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# Chemical hazards in food – a short critical review

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***Abstract***

The review focuses on the main risks associated to chemical compounds, even as contaminants or degrading derivatives that can be harmful for the consumer health. The chemical hazards determined by food additives (colorants, sweeteners, flavorings, preservatives, antioxidants), agricultural residues (pesticides, fungicides, herbicides) and heavy metals are emphasized. The overview reveals the correlation of these food chemical contaminants with some negative effects and long-term diseases for consumers and proposes further actions for reducing these chemical hazards.

***Keywords***: food products; chemical risks; chemical hazards; food quality and safety; food security; food additives; pesticides; heavy metals; contaminants

## 1. Introduction. Food hazard

Food contamination is a major human health problem, which can be caused by [1]:

- Pathogenic microorganisms
- Their metabolites
- Environmental contaminants (pesticides, drug residues, industrial chemicals, etc.).

Food safety is ensured through a systematic approach to food production, the HACCP (Hazard Analysis and Critical Control Point) system [1-5].

## 2. Chemical hazards in food

There are several classes of chemical components that can cause chemical hazards to food, which are classified as follows [1,6-9].

- Food additives (e.g., colorants, sweeteners, flavorings, preservatives, antioxidants, etc.);
- Contaminants from agriculture (pesticides, fungicides, herbicides);
- Heavy metals;
- Other contaminants that come from natural sources such as natural toxins from marine animals, toxins from plants, or that are generated during food processing due to the action of physical factors (temperature, radiation), such as furans, polycyclic aromatic hydrocarbons, or acrylamide and which are mainly discussed at physical risks.

### *2.1. Chemical hazards caused by food additives*

Food additives are defined as substances that directly or indirectly become components of the food product and influence its characteristics [2,10,11]. They can be colorants, sweeteners, flavorings, preservatives, antioxidants, etc. During food processing or preparation, food additives may cause chemical reactions with other components of the food.

#### *2.1.1. Colorants*

The color of a food is an organoleptic characteristic that significantly influences the acceptability of the product by the consumer. Both natural and synthetic

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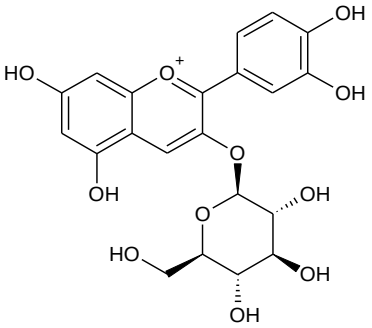
colorants are used as food additives in the colorant class. Synthetic colorants approved for use in food are usually much more stable under the action of environmental factors (pH, temperature, light), while natural colorants have a lower stability. This is the case of extracts of annatto (yellow) for butter, caramel (yellow to brown), dehydrated beets. On the other hand, natural colorants are more accepted, safer in terms of health and contribute to the functional properties of food. In the case of synthetic colorants, which have a wide color palette from yellow-orange to green and blue, the use in food is based on ADI values (acceptable daily intake). In addition to natural food colorants (anthocyanins, carotenoids or phenolic compounds) obtained as mixtures, purified or even identical-natural colorants (obtained by chemical synthesis, but which exist in nature) are also used [1,2,6,12].

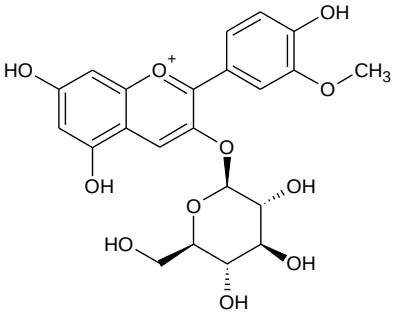
For example, the most commonly used commercial anthocyanins are cyanidin-3-*O*-glucoside, peonidine-3-*O*-glucoside, and pelargonidine-3-*O*-glucoside (Figure 1).

Their stability is strongly influenced by [1]:

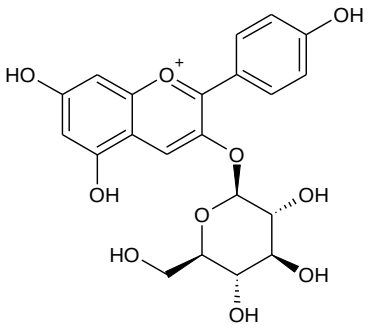
- pH;
- temperature;
- stress conditions;
- humidity;
- salt content (salinity);
- storage conditions.




