied.
- ▶ The chemical may be given to the animals by mouth (oral); by applying on the skin (dermal); by injection at sites such as the blood veins (i.v.- intravenous), muscles (i.m. - intramuscular) or into the abdominal cavity (i.p. - intraperitoneal).
- ▶ The LD<sub>50</sub> value obtained at the end of the experiment is identified as the LD<sub>50</sub> (oral), LD<sub>50</sub> (skin), LD<sub>50</sub> (i.v.), etc., as appropriate.
- ▶ Researchers can do the test with any animal species but they use rats or mice most often.
- ▶ In each case, the LD<sub>50</sub> value is expressed as the weight of chemical administered per kilogram body weight of the animal
- ▶ It states the test animal used and route of exposure or administration; e.g., LD<sub>50</sub> (oral, rat) - 5 mg/kg, LD<sub>50</sub> (skin, rabbit) - 5 g/kg. So, the example "LD<sub>50</sub> (oral, rat) 5 mg/kg" means that 5 milligrams of that chemical for every 1 kilogram body weight of the rat, when administered in one dose by mouth, causes the death of 50% of the test group.
- ▶ If the lethal effects from breathing a compound are to be tested, the chemical (usually a gas or vapour) is first mixed in a known concentration in a special air chamber where the test animals will be placed.
- ▶ This concentration is usually quoted as parts per million (ppm) or milligrams per cubic metre (mg/m<sup>3</sup>). In these experiments, the concentration that kills 50% of the animals is called an LC<sub>50</sub> (Lethal Concentration 50) rather than an LD<sub>50</sub>.
- ▶ When an LC<sub>50</sub> value is reported, it should also state the kind of test animal studied and the duration of the exposure, e.g., LC<sub>50</sub> (rat) - 1000 ppm/ 4 hr or LC<sub>50</sub> (mouse) - 5mg/m<sup>3</sup>/ 2hr.

# Factors determining adverse effects of food toxicants

- ▶ Intrinsic toxicity of the substance
- ▶ Dose: exposure dose, absorbed dose, administered dose and total dose. Generally, the higher the dose, the more severe the response
- ▶ Exposure conditions: routes of exposure, frequency & duration of exposure, mixed exposures, environmental circumstances
- ▶ Response of host: Toxicity can result from adverse cellular, biochemical, or macromolecular changes.
- ▶ Species of organism
- ▶ Age,
- ▶ Sex

# Examples of Acute Toxicity

- ▶ **Food Poisoning:** Contaminated food containing bacterial toxins or harmful chemicals can cause acute illness.
- ▶ **Insecticide Poisoning:** Accidental ingestion or inhalation of insecticides can lead to acute toxicity.
- ▶ **Household Product Misuse:** Improper use of cleaning products or medications can result in accidental poisoning.
- ▶ **Industrial Accidents:** Exposure to high levels of industrial chemicals can cause severe acute toxicity.



# Role of LD50 in risk assessment and regulatory considerations

- ▶ LD50 values are used to establish safe exposure limits for chemical substances in various occupational, environmental, and consumer settings.
- ▶ LD50 values are used to set regulatory standards and guidelines for the safe use, handling, storage, transportation, and disposal of chemical substances.
- ▶ LD50 provides a quick and relatively inexpensive way to categorize the acute toxicity of a substance. This helps prioritize further testing and risk assessment efforts for substances with lower LD50 values (indicating higher potential danger).
- ▶ LD50 helps establish a starting point for understanding the dose-response relationship of a substance. This relationship shows how the severity of the effect (in this case, death) increases with increasing dose.
- ▶ LD50 values allow for a basic comparison of the acute toxicity of different substances. This can be helpful in understanding the relative risks associated with different chemicals.

# Common toxicants in food

- ▶ **Natural toxins:** toxic compounds that are naturally produced by living organisms. These toxins are not harmful to the organisms themselves but they may be toxic to other creatures, including humans, when eaten.
  - a. Aquatic biotoxins: Algal toxins, ciguatoxins,
  - b. Phytotoxins (Cyanogenic glycosides),
  - c. Furocoumarins
  - d. Lectins
  - e. Mycotoxins
  - f. Solanines and chaconine (which are glycoalkaloids).
  - g. Muscimol and muscarine
  - h. Pyrrolizidine alkaloids
  - i. Aflatoxins (Grains, Nuts)

