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From Farm to Table: Understanding Food Safety Risks

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Introduction

A recent scare involving excessive pesticide levels in imported Shine Muscat grapes has heightened food safety concerns among Malaysian consumers. These grapes, popular among Malaysians for their glossy appearance, sweetness, and crisp texture, quickly captured public attention and raised awareness about potential food safety risks in everyday foods. Although Malaysia's Ministry of Health confirmed that the pesticide levels in the tested grape samples were within the Maximum Residue Level (MRL)[1,2], the incident still highlighted the vulnerabilities present in the food supply chain.

Food safety is defined as the "assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use[3]". It is closely linked to food security, as access to safe, nutritious food is a foundational component of food security itself. Compromised food safety may lead to the spread of foodborne diseases caused by many

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[1] MRL refers to the highest level of a pesticide residue legally permitted in food products.
[2] The Star (2024)
[3] Codex Alimentarius FAO-WHO (1969)

factors, including bacteria, viruses, parasites, and chemicals[4], with risks present at every stage of the food production and supply chain—spanning farming, transportation, processing, and retail. Imported foods, like the Muscat grapes, add complexity to managing food safety due to varying standards and regulations across countries.

Food safety risks can emerge in foods we consume daily, such as eggs, milk, undercooked poultry and seafood, as well as raw fruits and vegetables. As contamination can occur at any point in food production and across diverse food types, it is essential for consumers to be mindful of what they eat and aware of potential vulnerabilities in the food supply chain. This paper aims to provide a brief overview of food safety risks in everyday foods, covering various food sources including crops, land-based animal foods, and seafood. Additionally, it explores how climate change could potentially exacerbate these risks over time and highlights existing measures to mitigate food safety issues within the supply chain.

Potential Food Safety Concerns Across Different Food Sources

Understanding the potential food safety risks associated with various food sources is essential for safeguarding public health. Each type of food source presents unique hazards, as outlined in this section on crops, land-based animal products, and seafood. While this overview covers many significant concerns, it may not be exhaustive, as contamination sources and risks can vary widely based on agricultural practices, environmental conditions, and food handling protocols.

Crops

Crops are exposed to many types of contaminants, including biological, chemical, and physical hazards. Contamination sources are abundant, occurring at both pre-harvest and post-harvest stages. Pre-harvest contamination can arise from the soil, water, contaminated seeds, pesticides, fertilizers, faecal matter, and air. On the other hand, post-harvest contamination may result from equipment, human handling, air, water, storage, sorting, cutting, peeling, packaging, and transfer[5].

Biological hazards include bacteria, viruses, fungi, parasites, and related toxins[6], which can pose risks to human health and lead to major losses throughout the supply chain. Fruits and vegetables, especially when pre-cut, can serve as a vehicle for pathogenic bacterial growth, with *Salmonella* and *Escherichia coli* being the most common threats. Additionally, fungi such as *Penicillium*, *Aspergillus*, *Alternaria*, *Botrytis*, and *Rhizopus* can also contaminate crops. Another significant biological hazard is mycotoxins, toxic compounds produced by moulds and fungi. These mycotoxins contribute to food loss and decreased export value, and possess harmful properties

[4] WHO (2024b)
[5] Ölmez (2016)
[6] Diep Trinh, Trinh, and Lee (2024)

such as immunotoxicity[7], carcinogenicity[8], neurotoxicity[9], and developmental and reproductive toxicity, among others[10].

Chemical contamination in crops may originate from various sources, including fertilisers, pesticides, herbicides, and heavy metals. Fertilisers, while essential for crop growth, can contribute to chemical residues that remain on the surface of crops or infiltrate plant tissues, posing risks to human health upon consumption. Pesticide residues can also persist, and incidents of contamination, such as the scare surrounding Shine Muscat grapes, have raised concerns about food safety and quality. Additionally, heavy metals such as cadmium, lead, and arsenic can accumulate in soil and water, subsequently entering the food chain through crop uptake[11].

Physical hazards in crops often stem from foreign objects and materials that may inadvertently enter the food supply chain. These can include fragments of glass, plastic, metal, or wood that may be introduced during various stages of production, processing, and packaging. The presence of such contaminants can lead to choking hazards, cuts, or other injuries[12]. Additionally, improper handling techniques during harvest and transport can exacerbate the risk of physical contamination.

Land-Based Animal Foods

Land-based animal foods, including meat, eggs, and dairy products, also present unique biological, chemical, and physical hazards. Similar to crops, biological hazards in these foods include bacterial pathogens such as *Salmonella*, *Listeria*, and *Escherichia coli*, which can lead to foodborne illnesses in humans. Furthermore, animal products can also harbour parasites and viruses. For example, parasites like *Toxoplasma gondii* and *Trichinella spiralis* can be transmitted through undercooked meat, resulting in illnesses that may cause digestive issues or more severe health issues[13]. Additionally, viruses such as hepatitis E and avian influenza may be present in these products, leading to infections in humans if proper food handling and cooking practices are not observed[14].