*Cyanidin-3-O-glucoside*




*Peonidin-3-O-glucoside*




*Pelargonidine-3-O-glucoside*

**Figure 1.** Anthocyanins used as food additives (colorants)

Failure to comply with the regulations regarding the type and maximum permitted dose of such colorants may result in consumer health problems. Such problems often occur with unpackaged (bulk) foods, such as snacks, chewing gum / colored balls, colored candy, soft drinks. Examples of such uses of food colorants (or other coloring matters used in foodstuffs which are not approved as food additives) are given below (Figures 2 and 3) [1,6]:

- Titanium dioxide (may cause allergic reactions or behavioral disorders in children);
- Tartrazine (possible influence on the occurrence of attention deficit hyperkinetic disorders - ADHD; reduction in carcinogenic amines under the action of azoreductases);
- Sunset yellow FCF (possible influence on ADHD);
- Quinoline yellow (possible influence on ADHD);
- Carmoisine (azorubine; possible influence on ADHD);
- Ponceau 4R (cochineal Red A; possible influence on ADHD);

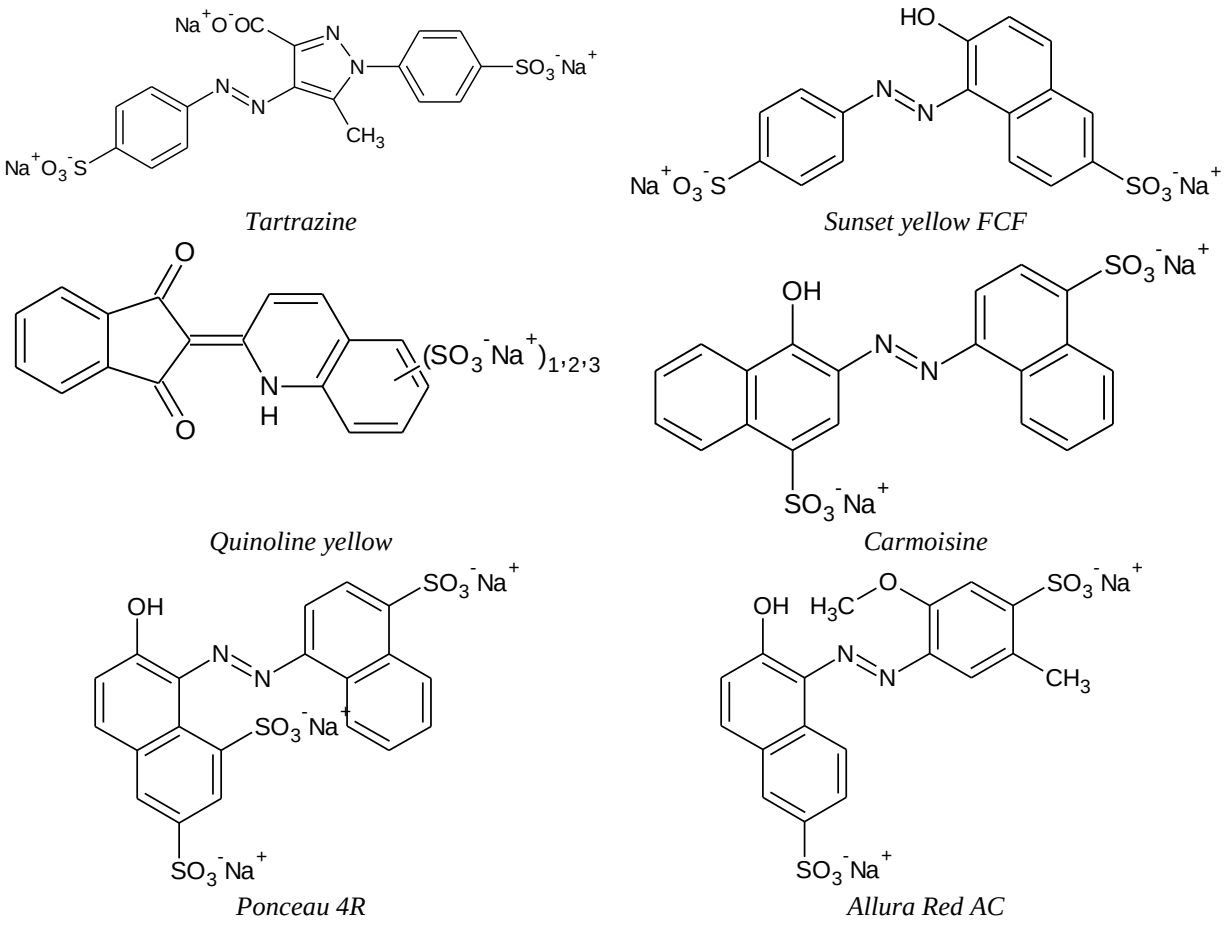



**Figure 2.** Synthetic dietary colorants that have a possible influence on the occurrence of attention deficit hyperactivity disorder (ADHD)

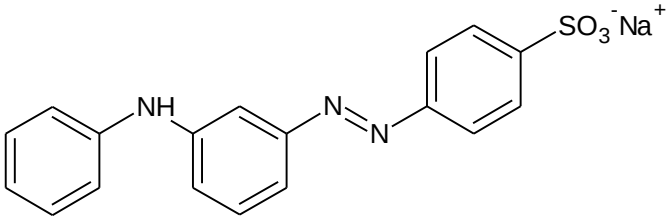


**Figura 3.** Structure of the Methanyl yellow colorant, used in the adulteration of turmeric

- Allura Red AC (possible influence on ADHD);
- Methanyl yellow (not allowed in food, but still used in counterfeiting turmeric powder; it is hepatotoxic).

*2.1.2. Sweeteners*

Sweeteners are food additives with a specific organoleptic effect. These can be nutritional sweeteners (polyols) or high-intensity sweeteners. Sweeteners with high-intensity sweetening power (natural or synthetic) are used in much lower contractions in food. Thus, the caloric intake, if exists, is very low and they are suitable for low-calorie foods designed for obese people and not only [1,6].