# Common toxicants in food

- ▶ **Heavy Metals**
- ▶ **Pesticide Residues**
- ▶ **Food Additives:** such as artificial sweeteners (e.g., aspartame, saccharin), artificial colors (e.g., tartrazine, sunset yellow), and preservatives (e.g., sulfites, nitrates/nitrites).
- ▶ **Environmental Contaminants:** Environmental pollutants, including polychlorinated biphenyls (PCBs), dioxins, polycyclic aromatic hydrocarbons (PAHs), and perfluoroalkyl substances (PFAS), can contaminate foods through air, water, soil, and food chain contamination.
- ▶ **Microbial Toxins:** Examples include bacterial toxins (e.g., *Staphylococcus aureus* enterotoxins, *Clostridium botulinum* neurotoxins), fungal toxins (e.g., aflatoxins, ochratoxin A), and marine biotoxins (e.g., saxitoxin, domoic acid).
- ▶ **Allergens:** proteins found in certain foods that can trigger allergic reactions in susceptible individuals (peanuts, tree nuts, milk, eggs, soy, wheat, fish, and shellfish).

# Sources of Food Toxicants

- ▶ **a. Natural Contaminants:** Naturally occurring substances in foods that can be toxic under certain conditions. Examples include:
  - ▶ Toxins produced by plants, such as alkaloids (e.g., solanine in green potatoes), glycoalkaloids (e.g., solanine in nightshade family plants), lectins, and cyanogenic glycosides (e.g., amygdalin in bitter almonds).
  - ▶ Toxins produced by fungi, such as mycotoxins (e.g., aflatoxins, ochratoxin A, patulin) that contaminate grains, nuts, fruits, and spices.
  - ▶ Toxins produced by algae, such as marine biotoxins (e.g., saxitoxin, domoic acid) that contaminate seafood.
- ▶ **b. Chemical Contaminants:** Synthetic or industrial chemicals that can contaminate foods through various routes, including:
  - ▶ Environmental pollution: Heavy metals (e.g., lead, mercury, cadmium, arsenic) from industrial emissions, mining activities, and agricultural runoff.
  - ▶ Pesticides: Residues from agricultural chemicals used for pest control, weed control, and disease management.
  - ▶ Food additives: Artificial sweeteners, artificial colors, preservatives, flavor enhancers, and other additives used in food processing.
  - ▶ Environmental contaminants: Polychlorinated biphenyls (PCBs), dioxins, polycyclic aromatic hydrocarbons (PAHs), and perfluoroalkyl substances (PFAS) from industrial processes and waste disposal.

# Sources of Food Toxicants

- ▶ **Microbial Contaminants:** Pathogenic microorganisms and their toxins that can contaminate foods through poor hygiene, improper handling, and inadequate food processing or storage. Examples include:
  - ▶ Bacterial toxins: Toxins produced by bacteria such as *Staphylococcus aureus* (enterotoxins), *Clostridium botulinum* (neurotoxins), *Bacillus cereus* (emetic toxin), and *Escherichia coli* (Shiga toxins).
  - ▶ Fungal toxins: Mycotoxins produced by molds such as *Aspergillus*, *Penicillium*, and *Fusarium* species.

# Modes of Contamination

- ▶ a. **Environmental Contamination:** Contamination of foods with toxic substances from the environment, including air, water, soil, and industrial pollutants.
- ▶ b. **Processing Contamination:** Introduction of toxicants into foods during manufacturing, processing, packaging, and transportation. Examples include cross-contamination, use of contaminated equipment, and migration of packaging materials.
- ▶ c. **Biological Contamination:** Growth of pathogenic microorganisms and production of toxins in foods due to improper storage, handling, and hygiene practices.
- ▶ d. **Intentional Contamination:** Deliberate addition of toxic substances to foods for fraudulent purposes, such as adulteration or economic adulteration.

# Potential Health Risks of Toxicity

- ▶ a. **Acute Toxicity:** Immediate adverse effects on health following short-term exposure to high doses of toxic substances. Symptoms may include nausea, vomiting, diarrhea, abdominal pain, neurological symptoms, and in severe cases, organ failure and death.
- ▶ b. **Chronic Toxicity:** Long-term adverse effects on health following repeated or prolonged exposure to low doses of toxic substances. Chronic exposure may lead to cumulative health effects, including neurological disorders, developmental delays, kidney damage, immune dysfunction, reproductive problems, and cancer.
- ▶ c. **Allergic Reactions:** Adverse immune responses to specific proteins or allergens in foods, leading to allergic reactions ranging from mild symptoms (e.g., hives, itching) to severe and life-threatening reactions (e.g., anaphylaxis).
- ▶ d. **Carcinogenicity:** Ability of certain toxic substances to cause cancer or increase the risk of cancer development over time. Chronic exposure to carcinogens in foods may lead to the development of various types of cancer, including liver cancer, kidney cancer, gastrointestinal cancer, and leukemia.

