Importance of Aflatoxins in Food and Agricultural Products

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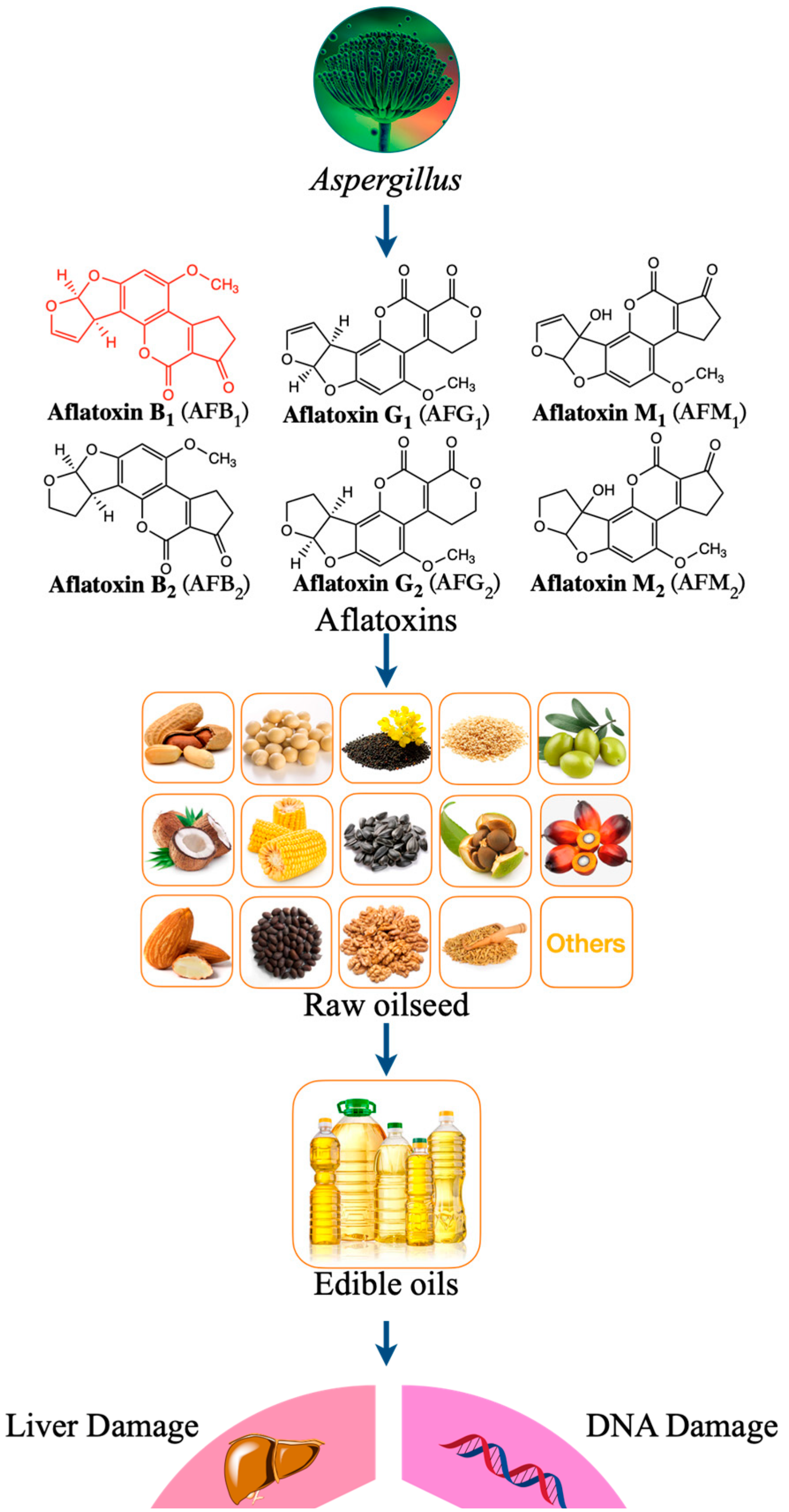
Contamination of agricultural products and foods by aflatoxin B_1 (AFB_1) is becoming a serious global problem, and the presence of AFB_1 in edible oil is frequent and has become inevitable, especially in underdeveloped countries and regions. As AFB_1 results from a possible degradation of aflatoxins and the interaction of the resulting toxic compound with food components, it could cause chronic disease or severe cancers, increasing morbidity and mortality.