The most used sweeteners with high-intensity sweetening power are:

- Aspartame;
- Acesulfame potassium;
- Saccharin;
- Cyclamic acid, sodium and calcium salts;
- Sucralose.

Tables 1 and 2 show the main natural and synthetic sweeteners with high-intensity sweetening power, approved for use in food. If used in higher concentrations than those approved by the regulations in force, these food additives can negatively alter the taste of food (bitter or metallic taste), and prolonged use can even lead to heart problems, neuronal diseases, physiological or various forms of cancer [1,5,8,13-15].

*2.1.3. Flavorings*

Flavorings are volatile or non-volatile chemical compounds that cause a food-specific odor and taste, respectively. Volatile flavorings belong to the following chemical classes: alcohols, esters, dicarbonyl compounds, aldehydes, short chain fatty acids and esters, lactones, phenolic compounds, methyl ketones, sulfur compounds. Examples of such flavoring compounds from some volatile oils are shown in Table 3. Some flavoring compounds used as food additives are extracted from plant sources, but there are many such additives obtained by synthesis [1,6,13].

*2.1.4. Preservatives*

Preservatives are food additives used to prevent the degradation of food or to maintain its nutritional value and flavor for a longer period of time. It works by eradicating microorganisms and inhibiting their growth. This also prevents the formation of toxins that can result from contamination of food with microorganisms. It can be used to preserve food by adding salt or sugar (high osmotic pressure), reducing the water content, or removing air that would come into contact with food (inert gas, paraffin film, etc.).

