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## CHAPTER 4

# Attributes of food quality and sources of danger in agri-food chains

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## 4.1 Introduction

Food quality is not easy to define. Moreover, there is no single definition of food quality that is comprehensive<sup>[1]</sup>, ie that would contain all the elements of the definition of food quality. W. Edwards Deming defines quality as: "... a predictable degree of consistency and reliability of a product with a quality standard that meets the customer"<sup>[2]</sup>, so it makes perfect sense that the definition of food quality changes depends on changing needs and requirements of customers or consumers.

Food quality is primarily directly related to the sensory properties of a particular food product<sup>[3]</sup> and each consumer determines the quality of food based on their senses and evaluates: appearance, texture and taste<sup>[4]</sup>. A holistic approach in defining food quality involves several value groups. These are: the *psychological* or nominal value of food, based on concepts usually difficult to explain, opinions (prejudices) and consumer expectations about the product.

The psychological or nominal value group is followed by a *cultural* or social food value group. This is followed by a *political* group of values that is particularly pronounced in developing countries, and finally there is the *ecological* group of values, which includes an assessment of the environmental impact of food production and processing<sup>[5]</sup>. However, food quality is also defined by specific types of food such as *ethnic food*<sup>[6]</sup>, which is specific to a particular ethnic group determined by culture, origin, socio-demographic characteristics and even social status<sup>[6]</sup>, such as *kosher*<sup>1</sup> food which must be prepared according to the provisions of the Jewish Food Law, ie *halal*<sup>2</sup> food according to Islamic Law<sup>[7]</sup>.

A specific group of foods includes *functional foods* which, in addition to their nutritional value, also have preventive and / or health benefits <sup>[8, 9]</sup>. If we add to this a specific form of tourist offer, known as *gastro tourism* (English food tourism <sup>[10]</sup>, and especially *organic food*<sup>[11]</sup>, then it is quite clear that there is no single definition of food quality, but we can speak about food quality attributes or properties in the production chain<sup>[12]</sup>.

<sup>1</sup> *Kosher* in Yiddish is a term for the Hebrew term *kāshér* (כָּשֵׁר), meaning 'fit' or healthy, in good 'shape'.

<sup>2</sup> *Halal* or Arabic *halaal* (حلال) means pure or permissible.

## 4.2 Attributes or properties of food quality in the production chain

Attributes or properties of food quality in the production chain<sup>[13]</sup> are divided into two groups:

1. External or extrinsic quality attributes
2. Internal or intrinsic quality attributes

External or extrinsic properties of food quality<sup>[13]</sup> relate to:

- Features of production systems
- Environmental aspects
- Marketing and communication.

*The characteristics of production systems* refer to the entire production process in which a particular food product originated in the entire agri-food chain. This really includes product features such as:

- origin of agricultural raw materials according to location and type of production (organic or conventional)<sup>[14]</sup>,
- use of pesticides, GMOs<sup>[15]</sup> and treatment of domestic animals<sup>[16, 17]</sup>,
- yields and quality of agricultural raw materials in a given production / vegetation year,
- stability and losses of agricultural products during harvest, storage and transport,
- length of transport<sup>[18]</sup> and distribution to consumers,
- technological process of processing an agricultural product into a food product, which includes the use of additives, control and analysis during the production process and keeping food products from spoilage<sup>[19, 20, 21, 22, 23]</sup>.

In other words, the characteristics of production systems include all the characteristics of agri-food chains and traceability within the agri-food chain<sup>3</sup>.

*Environmental aspects* of external (extrinsic) properties of food quality are mainly focused on *the impact of packaging materials on agricultural products on the environment*<sup>[24, 25]</sup> and on *food waste*<sup>[26]</sup>. Namely, packaging materials and food packaging design must ensure the stability of the food product in the prescribed storage conditions within a certain shelf life, which means effective prevention of spoilage. On the other hand, the most effective packaging materials also pose an environmental threat due to their slow degradability<sup>[27]</sup>. Due to the growing environmental awareness, most consumers in highly developed countries increasingly consider food packaging waste as a serious threat and choose food products whose packaging is biodegradable<sup>[28]</sup>. Moreover, such materials are being developed that will completely replace plastic<sup>[29]</sup>. Some of these materials are already in use and are part of the circular economy<sup>[30]</sup>.