aflatoxin B1 | edible oil | chromatographic technology | spectroscopic technology

1. Introduction

Food security has always been an issue of concern in the international community, and, in recent years, food contamination has become a major factor affecting food security. Contaminated food can not only adversely influence human health (poisoning events, chronic diseases, etc.) but also affect and slow down the economy. When people consume contaminated food, they need to spend a lot of money and time on treatment. There are many factors causing food contamination, such as biological, chemical, and physical factors. Among these, microbial contamination is common and mainly includes contamination by bacteria, fungi, molds, viruses, or their toxins and by-products [1][2]. Mycotoxins are common food contaminants, which can cause changes in the appearance, flavor, smell, and other characteristics of food [3][4][5][6][7]. Mycotoxins are secondary metabolites produced by fungi (e.g., *Fusarium*, *Aspergillus*, and *Penicillium*) that have multiple toxic effects on organisms and contaminate agricultural products (cereals, milk, etc.). More than 400 kinds of mycotoxins have been identified. Among them, aflatoxins (AFs) have become one of the major concerns due to their high toxicity and carcinogenicity, causing approximately 25% of animal deaths [8][9][10][11][12].

Edible vegetable oil plays an irreplaceable role in the human diet. The world oil crop output has increased year by year and had reached 635.5 million tons by 2021 [13]. From the growth of oil crops to the final product, i.e., oil, each link may be affected by external factors (such as mycotoxins), which may affect the quality and safety of edible vegetable oil [14]. This is because most oil crops, such as corn, peanut, soybean, rapeseed, sunflower seeds, olives, and nuts, are seasonal. During the growth process, they will be affected by climate, pests, and other factors and can be easily be infected by *Aspergillus* flavus. After harvest, the oil may deteriorate or be affected by mildew due to storage conditions (such as temperature and humidity, etc.) and storage methods [15]. At the same time, during the production of edible oil, fresh-pressed edible oil is vulnerable to contamination of raw materials infected with *Aspergillus* by aflatoxin B_1 (AFB_1) [16][17][18][19][20][21][22]. Therefore, contamination of edible vegetable oil products by AFB_1 is a serious food safety problem (**Figure 1**) [20][23][24][25].


Aspergillus
Aflatoxin B1 (AFB1)
Aflatoxin G1 (AFG1)
Aflatoxin M1 (AFM1)
Aflatoxin B2 (AFB2)
Aflatoxin G2 (AFG2)
Aflatoxin M2 (AFM2)
Aflatoxins
Others
Raw oilseed
Edible oils
Liver Damage
DNA Damage

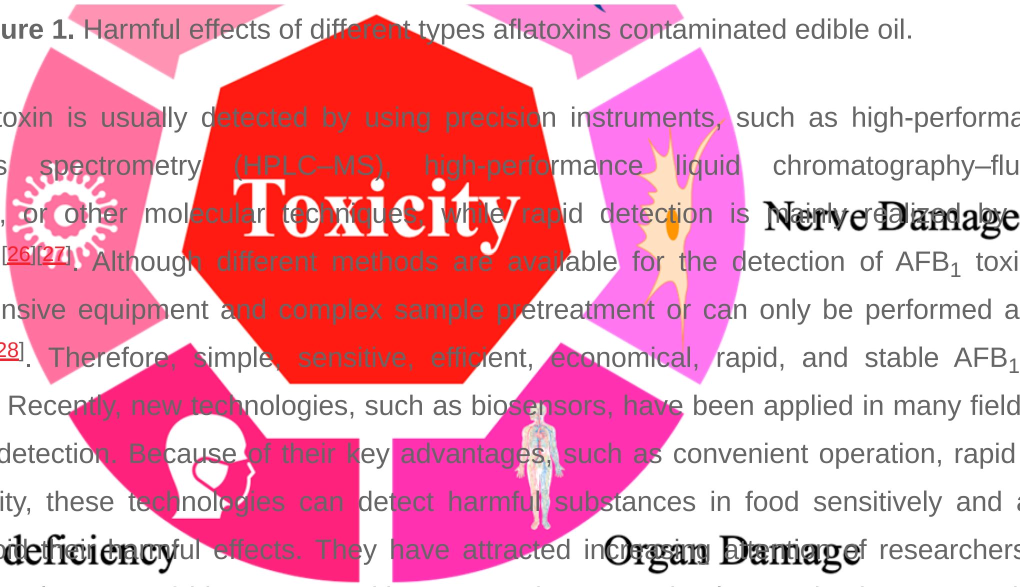


Figure 1. Harmful effects of different types aflatoxins contaminated edible oil.