# Food Detoxification methods

- ▶ **Physical food detoxification** methods involve the use of physical processes to remove or reduce contaminants, toxins, or undesirable substances from foods.
- ▶ **Washing and Rinsing:**
  - ▶ Washing fruits, vegetables, and grains under running water can help remove surface contaminants, pesticide residues, dirt, and debris.
  - ▶ Using a vegetable brush or scrubbing gently can further enhance the removal of residues and particles adhering to the surface of produce.
  - ▶ Rinsing foods thoroughly can also reduce microbial contamination and foodborne pathogens.
- ▶ **Peeling and Trimming:**
  - ▶ Peeling outer layers of fruits and vegetables can effectively remove surface contaminants, pesticide residues, and wax coatings.
  - ▶ Trimming visible areas of spoilage, damage, or bruising on produce can help eliminate microbial contaminants and reduce the risk of foodborne illness.
- ▶ **Cooking:**
  - ▶ Cooking foods at high temperatures can kill or inactivate microbial pathogens, parasites, and harmful bacteria.
  - ▶ Boiling, steaming, baking, grilling, frying, and roasting are common cooking methods used to detoxify foods and improve their safety.
  - ▶ Heat treatment can also destroy or denature toxins, antinutritional factors, and allergens present in raw foods.



# Food Detoxification methods

## ▶ **Filtration:**

- ▶ Filtration techniques can be used to remove solid particles, sediment, and impurities from liquids such as water, juices, and beverages.
- ▶ Membrane filtration processes, including microfiltration, ultrafiltration, and reverse osmosis, can remove microbial contaminants, suspended solids, and dissolved substances from liquids.

## ▶ **Sieving and Sifting:**

- ▶ Sieving and sifting involve the use of mesh screens or sieves to separate particles of different sizes in granular or powdered foods.
- ▶ These methods can remove foreign matter, debris, insects, and contaminants from grains, flours, spices, and powders.

## ▶ **Centrifugation:**

- ▶ Centrifugation is a separation technique that uses centrifugal force to separate components of different densities in liquid mixtures.
- ▶ It can be used to remove solid particles, sediments, fats, and impurities from liquids such as milk, fruit juices, and vegetable oils.

## ▶ **Drying and Dehydration:**

- ▶ Drying and dehydration processes involve removing moisture from foods to inhibit microbial growth, prevent spoilage, and extend shelf life.
- ▶ Sun drying, air drying, freeze-drying, and vacuum drying are common methods used to detoxify fruits, vegetables, meats, and seafood.

# Benefits of Physical detoxification

- ▶ **Safety:** Physical methods typically do not involve the use of chemicals or additives, making them safer for consumers and the environment compared to chemical detoxification approaches.
- ▶ **Minimal Alteration of Nutritional Content:** Many physical detoxification methods, such as washing, rinsing, and cooking, do not significantly alter the nutritional content of foods. This means that essential nutrients remain intact even after the detoxification process.
- ▶ **Versatility:** Physical methods can be applied to a wide range of foods, including fruits, vegetables, grains, meats, and seafood. They are adaptable to various food processing and preparation techniques, making them suitable for diverse culinary practices.
- ▶ **Ease of Implementation:** Physical methods are relatively straightforward to implement and do not require specialized equipment or expertise in most cases. They can be performed using simple tools and techniques accessible to consumers and food handlers.
- ▶ **Cost-Effectiveness:** Many physical detoxification methods are cost-effective and do not incur additional expenses beyond regular food preparation practices. They can be integrated into existing food processing, handling, and cooking procedures without significant investment.

