Summary of Responsibility-based Teaching in *Food Toxicology*

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Abstract *Food Toxicology* is a core course for the major of food quality and safety. The teaching objective is to enable students to acquire the basic theoretical concepts of *food toxicology*, understand the toxicity and poisoning mechanisms of exogenous chemicals in food, and thereby achieve the goal of ensuring food safety. This article summarized the teaching process of the course, aiming to enhance students' awareness of food safety. Through the course teaching process, in-class experiments, and small topic presentation sessions, it establishes students' sense of responsibility from input to output in an all-round manner, in order to provide an objective basis for improving the teaching of this course.

Key words *Food Toxicology*; Teaching; Responsibility

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Food Toxicology differs from other food-related specialized courses as it examines the health impacts of toxic and harmful substances in food from a toxicological perspective. It covers how to prevent poisoning incidents through aspects such as raw materials, processing, storage, and management, as well as how to identify and implement emergency measures in the event of food poisoning. *Food toxicology* also differs from pharmaceutical toxicology by placing greater emphasis on prevention and management. Ultimately, the goal is to cultivate students' prioritization of food safety. Therefore, fostering a sense of responsibility toward consumers is crucial in teaching this course. To build this awareness of food safety accountability, here are some key insights gained from the teaching of food toxicology.

Extending Theory to Real Life: Case-based Teaching

Food safety incidents serve as a vital bridge connecting theoretical knowledge to real-life situations, enhancing students' grasp of concepts by linking textbook principles to practical scenarios (Table 1). For example, the "melamine" incident can be analyzed theoretically: dairy manufacturers added melamine to milk powder. In the human body, melamine is decomposed into melamine and cyanuric acid, forming crystals in the kidneys that compress renal tubules, leading to kidney disease[1]. In pursuit of excessive profits, ordinary or even substandard milk powder was altered to yield high nitrogen content in tests[2]. When explaining this case, numerous photos of the affected infants, the victims, are displayed. The college juniors in the past two years, who were the parties to the incident that year, strengthened their sensitivity to the harm of this food safety incident. Thus, to bridge the gap between theoretical knowledge and real-life relevance, selecting case studies that resonate personally can transform the sense of professional responsibility from mere rhetoric into profound empathy. This approach strengthens students' ethical awareness in their future careers.

Extending from Paper to Hands: Experimental Teaching

The food toxicology course at Chengdu University includes an in-class experimental component, which is a distinctive feature of the curriculum. In the upcoming revision of the teaching syllabus, the proportion of experimental classes will be increased, precisely because this part of the teaching content sparks strong student interest and provides a tangible hands-on experience. For example, in the observation of food poisoning caused by microbial xenobiotics, students apply previously learned microbiological testing techniques to food safety detection by counting total bacterial colonies in spoiled food and observing them under a microscope, thereby reinforcing their knowledge. In the acute toxicity experiment of nitrite observation, students are instructed to carefully observe the acute poisoning phenomena caused by this exogenous chemical in mice. Clear manifestations of hypoxia are observed after the animals ingested large amounts of nitrite, ultimately leading to death[8]. This allows students to deeply internalize the effects of nitrite poisoning. Combined with the textbook content on the mechanism of nitrite toxicity, most students could understand and remember the process that nitrite (NO_2^-) enters the human body through the digestive tract, is absorbed into the bloodstream, and undergoes an oxidation reaction with ferrous iron (Fe^{2+}) in hemoglobin, forming ferric iron (Fe^{3+}) methemoglobin (MetHb).

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Normal hemoglobin binds and transports oxygen via Fe^{2+}, whereas the structural alteration of methemoglobin prevents effective oxygen binding, resulting in hypoxia in mice and even fatal outcomes[9-10]. In experimental teaching, the invisible and intangible toxic substances in toxicology are visually presented to students through experimental methods. Through animal experiments, students directly observe poisoning phenomena and animal deaths, which intensifies the visual impact of severe consequences caused by poisoning. This approach enhances students' reverence for food safety.