The presence of aflatoxin is usually detected by using precision instruments, such as high-performance liquid chromatography–mass spectrometry (HPLC–MS), high-performance liquid chromatography–fluorescence detection (HPLC-FD), or other molecular techniques, while rapid detection is mainly realized by enzymatic immunoassay ELISA [26][27]. Although different methods are available for the detection of AFB_1 toxicity, these methods require expensive equipment and complex sample pretreatment or can only be performed at relatively high concentrations [28]. Therefore, simple, sensitive, efficient, economical, rapid, and stable AFB_1 detection methods are required. Recently, new technologies, such as biosensors, have been applied in many fields, such as health care and food detection. Because of their key advantages, such as convenient operation, rapid response, and excellent portability, these technologies can detect harmful substances in food sensitively and accurately, helping effectively avoid their harmful effects. They have attracted increasing attention of researchers and also promoted the rapid development of biosensors. With progress in nanotechnology, scientists are paying special attention to biosensors based on nanomaterials. These new biosensors or detection systems are sensitive, rapid, consistent, and cost-effective and can be used to detect AFB_1 in food [29][30][31][32][33].

2. Importance of Aflatoxins

Aflatoxins are a type of mycotoxins. They are highly toxic metabolites of fungi, produced in food and agricultural products. They have severe toxic effects, such as immunosuppressive, nephrotoxic, teratogenic, carcinogenic, and mutagenic, on human and animal health [34][35][36][37][38].

Aflatoxins can be divided into aflatoxin B_1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G_1 (AFG_1), and aflatoxin G_2 (AFG_2) according to their fluorescence properties and chromatographic mobility (**Figure 1**) [39][40][41]. Aflatoxin M_1 (AFM_1) and aflatoxin M_2 (AFM_2) are hydroxylated metabolites of AFB_1 and AFB_2, respectively. AFB_1 is the most toxic among all AF species, with a high incidence rate and the most complex detection mechanism (**Figure 2**) [42].