# Limitations of Physical detoxification

- ▶ **Limited Efficacy Against Certain Contaminants:** While physical methods are effective at removing surface contaminants and debris, they may have limitations in detoxifying certain types of toxins, such as mycotoxins, heavy metals, and chemical residues deeply embedded within food matrices.
- ▶ **Potential Loss of Water-Soluble Nutrients:** Washing, rinsing, and blanching, can lead to the loss of water-soluble vitamins and minerals from foods. Overly aggressive washing or prolonged exposure to heat can leach out nutrients, reducing the overall nutritional value of foods.
- ▶ **Selective Effectiveness:** Certain physical detoxification methods may be more effective for specific types of foods or contaminants. For example, washing and rinsing may be less effective at removing pesticide residues or microbial pathogens that have penetrated the skin or surface of fruits and vegetables.
- ▶ **Time and Labor Intensive:** Some physical detoxification methods, such as hand washing, trimming, or peeling, can be time-consuming and labor-intensive.
- ▶ **Potential Impact on Food Quality and Texture:** Blanching or high-temperature cooking, can affect the texture, flavor, and appearance of foods. Overcooking or excessive processing may result in undesirable changes in sensory attributes, reducing consumer acceptability.

# Chemical detoxification

- ▶ Chemical detoxification methods involve the use of chemical agents or treatments to remove or neutralize contaminants, toxins, or undesirable substances from foods.
- ▶ **Acidification:**
  - ▶ Acidification involves the addition of acidic compounds, such as vinegar, citric acid, or lactic acid, to foods to lower pH levels and create an acidic environment.
  - ▶ Acidification can inhibit the growth of spoilage microorganisms, pathogens, and foodborne bacteria, thereby improving food safety and extending shelf life.
- ▶ **Alkaline Treatment:**
  - ▶ Alkaline treatment involves the use of alkaline solutions, such as sodium hydroxide (lye) or calcium hydroxide (lime), to raise pH levels and alkalize foods.
  - ▶ Alkaline treatment can help neutralize acidic compounds, reduce bitterness, and enhance the texture of certain foods, such as olives, cocoa beans, and nixtamalized corn.
- ▶ **Oxidation:**
  - ▶ Oxidation involves the use of oxidizing agents, such as hydrogen peroxide, ozone, chlorine dioxide, or ozone, to chemically react with and oxidize contaminants, toxins, or undesirable compounds in foods.
  - ▶ Oxidation can destroy microbial pathogens, reduce odors, and remove colorants, pesticides, or pesticide residues from fruits, vegetables, and food surfaces.

# Chemical detoxification cont'd

- ▶ **Chelation:** Chelation involves the use of chelating agents, such as EDTA (ethylenediaminetetraacetic acid) or citric acid, to bind with and sequester metal ions, such as heavy metals or trace minerals, in foods.
  - ▶ Chelation can help prevent oxidation, stabilize food colors, and reduce the bioavailability of heavy metals, thereby reducing the risk of metal toxicity and contamination in foods.
- ▶ **Adsorption:** Adsorption involves the use of adsorbent materials, such as activated charcoal, bentonite clay, or silica gel, to adsorb and bind with toxins, contaminants, or undesirable substances in foods.
  - ▶ Adsorption can help remove pesticides, mycotoxins, allergens, and chemical residues from food matrices, improving food safety and quality.
- ▶ **Enzymatic Treatment:** Enzymatic treatment involves the use of enzymes, such as proteases, lipases, or amylases, to catalyze biochemical reactions that degrade or modify specific compounds in foods.
  - ▶ Enzymatic treatment can break down proteins, fats, carbohydrates, and antinutritional factors, enhancing the nutritional value and digestibility of foods.
- ▶ **Hydrolysis:** Hydrolysis involves the use of water or aqueous solutions to chemically break down complex molecules into simpler compounds through the addition of water molecules.
  - ▶ Hydrolysis can be used to detoxify certain toxins, such as cyanogenic glycosides or glucosinolates, present in raw foods, grains, or seeds.

# Benefits of Chemical detoxification

- ▶ **Benefits:**
- ▶ **Efficiency:** Chemical detoxification methods can be highly effective at removing or neutralizing a wide range of contaminants, including microbial pathogens, toxins, pesticides, and chemical residues, from foods.
- ▶ **Broad Applicability:** Chemical methods can be applied to various types of foods, including fruits, vegetables, grains, meats, seafood, and processed food products. They are versatile and adaptable to different food processing and preservation techniques.
- ▶ **Rapid Action:** Chemical agents often work quickly to detoxify foods, allowing for rapid processing and treatment of contaminated or adulterated food items. This can help prevent further contamination and reduce the risk of foodborne illness.
- ▶ **Precision:** Chemical treatments can target specific contaminants or toxins in foods, providing a tailored approach to detoxification. This precision allows for effective removal or reduction of harmful substances while minimizing damage to food quality or nutritional content.
- ▶ **Scalability:** Chemical detoxification methods can be scaled up for use in commercial food processing operations, large-scale food manufacturing facilities, and industrial food production settings. They offer scalability and efficiency in handling high volumes of food products.