**Table 1.** Natural sweeteners with high-intensity sweetening power, used in food [1,6]

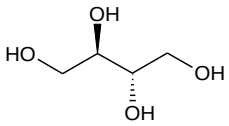
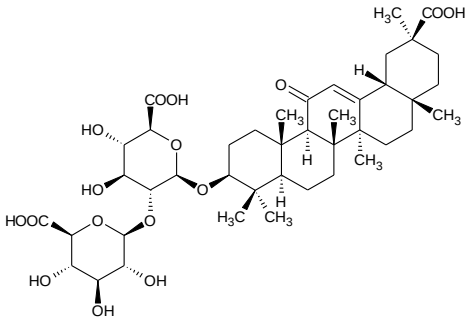
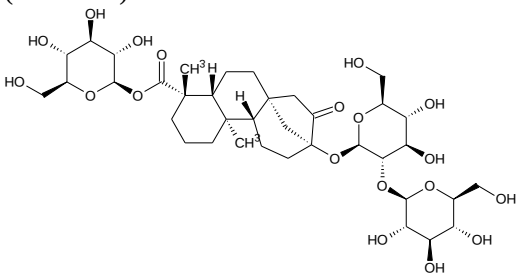
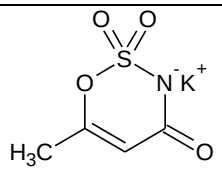
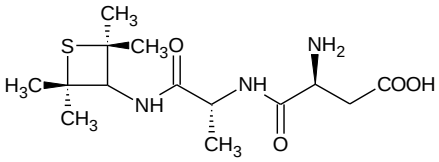
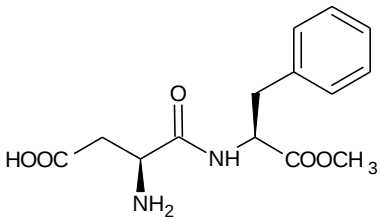
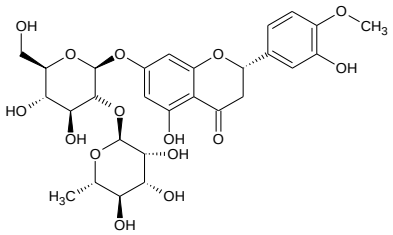
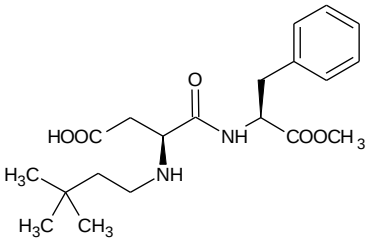
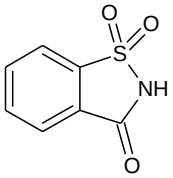
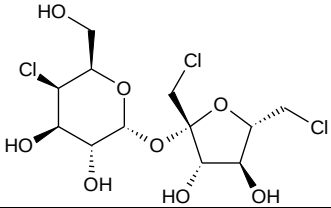
| Sweetener | Structure / occurrence | Food applications |
|---|---|---|
| Brazzein | Protein extracted from *Pentadiplandra brazzeana* Baillon, from West Africa | Low calorie sweetener |
| Curculin | Protein extracted from *Curculigo latifolia*, from Malaysia | Low calorie sweetener |
| Erythritol |  | Soft drinks |
| Glycyrrhizic acid |  | Natural flavoring and flavor enhancer |
| Miraculin | Protein extracted from *Synsepalum dulcificum*, from West Africa | Sour drinks |
| Mogrol glycosides | Glycosides from *Siraitia grosvenorii* (monkfruit) | Soft drinks and various foods |
| Steviol glycosides |  Glycosylated diterpene from *Stevia rebaudiana*, from South America | Soft drinks, chewing gum, dairy products, fruit drinks |
| Taumatin | Proteins isolated from the *Thaumatococcus daniellii* Bennett leaf, from West Africa | Flavor enhancer |