Table 1 List of common cases

No.	Curriculum content	Case	Event
1	The Origins of Toxicology	The silicosis incident among miners	In the 19th century, miners developed pulmonary fibrosis due to inhaling dust.
2	The Development of Toxicology	The thalidomide incident	In 1959, in West Germany, the anti-nausea drug "thalidomide" taken during pregnancy caused limb deformities in newborns.
3	The Development of Toxicology	Minamata disease	In 1956, in Minamata Bay, Japan, the discharge of industrial wastewater containing mercury led to methylmercury contamination in seafood. Consumption of these products caused a mysterious and fatal illness[3].
4	The Development of Toxicology	Itai-itai Disease	From 1955 to 1977, in the 'Jinzū-gawa' basin near Mount Fuji, Japan, cadmium-contaminated wastewater polluted water and rice. Consumption led to severe joint pain, brittle bones, and ultimately death from debilitation and pain[4].
5	Types of Food Poisoning	Mushroom poisoning	Every spring, news reports emerge from Yunnan province about poisonings caused by Boletus luridus and other wild mushrooms.
6	ADME Process	Pulmonary absorption of haze	Fine particulate matter in haze enters the lungs through the respiratory tract, deposits in pulmonary tissue, and distributes via blood and lymphatic fluid to organs such as lymph nodes and the spleen. This causes damage to the respiratory and immune systems[5].
7	Toxicity Caused by Impurities	Agent orange in the Vietnam War	During the Vietnam War, the herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) used in warfare contained the impurity tetrachlorodibenzo-p-dioxin (TCDD). This resulted in approximately 50 000 children being born with horrific deformities[6].
8	Common Food Poisonings	Aflatoxin poisoning	As early as the 1st century BC, records documented that spoiled grains could cause certain illnesses or lead to miscarriages and birth defects in pregnant women. In 1960, a British farm experienced the sudden death of 100 000 turkey poults. Autopsies revealed severe liver necrosis, and investigations traced the cause to the consumption of moldy peanut meal contaminated with aflatoxins, which were identified as the primary cause of liver necrosis and death[7].

From Input to Output: Report on Small Topics

The final session of this course involves free grouping among students, with 2 – 3 members per group, to share insights on food safety incidents. The analysis should cover the exogenous chemical responsible for an incident, the symptoms of poisoning caused by the substance, and the current research progress on it. Finally, students should summarize the emergency treatment methods and ways to prevent such incidents from occurring. Over the years of teaching, it has been observed that students engage very actively in this section of the course. Through researching materials, creating PowerPoint presentations, and delivering live speeches, they demonstrate various food safety incidents caused by exogenous chemicals (Table 2). The earlier part of the course primarily involves teacher-led lectures and passive absorption by students, representing the input process. After a semester of combining theoretical and experimental teaching, students have gained a foundational understanding of food toxicology concepts and basic knowledge. The final report on small topics integrates all previously learned knowledge and thought processes, summarizing the content as part of the output phase. This exercise stimulates students' interest in toxic exogenous chemicals, encourages independent thinking and creativity in designing their presentation slides, and allows them to share their findings with the entire class. Additionally, it boosts the presenters' confidence and enhances their grasp of toxicological knowledge. Every student becomes a communicator of food toxicology knowledge, educating classmates on how to prevent similar incidents. This process ultimately strengthens each student's sense of responsibility, laying a foundation for becoming food industry professionals who will safeguard food safety as their primary duty.

Conclusions

Food Toxicology is indeed distinct from other subjects in the food discipline, involving interdisciplinary knowledge that examines the causes, mechanisms, and effects of toxic food hazards on human health from a critical perspective. It reveals humanity's vulnerable aspect, which is also worth defending and protecting. Through case studies, laboratory experiments, and small topic presentations, the learning process reinforces awareness of the dangers posed by toxic foods. It also enhances professionals' emphasis on health and safety while strengthening students' sense of responsibility.