However, when it comes to food losses, as a form of external quality properties of food products, the situation is a bit more complicated. First, food waste and food waste management in agri-food chains<sup>4</sup> have only been discussed for twenty years. Namely, in agricultural production, great attention was paid to losses during the harvest, storage and transport of agricultural products. On the other hand, losses incurred in the food industry, households and restaurants went 'under the radar'. Today, food companies, due to their social influence and economic interests, are making more or less efforts to reduce losses in technological processes<sup>[31]</sup>. Fifteen years ago, it was noticed that large generators of food waste are members of the last 'link' in agri-food chains, which are consumers divided into two groups; restaurants<sup>[32]</sup> and households<sup>[33]</sup>. Unfortunately, this leads to a paradox, because often lower-income households with lower purchasing power waste more food than higher- and middle-income households<sup>[34]</sup>. In any case, the amount of food waste and food losses must be reduced, and in order to achieve this, many activities are needed to address the cause of this extremely negative phenomenon<sup>[35]</sup>. However, food waste will always occur in the agri-food chain. Therefore, in highly developed countries, food waste from households and restaurants are seen as a useful raw material in the circular economy<sup>[36]</sup>.

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<sup>3</sup> cf. ch. 1. Agricultural food chains → 1.6. Traceability in the agri-food chain

<sup>4</sup> cf. ch. 1. Agricultural food chains → 1.2. What are agri-food chains and who are the stakeholders in them?

*Marketing and communication* as external (extrinsic) property of food quality is something that is given the utmost attention, primarily for economic reasons, ie increased sales and consequently higher profits by food companies. Today, there is almost no serious food company that does not shower consumers with leaflets, promotional materials, advertisements in public media, posters, etc., presenting soy products and emphasizing their nutritional value, quality control of their products to care for consumer health, the origin or originality of raw materials, and often emphasizing the modern technological process of production and implementation of certain quality management systems as a guarantee of safety, reliability and health safety of their food products. Moreover, it is already common practice to find an info phone number on the packaging in a visible place where consumers can express their remarks, complaints and compliments on behalf of a particular food product.

However, in addition to all these activities, food incidents occur, which are most often manifested as acute food poisoning or are prevented in the event that state control bodies, specifically sanitary and market inspection according to the findings of accredited laboratories of state food agencies, act in accordance with their legal authority and order the withdrawal of certain food products from the market. In this case, *risk communication* is applied<sup>[37]</sup>. By definition, communication in risk situations is the exchange of information between risk assessors, risk managers, consumers and other stakeholders regarding the occurrence of risk, factors that determine its occurrence, consequences and prevention measures and/or specific actions of all stakeholders in the agri-food chain. Communication in risk situations is a component of barriers to risk assessment and management, whose three components are:

1. Risk assessment
2. Risk management
3. Communication in risky situations.

Effective communication in risky situations can be achieved;

- Physical or health well-being of people
- Consumer confidence in food supply and regulatory systems
- Environmental Protection
- Improving the overall quality of life including socio-economic and psychological factors.

*Internal or intrinsic properties of food quality*<sup>[13]</sup> refer to:

4. Consumer health safety
5. Shelf life of the product and its sensory (organoleptic) properties
6. Reliability and practicality of the product

*Consumer health safety* is a basic and ultimate property of food quality<sup>5</sup>. If the food is not healthy, poisoning occurs in acute<sup>[38]</sup> or in chronic form. The following factors threaten consumer health safety<sup>[13]</sup>:

- Pathogenic microorganisms<sup>[39, 40]</sup>
- Toxic substances<sup>[41]</sup>
- Foreign objects
- Occurrences of natural disasters and catastrophes

*The shelf life of a product and its sensory properties* is second in importance to food quality. The expiration date is primarily related to the reliability of consumer health, ie microbiological spoilage of the food product. However, in some cases the shelf life may be related to the physical properties of food products<sup>[42]</sup>, as well as to changes in the chemical composition and sensory properties of products<sup>[43]</sup>.

*Product reliability and practicality* is an extremely important property of product quality from a consumer perspective. Namely, modern consumers are looking for a food product that they expect to be:

- healthy and good nutritional properties,
- good taste,

<sup>5</sup> Explained in detail in ch. 4.3. Sources of danger in the agri-food chain.