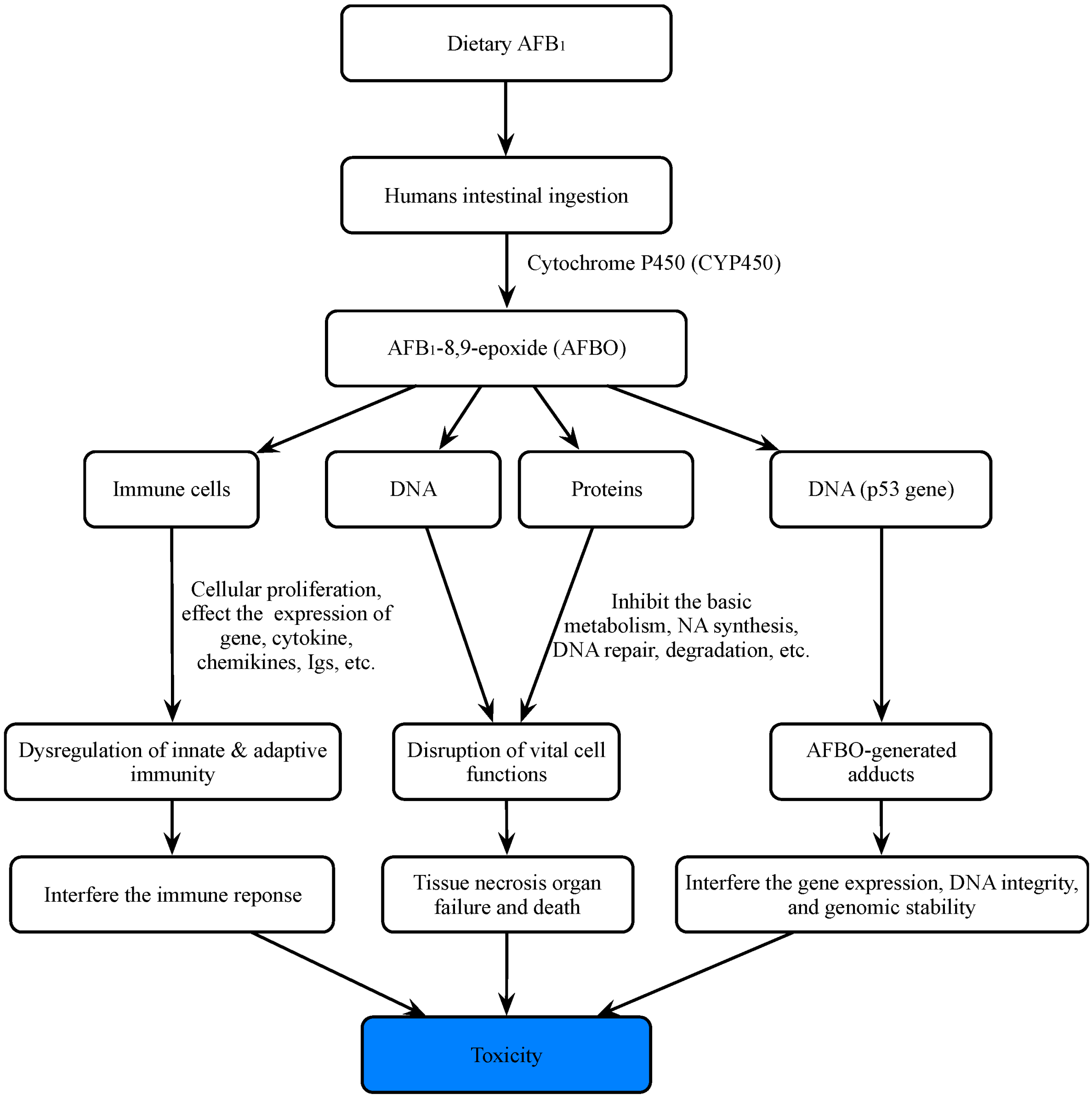


Figure 2. Main mechanisms of toxicity of aflatoxin B_1 for humans.

AFB_1 is a powerful carcinogenic, teratogenic, mutagenic, immunotoxic, hepatotoxic, and reproducible poison. Previous studies have shown that the toxicity of AFB_1 is 10, 68, and 416 times that of KCN, arsenic and melamine, respectively [43][44] (**Figure 2**). Therefore, AFB_1 has been classified as a class 1 carcinogen by many international authoritative organizations or institutions [45][46]. Due to the structural double bonds in the furan ring, AFB_1 has high carcinogenicity and toxicity [17][47]. The lipophilic structure of atrial fibrillation promotes its entry into the blood through gastrointestinal and respiratory tracts [48][49]. Once AFB_1 enters blood, it is distributed in various tissues and accumulates in the liver or other organs, resulting in liver cancer (**Figure 3**). In the liver, AFB_1 produces a variety of metabolites through the hydroxylation and demethylation of the first-stage drug metabolism enzymes (for example, cytochrome P450 oxidase and CYP450 superfamily members, such as CYP1A2, CYP3A4, and CYP2A6) [50]. Metabolic reaction (internal and external) activates the final carcinogen AFB_1 -8,9-epoxy metabolite, which covalently binds to cellular macromolecules (DNA, RNA, or protein) and plays a key role in acute and chronic poisoning. AFB_1 residues also destroy the function of tumor suppressor genes (p53 and Rb) in the liver, which affects normal cells and leads to liver injury, increasing the probability of tumor and liver cirrhosis [51][52][53][54][55]. It is estimated that about 30% of liver cancers in the world are caused by AFB_1. Its toxicity increases the infection rate of hepatitis B virus (HBV) and the risk of liver cancer [56]. A recent study found that the synergistic effect of AFB_1 and HBV leads to liver cancer [50]. The reason is that HBV infection directly or indirectly exposes hepatocytes to AFB_1 sensitive to tumors. The toxic effect of AFB_1 is also related to dose, age, sex, nutrition, exposure time, and type [57]. In addition, AFB_1 can be transmitted to the fetus through the placenta and affect the health of infants [58]. AFB_1 exposure also inhibits immunity, thereby increasing the susceptibility to immunodeficiency virus attack and the probability of infection with other infectious diseases [59][60][61][62][63].