**Table 2.** High-intensity synthetic sweeteners for use in foodstuffs [1,6]

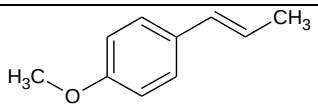
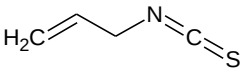
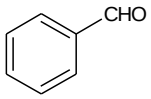
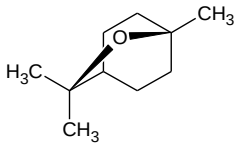
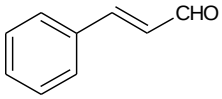
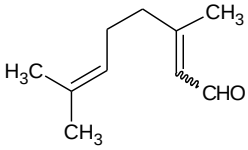
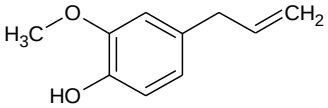
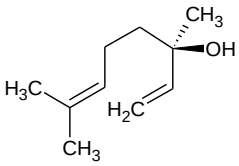
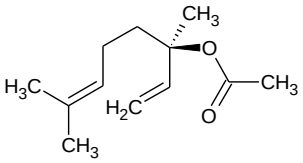
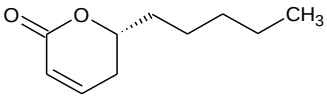
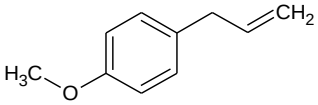
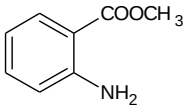
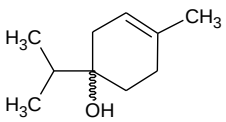
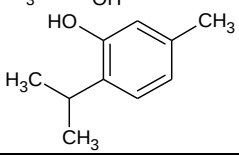
| Sweetener | Structure / occurrence | Food applications |
|---|---|---|
| Acesulfame potassium |  | Confectionery, fruit dairy products, carbonated and non - carbonated beverages |
| Alitam |  | Carbonated soft drinks |
| Aspartam |  | Pasteurized and sterilized flavored milk |
| Neohesperidine |  | Sweetening mixtures, artificial flavors |
| Neotam |  | Beverages, mixtures for sweetening |
| Saccharin |  | Sweetening mixes, cooked foods, beverages |
| Sucralose |  | Cooked and baked foods, sweetener mixtures, beverages |

Food additives used as preservatives are calcium propionate, sodium nitrite and nitrate, sodium bisulphate, potassium sulphites and hydrogen sulphites, or disodium EDTA. Vinegar, ethyl alcohol, sugar, salt or diatomaceous earth are also used as traditional preservatives.

Some preservatives can have harmful effects on the human body if used in high concentrations and consumed for a long time. Some examples are given below [1,6]:

- Sulfur dioxide (wine preservation): irritant to the bronchi in consumers with asthma;

**Table 3.** Examples of food flavorings from essential oils [1,6]

| Flavoring compound | Structure | Flavoring characteristics / Occurrence |
|---|---|---|
| Anetole |  | Anise, spicy / Anise (*Pimpinella anisum*), star anise (*Illicium verum*) |
| Allyl isothiocyanate |  | Spicy, pungent / Black mustard (*Brassica nigra*) |
| Benzaldehyde |  | Almonds / Bitter almonds (*Prunus amygdalus* var. *amara*) |
| 1,8-Cineole |  | Fresh, refreshing / Eucalyptus (*Eucalyptus globulus*) |
| Cinnamaldehyde |  | Spicy, warm / Cinnamon (*Cinnamomum*) |
| Citral |  | Lemon / Lemongrass (*Cymbopogon citrates*) |
| Eugenol |  | Spicy / Clove (*Syzygium aromaticum*) |
| Linalool |  | Woody / Basil (*Ocimum basilicum*), camphor tree (*Cinnamomum camphora*) |
| Linalyl acetate |  | Floral-fruity / Bergamot (*Mentha citrata*) |
| Massoia lactone |  | Coconut / Massoia tree (*Cryptocaria massoia*) |
| Methyl chavicol |  | Sweet / Basil (*Ocimum basilicum*) |
| Methyl anthranilate |  | Sweet-fruity / Tangerines (*Citrus reticulata*) |
| Terpinen-4-ol |  | Slightly peppered / Tea tree (*Melaleuca alternifolia*) |
| Thymol |  | Medicinal, sweet / Thyme (*Thymus vulgaris*) |

- Nitrates and nitrites (preservatives for meat products): carcinogenic potential when converted to nitric acid;
- Sulphites (preservatives for fruits and fruit products): headaches, palpitations, allergies, even cancer;
- Benzoates (antimicrobial preservatives): allergies, asthma, dermal eczema;
- Sorbic acid: urticaria, contact dermatitis.