- easy to use,
- whose preparation does not take long,
- which has stable sensory properties even after opening the packaging, of course provided that it is stored in the conditions prescribed in the instructions for use and storage,
- and which is packed in practical packaging that allows its easy use.

Therefore, food producers invest great efforts and resources in research and development of products that will meet the demands of consumers<sup>[44, 45, 46]</sup>.

In essence, the reliability and practicality of the product is the result of the first and second internal (intrinsic) attributes of the quality of the food product. However, the success of the sale of this food product depends on this internal attribute of quality, because if customers do not accept it, the return on investment in the development of this product will not be realized.

### 4.3 Sources of danger in agri-food chains

Sources of danger to human and animal health in agri-food chains can be;

- metabolic products of plants, animals and microorganisms,
- chemical and biological toxic substances from the environment,
- purposefully added food additives,
- and substances produced during food processing.

Although food is necessary for our body, if it is contaminated with pathogenic microbes or their toxins or other contaminants from the environment, in this case food can play a major role in the transmission or development of disease. Contamination of food with pathogenic microorganisms or toxic chemicals can cause a number of health problems. Food contamination is responsible for more than 200 diseases such as intestinal diseases and other foodborne diseases, and can lead to death. Of course, toxic components can be found in foods of animal and plant origin, as well as in higher fungi, which are used as a food source. Such toxic compounds can damage certain organs and systems, such as the skin, cardiovascular system, and can manifest systemic negative effects by binding to hormone receptors or affecting the nervous system. Food safety hazard refers to any product present in food that causes harmful effects on the health of consumers<sup>[47]</sup>.

All sources of danger in the agri-food chain (*food hazards*) are divided into:

- biological,
- chemical,
- physical.

#### 4.3.1 Sources of biological hazards in the agri-food chain

Some pathogenic bacteria and fungi, but also some viruses, prions and protozoa, contaminate food during production and processing, but also during its storage and transport before consumption. During their growth, these microorganisms can secrete various components, including toxins. Also, these organisms are responsible for the formation of some other harmful substances that can contaminate food after the breakdown of pathogens in the finished food or food product. Today, food is a global product and its transport takes place over long distances, and there are great opportunities for contamination during transport. Unfortunately, consumers and government food control agencies are aware of this only in developed countries, while countries do not have sufficient knowledge about foodborne diseases, despite the fact that there are millions of diagnosed cases of various forms of food poisoning worldwide<sup>[48, 49]</sup>.<sup>6</sup>

*Listeria monocytogenes*, *Campylobacter* spp., *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, *Bacillus cereus*, *Shigella* sp., *Shigella* sp., *Vibrio vulnificus* and *Vibrio parahaemolyticus*, are among the most

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<sup>6</sup> Cf. Chap. 1. Agricultural food chains → 1.1. Introduction → Uruguay Round of negotiations → GATT

common and dangerous foodborne pathogens. In order to prevent food contamination with these pathogens, measures are being taken to control the microbiological safety of fresh raw materials of animal origin (milk, meat, eggs, fish and seafood, but also fruits and vegetables) and to monitor the technological process of processing raw materials into food products, preventing the so-called *cross-contamination*. This term refers to the contamination of food with undesirable and harmful substances, which may be naturally present, added during the process of production, processing and storage of food, or which reached the food accidentally simply by momentary carelessness.

Namely, equipment and surfaces in contact with food in the food industry can themselves become a substrate for the development of pathogenic microbes, which is known as *biofilm*. By definition, biofilm is a sessile community of bacteria and molds in deposits of complex sugars, and proteins that contain sugars and in which dust from the air is deposited. Biofilm is usually created on the border between two aggregate states. This is exactly the case in the food industry. Therefore, numerous preventive measures are implemented, and in addition to constant microbiological controls of control laboratories that must be carried out by each food manufacturer and prescribed by law and other legal acts of individual countries and the EU, the obligatory preventive measure is *washing and disinfection of equipment and work surfaces* in the food industry. and food distribution, including the retail sale of fresh meat, cured meat products, fresh fish and shellfish.

Today, the best results in preventing biofilm formation are achieved by the use of surfactants<sup>7</sup> and alkaline compounds for the treatment of work surfaces and equipment before washing and rinsing with water under pressure<sup>[50, 51]</sup>.