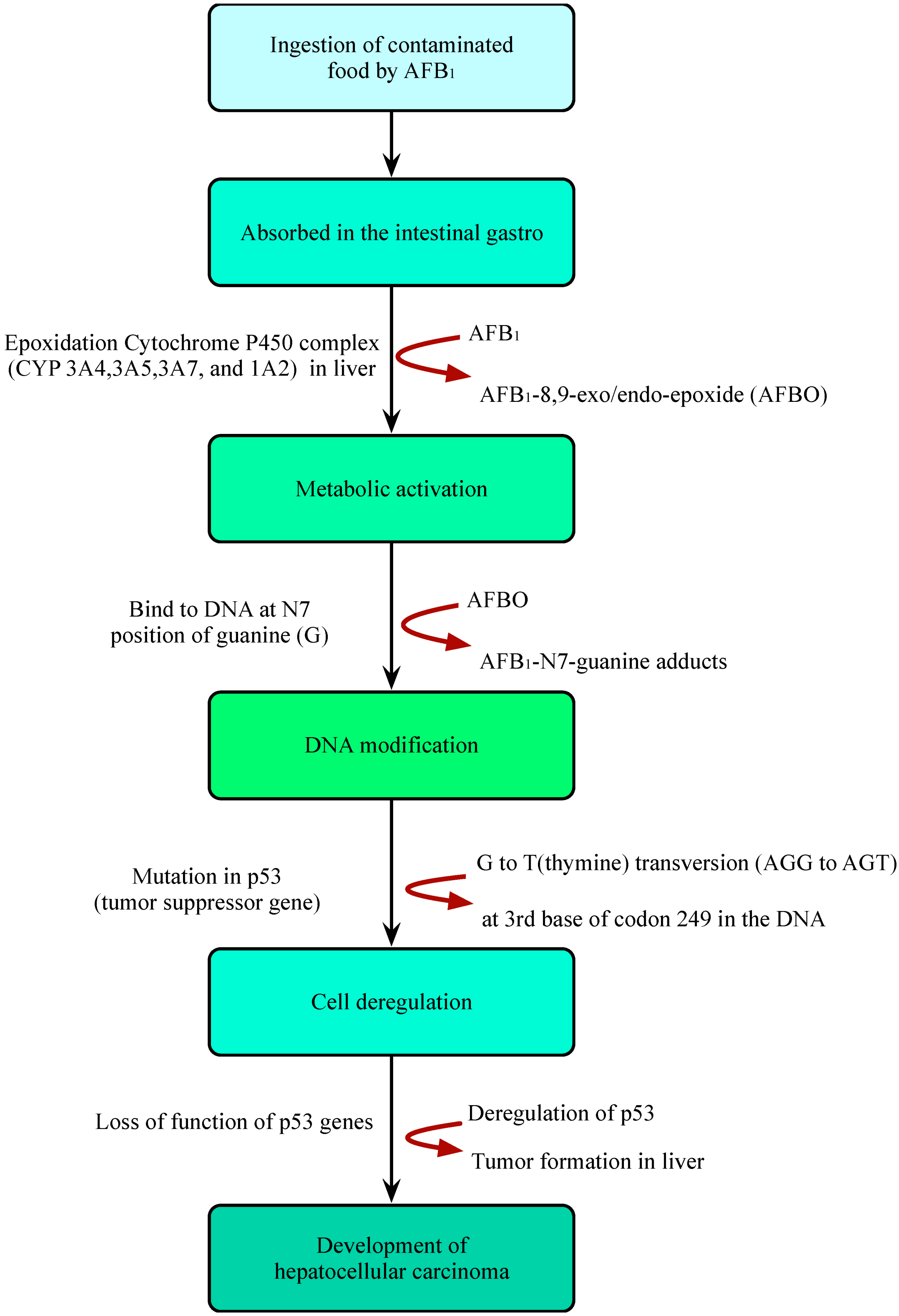


Figure 3. Illustration of the mechanism of hepatocellular carcinoma caused by ingestion of AFB_1-contaminated foods.

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