Chemical contamination in animal-based foods often involves residues of veterinary drugs. Drug residues in animal-derived products such as milk and dairy can lead to adverse effects, including allergic reactions, toxicities in organs and tissues, hormonal imbalances, and even teratogenic

[7] Any negative impact on the immune system, such as an allergic reaction or inflammation, caused by exposure to harmful substances.
[8] Chemical's ability or tendency to cause tumours—whether benign or malignant—to develop, increase in malignancy, or appear more rapidly.
[9] The ability of chemical, biological, or physical agents to induce harmful functional or structural changes in the nervous system.
[10] Alina Marc (2022)
[11] Rashid et al. (2023)
[12] Schweihofer (2024)
[13] Marín-García, Planas, and Llobat (2022)
[14] Meng (2010); WHO (2024a)

effects[15]. Common drugs found in these foods include residues of antimicrobials (e.g. antibiotics), hormones, and anthelmintics[16,17].

A major concern related to veterinary drug residues in animal products is the development of antimicrobial resistance (AMR). In animal agriculture, antibiotics are used both therapeutically—to treat and control disease—and non-therapeutically—to improve feed efficiency and prevent infection[18]. However, these practices can leave antimicrobial residues in food products. The repeated consumption of these residues contributes to the development of resistant bacterial strains, reducing the effectiveness of antibiotics for treating infections in humans. This has led to an increased presence of antimicrobial-resistant pathogens within the food supply and the environment. Additionally, residues of antimicrobial agents in animal-derived foods can lead to negative outcomes, such as allergic reactions and disruptions in normal functioning of human gut[19].

Physical hazards in land-based animal foods typically result from foreign materials like bone fragments, which can coincidentally enter food products during slaughter, processing, or packaging. These physical contaminants present risks such as choking or internal injury, further highlighting the need for careful handling and inspection throughout the food production process.

Seafood

Seafood is likewise exposed to biological, chemical, and physical hazards, which vary considerably depending on the environment in which the seafood is sourced. Biological hazards in seafood often stem from marine biotoxins. Marine biotoxins are compounds produced by phytoplankton and are associated with harmful algal blooms (HABs)[20,21]. Ingesting seafood contaminated with these biotoxins can lead to illness and, in severe cases, be fatal to both humans and aquatic organisms, causing various types of poisoning syndromes, such as shellfish and fish poisoning[22]. In Malaysia, incidents of marine biotoxin poisoning have occurred, including a case of paralytic shellfish poisoning (PSP) in Kota Kinabalu, Sabah, in 2013, which led to 58 reported cases and four deaths[23].

Chemical contamination in seafood primarily involves heavy metals such as mercury, lead, and cadmium, which are toxic, persistent, and bioaccumulative[24]. Unable to degrade, these metals are deposited in water and sediment, where they are absorbed by aquatic animals and enter the

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[15] Harmful impacts on a developing embryo or foetus caused by exposure to certain substances, leading to birth defects or abnormalities.
[16] Anthelmintics, also known as parasiticides, endectocides, or nematocides, are drugs used to treat infections caused by parasitic worms.
[17] Baydan et al. (2017)
[18] McDermott et al. (2002)
[19] WHO Regional Office for Europe (2020)
[20] Harmful algal blooms (HABs) happen when algae — simple, photosynthetic organisms found in both seawater and freshwater — multiply excessively, producing toxins that negatively impact people, fish, shellfish, marine mammals, and birds.
[21] Estevez et al. (2019)
[22] Nicolas et al. (2017)
[23] Suleiman et al. (2017)
[24] Kuplulu et al. (2018)

human food chain through seafood consumption. While severe heavy metal poisoning is uncommon, these contaminants remain a public health concern due to the serious health effects that can result from long-term exposure. Lead and mercury, for example, can impair nervous system development, particularly in children, infants, and foetuses through maternal ingestion, while cadmium exposure is associated with kidney damage and potential carcinogenic effects[25].

Physical contamination in seafood has recently become a major concern due to microplastics[26]. They can originate from various sources, including industrial waste, personal hygiene and cosmetic products (such as microbeads), or the breakdown of larger plastic items exposed to UV light and physical abrasion[27]. The amount of microplastics in aquatic environments has been rising annually, driven by increasing plastic consumption and inadequate waste management. These microplastics are ingested by aquatic species, which are then consumed by humans. It is estimated that around 57% of plastic particles in foods come from aquatic sources, making seafood a primary pathway for microplastic exposure in humans[28].

How Climate Change Exacerbates Existing Food Safety Issues

The impact of climate change on food safety has been studied quite extensively[29]. Shifts in temperature, altered precipitation patterns, frequent extreme weather events, ocean warming, and rising sea levels collectively create conditions that intensify existing food safety challenges[30].

As global temperatures rise, so does the incidence of foodborne pathogens like bacteria, viruses, parasites, and fungi, which thrive in warmer environments. This has led to a broader geographic spread and increased persistence of pathogens such as *Salmonella* and *Campylobacter*, both of which are now linked to higher infection rates in warmer regions worldwide[31]. Furthermore, extreme weather conditions, such as hurricanes, floods, and droughts, disrupt ecosystems and water supplies, facilitating the transmission of foodborne and waterborne diseases by altering the stability and distribution of contaminants[32].

