FACTFILE:

GCE NUTRITION & FOOD SCIENCE

CHEMICAL CONTAMINATION

Rewarding Learning

Chemical contamination

Learning outcome

- Describe the possible risks to public health of each of the following chemical contaminants:
  - acrylamide;
  - arsenic in rice;
  - Bisphenol-A (BPA);
  - dioxins; and
  - heavy metals, for example mercury, lead and cadmium.

Acrylamide

Acrylamide

Acrylamide is a chemical produced naturally in food as a result of cooking starch rich food at high temperatures, such as when baking or frying. It is also likely to be produced by grilling and roasting food.

Acrylamide forms particularly in plant-based carbohydrate-rich foods during high temperature cooking (usually above 120 °C) as a consequence of the Maillard reaction. The Maillard reaction is a reaction between a reducing sugar (such as glucose, fructose or lactose) and an amino acid (the building block of protein) that results in the browning and characteristic flavours of certain foods cooked at high temperatures. Besides these sensory changes the Maillard reaction can also result in the formation of undesirable substances, such as acrylamide. Additionally the ingredient's storage and processing conditions also greatly influence acrylamide formation in food.

Fried potato products, coffee, biscuits, crackers and breads are the main dietary sources of acrylamide.

Possible risks to public health

The European Food Safety Authority (EFSA) released its scientific opinion on acrylamide in food as far back as 2015. The conclusion was that, based on evidence from animal studies, dietary exposure to acrylamide potentially increases the risk of developing cancer for consumers in all age groups.

The panel undertook a rigorous review of available scientific research on acrylamide and glycidamide (one of its breakdown products in the body) provided by animal and human studies. These included original study reports, previous evaluations and information submitted following public calls for data. Although results from human studies provide limited and inconsistent evidence, EFSA concluded that, based on animal studies,

acrylamide and glycidamide are genotoxic (i.e. can damage DNA, our genetic material) and carcinogenic (can cause cancer). Since acrylamide is present in a wide range of everyday foods, this concern applies to all age groups but children may experience more exposure to acrylamide relative to their lower body weights.

EFSA also considered other effects of acrylamide on the nervous system, pre- and post-natal development and male reproduction. These effects were not considered to be a concern at current levels of dietary exposure.

Although acrylamide has caused nerve damage in people who have been exposed to very high levels as a result of occupational and accidental exposure through industrial use, it is less clear what the risks are from the acrylamide found in food. Acrylamide is considered to be a genotoxic carcinogen because it has the potential to cause cancer by interacting with cell DNA. Based on independent expert scientific advice, the Food Standards Agency believes that exposure to such chemicals should be as low as reasonably practicable (ALARP).

Given the uncertainties in exposure and the possible exposure to sources other than food, scientists have concluded that it is not possible to draw any definitive conclusions about the cancer risks of acrylamide in food.

Arsenic in rice

According to the Food and Agricultural Organisation (FAO), arsenic is a naturally occurring element in the earth's crust. It is present in many foods due to absorption from the soil and water. Rice in particular can take up more arsenic than other foods and due to its high consumption can contribute significantly to arsenic exposure.

The FAO have also stated that long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. It has also been associated with developmental effects, heart disease, diabetes, and damage to the nervous system and brain. To protect consumers from excessive exposure the Codex Alimentarius Commission recommends that the level of arsenic in rice should not exceed 0.2 mg/kg.

According to the World Health Organisation (WHO), arsenic occurs in inorganic and organic forms. Inorganic arsenic compounds, such as those found in water, are highly toxic while organic arsenic compounds, such as those found in seafood, are less harmful to health.

Acute effects

The immediate symptoms of acute arsenic poisoning include vomiting, abdominal pain and diarrhoea. These are followed by numbness and tingling of the extremities, muscle cramping and, in extreme cases, death.

Long-term effects

The first symptoms of long-term exposure to high levels of inorganic arsenic (e.g. through drinking-water and food) are usually observed in the skin, and include pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis). These occur after a minimum exposure of approximately five years and may be a precursor to skin cancer.

In addition to skin cancer, long-term exposure to arsenic may also cause cancers of the bladder and lungs. The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans, and has also stated that arsenic in drinking water is carcinogenic to humans.