### *2.1.5. Antioxidants*

Antioxidants are compounds that inhibit oxidative processes, which can occur in foods. These degradations are mainly related to lipid oxidation, due to the presence of mono- and polyunsaturated fatty acid residues, whose oxidation generates free radicals harmful to human cells (leading to premature aging, cancer, rheumatoid arthritis, or atherosclerosis) [1,6]. Antioxidants used as food additives belong mainly to the class of phenols (mono- or polyphenols), and can be natural or synthetic. Among the natural antioxidants, lycopene, nordihydroguaiaretic acid, avonoids (diosmin and hesperidin), sesamol, gossypol, flavonoids, anthocyanins, or minerals (Zn, Se), enzymes (catalase, glutathione peroxidase, superoxide dismutase), lecithin and vitamin E, are often used (Figure 4). However, some of natural antioxidants have side effects to humans. On the other hand, among the synthetic antioxidants, the most widely used are *tert*butyl-hydroxy-anisole (BHA), *tert*butyl-hydroxy-toluene (BHT) or *tert*butyl-hydroquinone (TBHQ), as well as gallic acid esters (Figure 5).

Antioxidants have many positive effects on consumer health, but there are also side effects such as vitamin C, which when overused can lead to cardiovascular disease, and some synthetic polyphenolic antioxidants can have potentially carcinogenic effects at high doses [1,6].

## 2.2. Chemical hazards caused by agricultural residues

### *2.2.1. Pesticides*

Pesticides are chemicals that kill insects and parasites on crops. Pesticides are essential for maintaining high productivity, but also for food security. It is estimated that there is a loss of about 35% worldwide due to insects and pests [1].

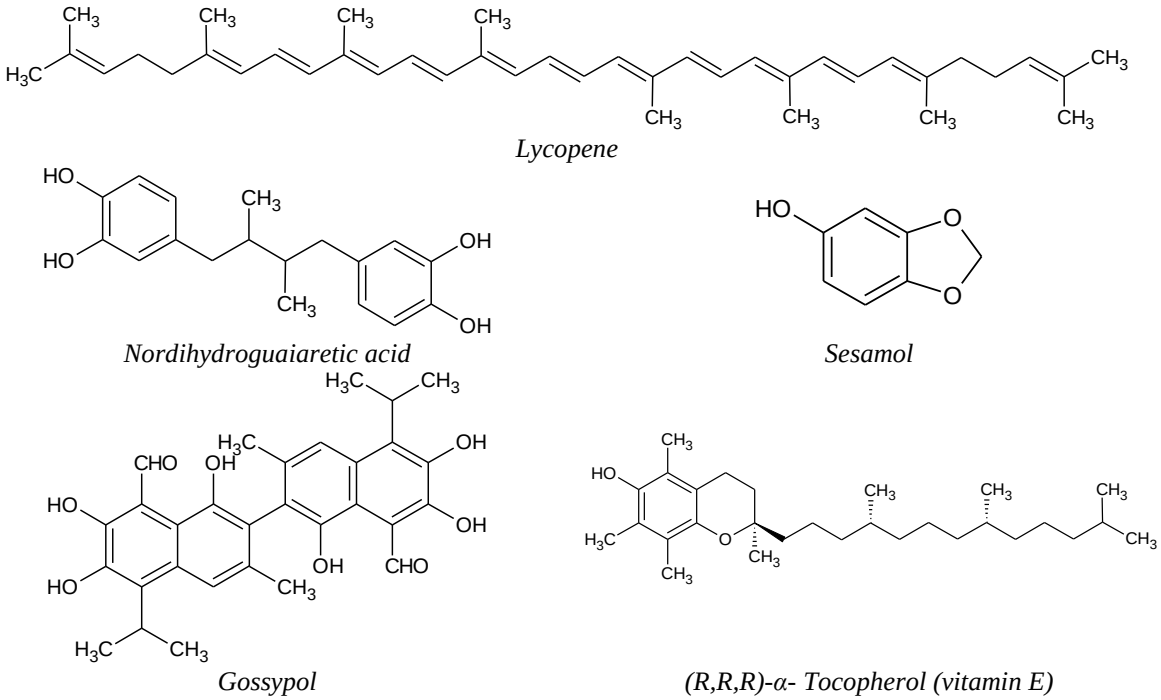
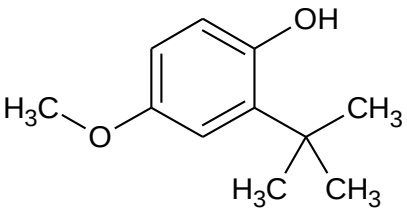
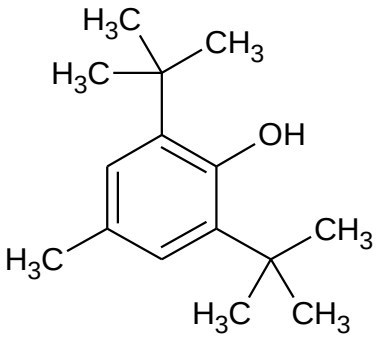