Ocean warming further compounds these risks. Rising sea temperatures enhance the methylation of mercury[33], which subsequently bioaccumulates in marine organisms. For every degree Celsius increase in ocean temperature, mercury methylation rates in fish and marine mammals may rise by 3–5%, leading to elevated levels of methylmercury in seafood and increasing dietary exposure for humans[34].

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[25] Kuplulu et al. (2018)
[26] Microplastics are plastic particles that are smaller than 5mm.
[27] Hantoro et al. (2019)
[28] Zhao and You (2024)
[29] FAO (2008); Duchenne-Moutien and Neetoo (2021)
[30] Tirado et al. (2010)
[31] FAO (2020)
[32] FAO (2008)
[33] Methylation of mercury is a process in which microorganisms convert inorganic mercury, commonly found in the environment, into methylmercury—an organic form that is more toxic and readily absorbed by living organisms.
[34] FAO (2008)

Sea-level rise, another consequence of climate change, contributes to the salinisation of freshwater resources, especially in coastal areas. Saltwater intrusion reduces freshwater availability and affects agriculture by raising salt levels in irrigation water, which can degrade soil quality and reduce crop yields[35]. Additionally, climate change-driven fluctuations in flood and drought cycles contribute to soil contamination.

Shifting climate conditions also foster the growth of toxigenic fungi, which produce harmful mycotoxins that can contaminate crops. Fungi generally thrive within specific temperature and moisture ranges. As climate change broadens these suitable zones, fungal outbreaks have become more common in regions previously unaffected[36]. After heavy rains or flooding, fungi grow even more vigorously in moist conditions, increasing the potential for mycotoxin contamination. Plants under stress—whether from drought, pest attacks, or nutrient deficiencies—are particularly vulnerable to fungal infection, heightening the risk of contamination[37].

Existing Food Safety Measures in Place

While numerous food safety challenges exist, Malaysia has a relatively robust system in place to safeguard public health. The foundation of this system is the Food Act of 1983, supported by the Food Regulations 1985, the Food Hygiene Regulations 2009, and the Food (Issuance of Health Certificate for Export of Fish and Fish Products to EU Regulations) 2009. Together, these laws provide a comprehensive legal framework that covers various aspects of food safety, including production, processing, handling, labelling, and export standards, ensuring that food reaching consumers is monitored for quality and safety.

Malaysia has also developed specific standards to ensure safety across the different stages of the food supply chain. Malaysia Good Agricultural Practices (MyGAP), for instance, applies to the agricultural sector, covering crops, livestock, and aquaculture to ensure safe practices at the production level. For the manufacturing phase, standards like Good Manufacturing Practice (GMP) and MESTI are implemented to uphold safety during food processing and production.

Additionally, many food companies in Malaysia follow international safety protocols, including Hazard Analysis and Critical Control Points (HACCP) and ISO standards. These protocols provide a comprehensive approach to managing food safety throughout the supply chain—from production and manufacturing to distribution and consumption.

To ensure imported food meets safety standards, the Malaysia Quarantine and Inspection Service (MAQIS) conducts random checks and sampling at 28 entry points across the country to verify compliance with national standards and regulations[38]. On the other hand, the Department of Veterinary Services (DVS) oversees the safety of foods of animal origin, making sure that all imports of red meat, poultry, pork, egg, and dairy come from facilities that are either registered

[35] FAO (2008)
[36] Ibid.
[37] Ibid.
[38] USDA (2022)

with or approved by the DVS. Additionally, the DVS manages the importation of livestock, requiring both import permits and health certificates to maintain the safety of live animal trade[39].

While Malaysia has established a comprehensive regulatory framework and multiple quality assurance standards to safeguard food safety, issues may continue to arise due to several complex factors. One challenge is the enforcement of these regulations across a diverse and fragmented food supply chain, which includes both small-scale producers and large corporations. The various stages in this chain each introduce opportunities for contamination, making consistent oversight difficult. Additionally, resource limitations in inspection and monitoring can lead to compliance gaps, particularly in remote areas. Global trade introduces further variability, as imported food products might have been subjected to different standards and practices.

Conclusion

Upholding food safety is of utmost importance, as foodborne outbreaks and illnesses can carry substantial costs. These include medical expenses, nonmedical costs, productivity losses, costs incurred by the implicated manufacturers, and expenses borne by responding local, provincial, and federal agencies as well as public health and food safety authorities[40].

By understanding the potential sources and types of contamination—from biological and chemical to physical hazards—we can foster a culture of caution and awareness in food consumption and handling. This knowledge not only helps consumers make safer choices but also underscores the importance of robust safety practices at every stage of the food supply chain, from farm to table. As food safety concerns continue to evolve with challenges like climate change, consistent vigilance and adherence to regulatory measures are critical to ensuring the safety and integrity of our food supply.

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[39] USDA (2022)
[40] King et al. (2017)

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