Other adverse health effects that may be associated with long-term ingestion of inorganic arsenic include developmental effects, neurotoxicity, diabetes and cardiovascular disease. In China (Province of Taiwan), arsenic exposure has been linked to 'blackfoot disease', which is a severe disease of blood vessels leading to gangrene. However, this disease has not been observed in other parts of the world, and it is possible that malnutrition contributes to its development.

Bisphenol-A

Bisphenol A (BPA) is a synthetic chemical used in polycarbonate plastic food and drink packaging and in epoxy resins that line some metal cans of food and drink. The concern is that BPA is able to migrate and it can leach into food and drink from packaging. Exposure to ultra-violet light, high temperatures or to acidic conditions will increase leaching. However, the level of BPA found in food is not considered to be harmful.

Possible risks to public health

Independent experts have worked out how much BPA we can consume every day over a lifetime without coming to any harm, and the amount people actually absorb from all food and drink is significantly below this level.

Independent studies have shown that, even when consumed at high levels, BPA is rapidly absorbed, detoxified and eliminated from humans and, therefore, is not a health concern.

BPA belongs to a group of substances which have hormone-like (e.g. estrogenic) effects. In principle, such substances can have effects on any hormone dependent process and therefore have been associated with health effects such as cancer and developmental defects. However, current research indicates that BPA does not accumulate in the body and the small amounts from daily exposure are rapidly excreted from humans and are not a health concern.

Extensive assessments have been carried out on BPA and the current conclusion is that dietary exposure to BPA is not a health concern for any age group. The Food Standards Agency agree that BPA currently poses no risk to health and is safe for use in production of plastics.

Dioxins

Dioxins are members of a group of chemical compounds that are described as persistent organic compounds (POP). Some POP are highly toxic and carcinogenic, although their toxicity varies greatly. Given their toxicity, levels of dioxins in feed and food are regulated in the UK, Europe, USA and other countries and are well controlled and monitored. As a result concentrations in the food we eat are decreasing.

Possible risks to public health

For most people 90 percent of human dioxin exposure comes from food. Dioxins deposited in land and in waterways, in the form of contaminated soil and/or contaminated animal feed are ingested by a variety of animals used as human food. They accumulate in the fat tissues of animals and some organs. Proteins in the liver, for example, can bind dioxins. Dioxins are found in low levels in all foods, especially oily or fatty food of animal origin such as meat, fish, poultry, cheese, milk, butter, free range eggs and oily fish.

Dioxins in the food chain are of concern because of a number of adverse health effects that can occur at very low levels of exposure. Acute exposure at relatively high levels can result in chloracne (a skin condition) but of greater concern are the chronic effects of low level exposure (typically through the diet) which can cause reproductive, carcinogenic and developmental effects.

Heavy Metals

Cadium

Cadmium (Cd) is a heavy metal found as an environmental contaminant, both through natural occurrence and from industrial and agricultural sources. Foods such as cereals and cereal products, vegetables, nuts and pulses, starchy roots or potatoes meat and meat products, are the main source of cadmium exposure for the non-smoking general population.

Possible risks to public health

The levels of cadmium exposure through food that are consumed by most people are not of major health concern. Cadmium absorption after dietary exposure in humans is relatively low (3–5%) but cadmium is efficiently retained in the kidney and liver in the human body frequently resulting in kidney damage.

Cadmium is a cumulative poison, i.e. the danger lies primarily in the regular consumption of foodstuffs with low contamination.

Cadmium is primarily toxic to the kidneys, especially to the proximal tubular cells where it accumulates over time and may cause renal dysfunction. Cadmium can also cause bone demineralisation, either through direct bone damage or indirectly as a result of renal dysfunction. After prolonged and/or high exposure the tubular damage may progress to decreased glomerular filtration rate, and eventually to renal failure.

The International Agency for Research on Cancer has classified cadmium as a human carcinogen (group 1) on the basis of occupational studies. Newer data on human exposure to cadmium in the general population have been statistically associated with increased risk of cancer such as in the lung, endometrium, bladder, and breast.

Lead

Lead is a naturally occurring toxic metal found in the earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems in many parts of the world.