# Limitations of Chemical detoxification

- ▶ **Safety Concerns:** Some chemical agents used for food detoxification, such as chlorine-based sanitizers, disinfectants, or fumigants, may pose health risks if not used properly. Residual chemical residues or byproducts in treated foods can also raise safety concerns for consumers.
- ▶ **Potential Residual Effects:** Chemical detoxification methods may leave behind residual chemical residues or byproducts in treated foods, which can affect taste, flavor, odor, and nutritional quality. Long-term exposure to low levels of chemical residues may raise health concerns.
- ▶ **Environmental Impact:** Chemical treatments used for food detoxification may have environmental implications, including contamination of water sources, soil degradation, and ecosystem disruption. Improper disposal of chemical waste or runoff can contribute to environmental pollution.
- ▶ **Regulatory Compliance:** Chemical food detoxification methods are subject to regulatory oversight and approval by government agencies, such as the Food and Drug Administration (FDA) or the European Food Safety Authority (EFSA). Compliance with regulatory standards and maximum residue limits is necessary to ensure consumer safety and regulatory compliance.
- ▶ **Potential for Adverse Effects:** Some chemical agents used for food detoxification may have adverse effects on food quality, sensory attributes, and nutritional value. Excessive or improper use of chemicals can lead to off-flavors, texture changes, nutrient loss, and other undesirable effects in treated foods.

# Biological detoxification

- ▶ Biological food detoxification methods involve the use of living organisms, such as microorganisms, enzymes, or natural processes, to remove or degrade contaminants, toxins, or undesirable substances from foods.
- ▶ These methods utilize the metabolic activities of biological agents to detoxify foods and improve their safety, quality, and suitability for consumption. Here are some common biological food detoxification methods:
- ▶ **Fermentation:**
  - ▶ Fermentation is a biological process that involves the metabolic activity of microorganisms, such as bacteria, yeast, or molds, to convert sugars and other organic compounds into alcohol, acids, gases, or other products.
  - ▶ Fermentation can detoxify foods by producing organic acids, alcohol, and antimicrobial compounds that inhibit the growth of spoilage microorganisms, pathogens, and foodborne bacteria.
  - ▶ Fermented foods, such as yogurt, cheese, sauerkraut, kimchi, tempeh, miso, and sourdough bread, undergo natural fermentation processes that enhance food safety, flavor, and shelf life.
- ▶ **Enzymatic Treatment:**
  - ▶ Enzymatic treatment involves the use of enzymes, which are biological catalysts, to catalyze biochemical reactions that degrade, modify, or transform specific compounds in foods.
  - ▶ Enzymes can break down complex molecules into simpler compounds, facilitating the detoxification of toxins, antinutritional factors, and undesirable substances in foods.
  - ▶ Examples of enzymatic treatments include enzymatic hydrolysis to break down proteins, lipids, or carbohydrates, as well as enzymatic degradation of mycotoxins, allergens, or phenolic compounds.



# Biological detoxification

## ▶ **Bioremediation:**

- ▶ Bioremediation is a biological process that uses microorganisms, such as bacteria, fungi, or algae, to degrade, metabolize, or transform environmental pollutants, contaminants, or toxins in foods and food production systems.
- ▶ Bioremediation can detoxify foods by breaking down hazardous compounds into harmless byproducts through microbial metabolism or enzymatic activity.
- ▶ Bioremediation techniques may involve the use of specific microbial strains or consortia, as well as optimized environmental conditions, to enhance the detoxification process.

## ▶ **Biological Control:**

- ▶ Biological control methods use natural enemies, such as predatory insects, parasitic nematodes, or microbial antagonists, to control pests, pathogens, or contaminants in agricultural crops and food processing facilities.
- ▶ Biological control agents can suppress the growth of harmful organisms, such as insects, fungi, or bacteria, that may contaminate or spoil foods, reducing the need for chemical pesticides or preservatives.
- ▶ Examples of biological control include the use of beneficial insects, such as ladybugs or parasitic wasps, to control pest populations in agricultural fields, as well as the use of biocontrol agents, such as bacteriophages or antagonistic bacteria, to inhibit the growth of foodborne pathogens in food processing environments.