Table 2 List of some small topics shared by students

No.	Topics	Main content
1	Recognition and prevention of poisonous mushrooms	Distribution, morphology, identification methods, toxic components, poisoning symptoms, first aid measures, and preventive strategies for toxic fungi
2	Histamine in food	Sources of histamine, hazards, prevention and control measures, detection methods, and current research progress
3	Solanine	Sources of solanine, toxicity, poisoning cases, research progress, and prevention and control measures
4	Research progress and control of benzoyl peroxide	Properties and sources of benzoyl peroxide, toxicity and hazards, research progress, and control measures
5	Trans-fatty acids-the hidden killer in food	Health hazards of trans-fatty acids, prevention and control measures, and daily protection
6	Research progress and prevention of tetrodotoxin	Physicochemical properties of tetrodotoxin, poisoning mechanism, research progress, detection methods, case studies, and prevention measures
7	Acrylamide in food	Sources of acrylamide, latest research progress, toxicity and formation mechanisms, preventive measures, health risks, and limit standards
8	Cyanides	Hazards of cyanides, toxic dosage, sources, and prevention
9	The silent killer: an in-depth analysis of the toxic substance lead	Sources and poisoning pathways of lead, harm to the human body, analysis of lead pollution incidents, cutting-edge prevention technologies and remediation solutions, public action initiatives and future prospects
10	Research progress and prevention of ricin toxin	Basic characteristics of ricin, mechanisms of toxicity, research advances, applications and challenges, prevention measures, and future research directions
11	Research progress and prevention strategies of colchicine	Sources of colchicine, toxicity mechanisms and cases, new research advances, prevention strategies, and future prospects
12	Mercury risks and prevention	Basic properties of mercury, primary sources, mechanisms of toxicity, pollution status, risk assessment and limits, prevention and control measures
13	Benzopyrene: the invisible carcinogen in food	Sources of benzopyrene, toxicity and carcinogenic mechanisms, how to reduce exposure risks, case studies and reflections
14	Oxalates	Metabolism and health effects in humans, clinical manifestations and detection of poisoning, treatment detoxification and prevention
15	Aflatoxin	Sources of aflatoxin, toxicity mechanisms, latest research advances, detection technologies, degradation techniques, and detoxification methods
16	Research progress and prevention of N-nitroso compounds	Toxicity, research advances, and prevention measures of N-nitroso compounds 。
17	Amygdalin: a natural compound with both medicinal value and risks	Sources of amygdalin, effects on the human body, emergency treatment, and preventive measures
18	Fumonisin	Sources and physicochemical properties of fumonisin, international standards and control measures, agricultural source control
19	Progress and prevention of toxic and harmful substances in food: nitrites	Sources of nitrites, hazards, research advances, and prevention methods
20	Prevention, control and research progress of creotoxin	Introduction to creotoxin, pathogenic mechanisms and hazards, current research progress, detection technologies, comprehensive prevention and control measures, applications and challenges
21	Research on food safety risks and prevention systems of arsenic toxins	Physicochemical properties of arsenic toxins, food contamination status, toxicity mechanisms and typical cases, research progress, and prevention technologies
22	Polychlorinated biphenyls (PCBs)	Properties of PCBs, toxicity mechanisms, analysis of typical cases, risk prevention and management

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guidance for practical work in the field of food safety.

Currently, food safety issues remain severe, making continuous innovation and development in risk early-warning technologies crucial. In the future, with the advancement of science and technology, particularly the deep integration of analytical chemistry with related disciplines, food safety risk warning technologies will achieve further breakthroughs. It is anticipated that a more robust food safety warning system will be established through more precise and efficient risk identification and monitoring approaches, thereby effectively safeguarding public dietary safety and promoting social harmony and stability.

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