Important sources of environmental contamination include mining, smelting, manufacturing and recycling activities, and in some countries the continued use of leaded paint and leaded petrol. More than three quarters of global lead consumption is for the manufacture of lead-acid batteries for motor vehicles. Lead is, however, also used in many other products, for example pigments, paints, solder, stained glass, crystal vessels, ammunition, ceramic glazes, jewellery, toys and in some cosmetics and traditional medicines. Drinking water delivered through lead pipes or pipes joined with lead solder may contain lead. Much of the lead in global commerce is now obtained from recycling.

Possible risks to public health

The use of lead in paint, petrol, food cans and water pipes has been phased out and the use of lead in many other industries is on the decline.

Exposure to inorganic lead occurs primarily through food and drinking water. In the UK lead levels are under stringent control and exposures to lead in food and water are reduced to the lowest practical level to minimise possible risks to health.

In March 2010 an EFSA opinion on lead in food identified it can cause developmental neurotoxicity in young children and cardiovascular issues in adults. The authority expressed a concern that the levels of dietary exposure to lead might affect neurodevelopment in foetuses, infants and children.

Findings were supported by a report from the Joint FAO/WHO Expert Committee on Food Additives and Contaminants in the same year. The Codex Alimentarius Commission then lowered the maximum level for lead in several products including certain foods for infants and young children. To help fight fraud, such as the addition of lead chromate to turmeric, maximum levels for spices were also established.

Cereals products and grains, vegetables such as potatoes and leafy vegetables and tap water are the most important contributors to lead dietary exposure in the UK and Europe.

Mercury

Mercury is a volatile, metallic element occurring naturally in the environment as elemental mercury, inorganic mercury or methylmercury compounds. Historically, mercury has had many uses. In recent

years many of these uses have been phased out, banned or restricted in favour of safer alternatives. Methylmercury is the most toxic and bioavailable mercury compound. It is formed by microorganisms in soil, sediment and water converting elemental mercury into methylmercury. Low levels of mercury in surface waters can lead to high concentrations in insects, fish and birds. This results in very toxic contamination in parts of the ecosystem, especially in higher levels in the food chain.

Human exposure to methylmercury is almost exclusively through consumption of contaminated fish and shellfish. Fish absorb methylmercury from their food and from water as it passes over their gills. Mercury is tightly bound to proteins in all fish tissue, including muscle.

Seawater contains only small concentrations of mercury. However, sea plants such as algae absorb it. Fish then eat the alga absorbing and retaining its mercury. Larger predatory fish then accumulate higher levels from eating smaller fish. Larger predatory fish may contain mercury concentrations up to ten times higher than the fish they consume. Mercury levels in fish are regulated and monitored in the UK. Levels in fish are well below the food regulatory limit for mercury in fish and fisheries products and do not represent a risk to the consumer providing advice from the Food Standards Agency is followed.

Possible risks to public health

Mercury is highly toxic to humans. Exposure, even to small amounts, may have toxic effects on the nervous, digestive and immune systems, and on the lungs, kidneys, skin and eyes. Methylmercury is particularly damaging to developing embryos, which are five to ten times more sensitive than adults.

Some studies link exposure to heavy metals such as mercury to conditions like Alzheimer's, Parkinson's, autism, depression and anxiety. However, further research is needed to confirm this link. Mercury exposure is linked to high blood pressure, an increased risk of heart attacks and higher LDL cholesterol.

Revision Questions

1. Briefly explain how dioxins, mercury and lead can contaminate food.

2. Describe the possible risks to human health of each of the following chemical contaminants:
   - acrylamide
   - arsenic in rice

Further Activity

To help form a balanced view it is important to consider what is being done to minimise the health risks for consumers. Ask the questions:

- What regulations are in place for the safe use of these chemicals in food?
- Have safe levels or limits been established?
- How are the regulations and safe levels monitored and controlled?
- What guidance is available for the food industry on the use of these chemicals?
- How can consumers minimise their risk of contamination from these chemicals?
- What is the role of the Food Standards Agency in ensuring the safe use of these chemicals?
- What does the most recent research tell us about the potential risks to public health in relation to these chemicals?
- How do the health risks from these chemicals compare with other dietary risks to health such as effect of alcohol, smoking, high fat diet, low activity levels?