## ▶ **Probiotic Treatment:**

- ▶ Probiotics are beneficial microorganisms, such as certain strains of bacteria or yeast, that confer health benefits when consumed in adequate amounts.
- ▶ Probiotic treatment involves the addition of probiotic cultures to foods to improve their safety, quality, and nutritional value.
- ▶ Probiotics can detoxify foods by competing with pathogenic microorganisms, modulating the gut microbiota, and enhancing immune function, thereby reducing the risk of foodborne illness and promoting overall health.

# Benefits of Biological detoxification

- ▶ **Benefits:**
- ▶ **Natural and Environmentally Friendly:** Biological detoxification methods rely on natural processes and living organisms, making them environmentally friendly alternatives to chemical treatments. They minimize the use of synthetic chemicals and reduce the environmental impact of food processing.
- ▶ **Selective Action:** Biological agents, such as microorganisms and enzymes, can target specific contaminants or toxins in foods, providing a tailored approach to detoxification. They can selectively degrade or metabolize harmful substances while preserving food quality and nutritional value.
- ▶ **Versatility and Adaptability:** Biological methods can be applied to a wide range of foods and contaminants. They are versatile and adaptable to different food matrices, processing conditions, and environmental settings, allowing for flexible implementation in diverse food production systems.
- ▶ **Potential for Self-Regeneration:** Some biological agents have the ability to self-regenerate or reproduce, allowing for continuous detoxification over time. Microbial cultures and enzyme systems can be replenished or maintained to sustain detoxification activity in food processing operations.
- ▶ **Enhanced Nutritional Value:** Biological detoxification methods can enhance the nutritional value and digestibility of foods by breaking down antinutritional factors, improving nutrient bioavailability, and promoting beneficial metabolic activities in foods.

# Limitations of Biological detoxification

- ▶ **Variable Efficacy:** The efficacy of biological detoxification methods can vary depending on factors such as microbial strains, enzymatic activities, environmental conditions, and food composition. Some methods may be less effective against certain contaminants or toxins.
- ▶ **Processing Time:** Biological detoxification methods may require longer processing times compared to chemical or physical treatments. Microbial growth, enzymatic reactions, and metabolic processes may take time to achieve desired detoxification outcomes, leading to delays in food processing and production.
- ▶ **Safety Concerns:** Biological agents used for food detoxification, such as microbial cultures or enzyme preparations, may pose safety concerns if not properly controlled or monitored. The presence of pathogenic microorganisms or allergenic proteins in biological agents can pose risks to consumer health.
- ▶ **Regulatory Compliance:** Biological detoxification methods are subject to regulatory oversight and approval by government agencies. Compliance with regulatory standards, quality control measures, and safety regulations is necessary to ensure consumer safety and regulatory compliance.
- ▶ **Potential for Unintended Effects:** Biological agents may have unintended effects on food quality, sensory attributes, and shelf life. Changes in flavor, texture, odor, or appearance may occur as a result of microbial activity or enzymatic reactions, impacting consumer acceptability.

# Toxicological indices used in assessing toxicity

- ▶ Toxicological indices are quantitative measures used in assessing the toxicity of chemical substances
- ▶ **LD50 (Lethal Dose 50):**
  - ▶ LD50 is a measure of acute toxicity that represents the dose of a substance required to cause death in 50% of the test population (usually laboratory animals) within a specified time period, typically 24 to 72 hours.
  - ▶ LD50 values are expressed in terms of milligrams of substance per kilogram of body weight (mg/kg). Lower LD50 values indicate higher toxicity, while higher LD50 values indicate lower toxicity.
- ▶ **NOAEL (No Observed Adverse Effect Level):**
  - ▶ NOAEL is the highest dose of a substance tested in a toxicological study at which no adverse effects are observed in the test animals under specified experimental conditions.
  - ▶ NOAEL serves as a reference point for determining safe exposure levels in risk assessment and regulatory decision-making. It is used to establish acceptable daily intake (ADI) values for human exposure.

# Toxicological indices used in assessing toxicity

- ▶ **LOAEL (Lowest Observed Adverse Effect Level):**

- ▶ LOAEL is the lowest dose of a substance tested in a toxicological study at which adverse effects are observed in the test animals under specified experimental conditions.
- ▶ LOAEL provides information on the lowest dose at which toxic effects occur and is used to establish safety factors and uncertainty factors for risk assessment.

- ▶ **ADI (Acceptable Daily Intake):**

- ▶ ADI is an estimate of the amount of a substance in food or drinking water that can be ingested daily over a lifetime without appreciable health risk to humans.
- ▶ ADI values are derived from NOAEL or LOAEL data and incorporate safety factors to account for uncertainties in toxicological data and individual variability in human susceptibility.