#### **4.3.2 Sources of chemical hazards in the agri-food chain**

Certainly the most drastic epidemiological case of chemical poisoning in the food chain is the example of Minamata disease (syn. Minamata syndrome) which was recognized and described on May 1, 1956, and the epidemiological study was completed in early January 1957 under the leadership of Dr. sc. Shoji Kitamura, full professor at Kumamoto University School of Medicine in Japan<sup>[52]</sup>. Namely, the Japanese chemical company Chisso from its factory located near the city of Minamata released large amounts of methylmercury into the Minamata River in wastewater. As the river flows into the bay of the same name, which is rich in fish, mercury has accumulated in marine organisms and through the food chain has accumulated in humans, causing severe neurological disorders and even malformations in fetuses<sup>[53]</sup>. The next case was repeated five years later in Ontario, Canada, when the chemical company Dryden was found to have polluted the Wabigoon River ecosystem with approximately 10 tons of mercury between 1962 and 1970, and it is estimated that recovery of the ecosystem will take 50-70 years<sup>[54]</sup>.

These are just two drastic examples of mercury poisoning of aquatic ecosystems that reaches fish and shellfish consumers through the food chain.

Sources of chemical hazards in the agri-food chain are:

- *Heavy metals*; with two drastic examples of contamination and food poisoning by heavy metals, specifically mercury, described above.
- *Food additives*; food colors, sweeteners, flavor enhancers, preservatives and antioxidants. Namely, although their maximum quantities in which they may be present in food products are strictly determined and controlled by the competent laboratories, in case of any non-compliance they can be a serious source of chemical danger to consumer health.
- *Residues of plant protection products*; the active substances of many plant protection products are neurotoxic and even potentially carcinogenic and some are under strict control and their actual carcinogenicity is still being investigated<sup>[55]</sup>.

<sup>7</sup> Surfactants are substances that reduce the surface tension of water, ie reduce the forces acting on the interface between the two phases, which allows the formation of foam, creating an aqueous emulsion with liquids with which water does not mix (eg oil) and aqueous suspensions with substances which water does not otherwise dissolve (e.g. with fat). Surfactants are the main ingredients of detergents, industrial means for removing impurities by washing in water.

- *Mycotoxin residues*; which represent an increasing source of danger in the agri-food chain, especially in post-harvest management and storage of agricultural and food products.<sup>8</sup>
- *Dioxins*; which occur in the wild after large forest fires, and cases of dioxins entering the agri-food chain<sup>9</sup> are also known. Cases of intentional dioxin poisoning are also known to the public<sup>10</sup>.

In any case, the sources of chemical hazards in the agri-food chain can only be controlled by strict preventive measures that include analysis of soil, water, agricultural raw materials that go into processing and, finally, finished food products.

### 4.3.3 Sources of physical danger in the agri-food chain

One of the drastic examples of sources of physical danger in the agri-food chain is the contamination of milk and dairy products, meat, fish, vegetables and grain crops with radionuclides <sup>131</sup>I, <sup>134/137</sup>Cs, <sup>90</sup>Sr after the Chernobyl disaster on April 26, 1986. This has led to a ban on agricultural production on 265,000 ha in Belarus, 130,000 ha in Ukraine and 17,000 ha in Russia<sup>[56]</sup>. However, radionuclides do not reach the agri-food chain through nuclear disasters, but also through the use of mineral fertilizers, in which phosphorus is derived from phosphate ores that have a naturally elevated concentration of radionuclides that accumulate in the plant. transfer of natural radionuclides from soil to crop<sup>[57, 58, 59]</sup>.

However, radionuclides are not the only source of physical danger in the agri-food chain, but they can also be pieces of glass or small metal and plastic objects, which can fall into the packaging of the food product before it is closed.

## 4.4 Incident prevention in agri-food chains

Incident prevention in agri-food chains takes place at three levels:

1. Providing the necessary quantities of food, in order to achieve *food security* of the population of each country or region<sup>11</sup>
2. Ensuring hygienically and healthily correct food, ie *food safety*, the consumption of which will not cause acute poisoning, nor chronic diseases of those who consume it.<sup>11</sup>
3. *Food defense* measures

However, the main tool used at all three levels is traceability in agri-food chains.<sup>12</sup>

### 4.4.1 Food security of the population of each country or region

The most accurate definition of food security of the population of each country or region was given at the World Food Summit in 1996 and it reads:

“Food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food that meets their nutritional needs and inclinations for an active and healthy life.”