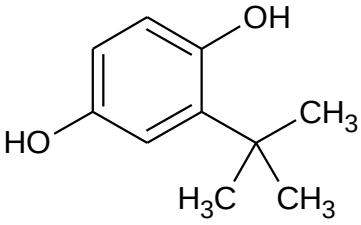

**Figure 4.** Examples of natural antioxidants used as food additives



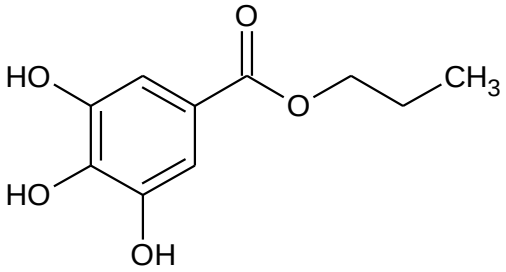

*Tertbutyl-hydroxy-anisole (BHA)*




*Tertbutyl-hydroxy-toluene (BHT)*




*Tertbutyl-hydroquinone (TBHQ)*




*Propyl gallate*

**Figure 5.** Examples of synthetic antioxidants used as food additives

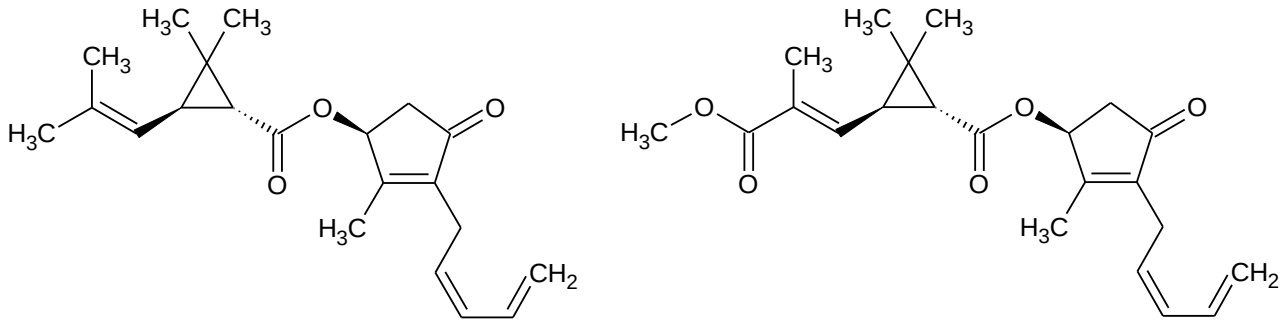
Regarding the classification of pesticides, they belong to the following structural groups [1,5,6]:

- Organochlorine compounds;
- Organophosphorus compounds;
- Fluorine compounds;
- Carbamic and thiocarbamic derivatives;
- Phenol and nitrophenol derivatives;
- Metal-organic and inorganic compounds;
- Heterocyclic compounds (benzimidazole and triazole derivatives);
- Hydrocarbons, ketones, aldehydes and their derivatives;
- Urea derivatives;
- Natural and synthetic pyrethroids.

Unfortunately, pesticides also affect the environment, both vegetation and animals and birds. It also pollutes the air, water and soil when used improperly, reaching the food consumed by humans.

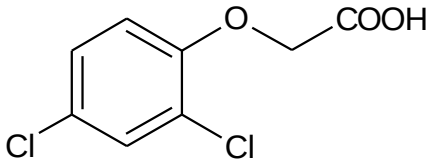
Pesticides can reach the human body by ingestion (food, water), inhalation (air) or by absorption into the dermis (workers working in agriculture and the pesticide industry). Pesticides have various toxic effects on the human body, possibly carcinogenic, neurotoxic, immunotoxic or toxic to the reproductive system, especially if there is prolonged exposure to them. Neurodegenerative diseases can also occur and have an impact on the biological parameters of the human body, especially the protein metabolism, endocrine and reproductive systems [1,5,6].