- ▶ **Tolerable Daily Intake (TDI):**

- ▶ TDI is similar to ADI and represents the maximum amount of a substance that can be ingested daily over a lifetime without exceeding a specified level of risk to human health.
- ▶ TDI values are used in risk assessment for chemicals, contaminants, and food additives to establish regulatory limits and safety standards.

# Toxicological indices used in assessing toxicity

## ▶ **MRL (Maximum Residue Limit):**

- ▶ MRL is the maximum allowable concentration of a pesticide residue or veterinary drug residue in food commodities, typically expressed in parts per million (ppm) or milligrams per kilogram (mg/kg).
- ▶ MRL values are established based on toxicological data, residue levels, and dietary exposure assessments to ensure consumer safety and compliance with food safety regulations.

## ▶ **Margin of Safety (MoS):**

- ▶ MoS is a ratio that compares the estimated exposure of a substance to its toxicological threshold (e.g., NOAEL or ADI). It represents the degree of safety or cushion between the actual exposure level and the level associated with adverse effects.
- ▶ A larger MoS indicates a greater margin of safety and lower risk of adverse effects, while a smaller MoS suggests a higher risk of toxicity and potential health concerns.

# Considerations for determining safe exposure levels

- ▶ Determining safe exposure levels of food toxicants involves a thorough evaluation of toxicological data, exposure pathways, population characteristics, and risk factors specific to foodborne contaminants.
- ▶ Several considerations are essential in this process to establish safe exposure levels and ensure the protection of human health. Here are key considerations:
- ▶ **Toxicological Data:**
  - ▶ Assessment of available toxicological data from animal studies, human studies, and mechanistic studies to understand the toxicity profile, dose-response relationship, and adverse effects associated with the food toxicant.
  - ▶ Selection of appropriate toxicological endpoints, such as NOAEL (No Observed Adverse Effect Level) or LOAEL (Lowest Observed Adverse Effect Level), based on the severity, duration, and reversibility of toxic effects observed in relevant studies.
- ▶ **Exposure Assessment:**
  - ▶ Identification of exposure pathways and routes of exposure to the food toxicant, including dietary intake, inhalation, dermal contact, and environmental exposure.
  - ▶ Estimation of dietary exposure levels across different population groups, considering variations in consumption patterns, dietary habits, and food preferences.

# Considerations for determining safe exposure levels

## ▶ **Food Processing and Preparation:**

- ▶ Consideration of food processing, cooking methods, and culinary practices that may affect the concentration, bioavailability, and toxicity of the food toxicant in processed foods.
- ▶ Evaluation of cooking temperatures, processing techniques, and food additives that may influence the formation, degradation, or transformation of toxicants during food preparation and storage.

## ▶ **Sensitive Populations:**

- ▶ Identification of vulnerable populations, including infants, children, pregnant women, elderly individuals, and individuals with pre-existing health conditions, who may be more susceptible to the adverse effects of food toxicants.
- ▶ Incorporation of safety factors or uncertainty factors to account for potential differences in sensitivity, metabolism, and susceptibility among various population groups.

## ▶ **Exposure Scenarios:**

- ▶ Assessment of exposure scenarios under different dietary patterns, consumption habits, and lifestyle factors to capture realistic exposure scenarios and potential sources of exposure to the food toxicant.
- ▶ Evaluation of acute exposure, short-term exposure, long-term exposure, and chronic exposure scenarios to assess cumulative risks and establish appropriate exposure limits.



# Considerations for determining safe exposure levels

## ▶ **Regulatory Standards:**

- ▶ Compliance with regulatory standards, guidelines, and maximum residue limits (MRLs) established by government agencies, international organizations, and scientific authorities to ensure safety and regulatory compliance.
- ▶ Adherence to regulatory frameworks such as acceptable daily intake (ADI), reference dose (RfD), tolerable daily intake (TDI), and maximum permissible levels (MPLs) for specific food toxicants.

# Hepatological examinations in toxicology

- ▶ Hepatological examinations in toxicology focus on assessing liver function and detecting liver damage caused by exposure to toxic substances.
- ▶ **Liver Toxicity Assessment:** The liver is the primary organ responsible for detoxification. Toxic substances, whether ingested, inhaled, or absorbed, often undergo metabolic processes in the liver.

Hepatological examinations help assess the impact of toxic substances on liver function and structure. This includes evaluating liver enzyme levels, bilirubin, and other markers of liver damage.

# Indicators of liver damage and dysfunction

- ▶ **Elevated Liver Enzymes:** Liver enzymes such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), and gamma-glutamyl transferase (GGT) are released into the bloodstream when liver cells are damaged. Elevated levels of these enzymes in blood tests indicate liver injury or dysfunction.
- ▶ **Abnormal Bilirubin Levels:** Bilirubin is a yellow pigment produced from the breakdown of red blood cells. Elevated levels of bilirubin in the blood, especially direct (conjugated) bilirubin, can indicate impaired liver function or obstruction of bile flow from the liver (cholestasis).
- ▶ **Changes in Albumin and Total Protein Levels:** Albumin and total protein are synthesized by the liver. Decreased levels of these proteins in blood tests may indicate liver dysfunction, as the liver's ability to produce proteins is compromised.
- ▶ **Prothrombin Time (PT) and International Normalized Ratio (INR):** The liver produces clotting factors necessary for blood clotting. An increase in PT and INR indicates impaired liver function and decreased production of clotting factors, which can lead to a tendency for bleeding.

# Indicators of liver damage and dysfunction

- ▶ **Changes in Serum Ammonia Levels:** Ammonia is normally processed and detoxified by the liver. Elevated levels of ammonia in the blood (hyperammonemia) suggest liver dysfunction, as the liver may not be effectively clearing ammonia from the bloodstream.
- ▶ **Liver Imaging Abnormalities:** Imaging studies such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) can reveal structural abnormalities in the liver, including enlargement, fatty infiltration, tumors, or signs of cirrhosis.
- ▶ **Symptoms:** Symptoms of liver damage and dysfunction may include jaundice (yellowing of the skin and eyes), fatigue, abdominal pain or swelling, nausea, vomiting, loss of appetite, dark urine, and pale stools.
- ▶ **Physical examination** may reveal an enlarged liver (hepatomegaly) or spleen (splenomegaly), abdominal tenderness, or signs of chronic liver disease such as spider angiomas or palmar erythema.
- ▶ **Liver Biopsy Findings:** Histological examination of liver tissue can reveal inflammation, fibrosis, fatty infiltration, cirrhosis, or signs of specific liver diseases.

# Role of blood examinations in toxicology

## ▶ **Blood Examinations:**

- ▶ **Detection of Toxic Substances:** Blood tests can detect the presence of toxic substances or their metabolites circulating in the bloodstream. This includes drugs, chemicals, heavy metals, and other toxins.
- ▶ **Quantification of Substances:** Blood tests can quantify the concentration of toxic substances, helping determine the degree of exposure and potential toxicity.
- ▶ **Assessment of Organ Function:** Blood tests, such as liver function tests (LFTs) and kidney function tests, provide information about the function of vital organs involved in the metabolism and elimination of toxicants.
- ▶ **Identification of Biomarkers:** Changes in blood biomarkers, such as liver enzymes, bilirubin, electrolytes, and blood gases, can indicate organ damage or dysfunction caused by toxic exposure.

# Role of urine examinations in toxicology

## ▶ **Urine Examinations:**

- ▶ **Metabolite Analysis:** Urine tests can identify and quantify metabolites of toxic substances excreted by the body. This helps assess the metabolism and elimination of toxicants and can provide insight into the extent of exposure.
- ▶ **Drug Screening:** Urine drug tests are commonly used to screen for the presence of drugs or their metabolites, including both prescribed medications and illicit substances.
- ▶ **Assessment of Kidney Function:** Urine tests, such as urinalysis and measurement of urinary protein or creatinine levels, help evaluate kidney function and detect nephrotoxic effects of certain toxicants.

# Role of fecal examinations in toxicology

## ▶ Fecal Examinations:

- ▶ **Excretion of Toxicants:** Fecal examinations can identify toxic substances or their metabolites excreted in the feces. Some toxicants may undergo enterohepatic circulation, where they are excreted via the bile into the intestines and then reabsorbed or eliminated in the feces.
- ▶ **Assessment of Gastrointestinal Function:** Fecal tests, such as fecal occult blood tests, can detect gastrointestinal bleeding, which may occur as a result of toxic exposure or damage to the gastrointestinal tract.
- ▶ **Microbiome Analysis:** Fecal microbiome analysis can provide insights into the impact of toxicants on the gut microbiota and gut health, which can influence the metabolism and toxicity of certain substances.