At present, pesticides with very low toxicity and low persistence, but with maximum effectiveness, are marketed. Examples of this are pyrethroids (Figure 6) and pesticides based on *Bacillus thuringiensis*, a Gram-positive bacteria widely used as a biological pesticide. During sporulation, *B. thuringiensis* produces crystalline proteins called delta-endotoxins with insecticidal effect [1,5,6].

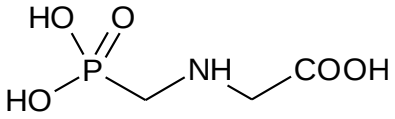



*Pyrethrin I* *Pyrethrin II*

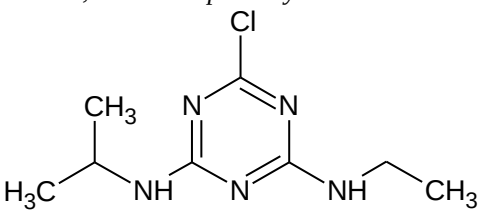
**Figure 6.** The structures of the main pyrethroids in the pyrethrum (*Chrysanthemum cinerariifolium*), with pesticide action



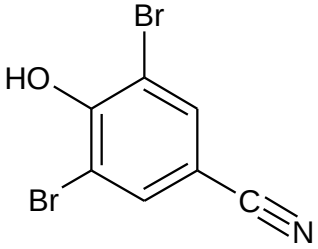

*2,4-Dichlorophenoxyacetic acid*




*Glyphosate*




*Atrazine*




*Bromoxynil*

**Figure 7.** Examples of herbicide structures

### *2.2.2. Fungicides*

Fungicides are chemical compounds that inhibit the growth of fungi and / or sporulation. They are mainly used to protect fruits, vegetables or tubers during storage, but also in crops, forests, ornamentals or lawns. They are classified according to the mode of action (contact, translaminar or systemic), its mode of application, its origin (biological and chemical; for example, *Bacillus licheniformis*) or its structural class (organic or inorganic). Some fungicides are toxic to the human body (carcinogenic), although few of them are often non-degradable and pollute the environment, reaching food, and then ingested by humans. There are currently new fungicides with moderate toxicity [1].

### *2.2.3. Herbicides*

In addition to the mechanical operations of removing weeds from crops, herbicides are also used. They are chemical compounds that selectively destroy weeds in crops. Their classification is based on the mode of action (there are over 20 modes of action, such as inhibition of acetyl-CoA carboxylase), by mode of application, by chemical affinity or structural similarity [1]. Herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D), glyphosate, atrazine or bromoxynil are used today, with various modes of action [6]. Their retention in soil, water and later in food, as well as inhalation / ingestion or absorption of herbicides at the time of application (or in the case of workers in the specific industry), can lead to various harmful actions. For example, 2,4-D causes DNA degradation, according to studies on hamster ovarian cells [1].

### 2.3. Chemical hazards caused by heavy metals

Heavy metals normally exist in the environment, either as elements or derivatives (salts, organometallic compounds, etc.) in the soil, or as a result of pollution (industrial, waste, etc.). These heavy metals are absorbed from water, soil and even air by plants and animals (including marine animals or fish), so they are found in various concentrations in food. Examples of such foods in which heavy metals have been identified are tea, fish, various vegetables, fruits, and soft drinks. It accumulates in the human body mainly in the lipid parts (liver, heart, kidneys, spleen) and can cause various diseases, even in very small quantities (e.g. lead, mercury, cadmium, arsenic) [1,6,13].

## 3. Conclusion and further perspectives

This short review emphasized the chemical hazards from food products. The main chemical compounds that can occur in foods and have side or harmful effects to humans are systematically presented as chemical structures correlated to various activities. Even natural additives or synthetic compounds can be harmful to humans. Besides the chemical class, these biological activities are also related to the concentration level in food and the long-time of consuming. As a consequence, the urgent actions regarding the chemical hazard in foods are the reviewing of food additives used at industrial level, as well as the systematic control of these chemicals during the food chains.

**Compliance with Ethics Requirements.** Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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