For food security to exist, four elements must be met<sup>[60]</sup>:

1. *Availability of food*: Availability of sufficient quantities of food of adequate quality, supplied by domestic production or import (including food aid).
2. *Access to food*: Access of individuals to adequate resources (rights) to acquire adequate food. A right is defined as a set of all goods over which a person can establish control over the legal, political, economic and social organization of the community in which he lives (including traditional rights such as access to shared resources).

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<sup>8</sup> See ch. 1. Agricultural food chains → 1.4. Post-harvest management of agricultural products in agri-food chains

<sup>9</sup> Link: <https://www.europarl.europa.eu/news/en/headlines/society/20110121STO12289/dioxin-contamination-in-ger-many-meps-call-for-stricter-controls-penalties>

<sup>10</sup> Link: <https://www.newscientist.com/article/dn17570-skin-growths-saved-poisoned-ukrainian-president/>

<sup>11</sup> See ch. 1. Agricultural food chains → 1.2. What are agri-food chains and who are the stakeholders in them?

<sup>12</sup> See ch. 1. Agricultural food chains → 1.6. Traceability in the agri-food chain

3. *Use*: The use of food through proper nutrition, clean water, sanitation and health care to achieve a state of nutritional well-being in which all physiological needs are met. This reveals the importance of non-food inputs in food safety.

4. *Stability*: It means that the population, household or individual must have access to adequate food at all times. The risk of losing access to food as a result of sudden shocks (eg economic or climate crisis) or cyclical events (eg seasonal food insecurity) should be kept to a minimum. Therefore, the concept of stability can refer to both the availability and the access dimension of food safety.

Unfortunately, food insecurity is present in many parts of the world today<sup>[61]</sup>, and the main reason for this is global climate change, which particularly affects third world countries<sup>[62]</sup>. If climate change is added to the loss of natural resources, especially the soil necessary for food production<sup>[63, 64]</sup>, the threat of world hunger becomes a certain scenario<sup>[65]</sup>.

#### 4.4.2 Hygienic and health food safety

Hygienic and health safety of food is essentially the biological, chemical and physical status of food that allows its consumption without the risk of injury, disease or mortality<sup>[66]</sup>.

However, the international term 'food safety' includes culture, organization and social climate, ie the overall production, economic, technological, legal and social conditions in which food is produced, distributed and consumed without or with a minimum level of risk to consumer health<sup>[67]</sup>. As food security is a strategic issue extremely important for the national security of each country and region, on 28 January 2002, the European Union adopted Regulation No 178/2002 of the European Parliament and of the Council laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety<sup>[68]</sup>. Based on this document, the European umbrella organization in charge of proposing, coordinating and implementing food safety policy is the European Food Safety Authority (EFSA).<sup>13</sup> Food agencies in all EU member states work closely with this organization because it is known that all provisions of the European Parliament and the Council of Europe, as well as European Commission directives have binding and direct implementation in the legislation of EU member states. As EFSA was founded with the aim of being a source of scientific advice and communication on the risks associated with the food chain, its official journal *EFSA journal*<sup>14</sup> publishes a number of analyzes, opinions, recommendations and studies available to every EU and global citizen.

At the United Nations level, the same activities are carried out by the Food and Agriculture Organization (FAO)<sup>15</sup>, which operates mainly in third world countries through education and technical assistance. In the United States, it is the US Food and Drug Administration (FDA)<sup>16</sup> and the United States Department of Agriculture (USDA).<sup>17</sup>

In any case, despite all the concerns about food safety in terms of hygiene and health, one thing is certain, and that is that "there is no food security without food safety"<sup>18[69]</sup>.

#### 4.4.3 Food defence

Food is a strategic product, so today more and more attention is paid to the defense aspects of the protection of agri-food chains within food systems. This term is known as food defence and represents the adoption and implementation of all measures of protection against *agroterrorism and food terrorism*, in order to ensure protection against any intentional food poisoning and the use of contaminated food as a weapon<sup>[70]</sup>. Namely,

<sup>13</sup> Link: <https://www.efsa.europa.eu/en/aboutefsa>

<sup>14</sup> *EFSA journal* [Online ISSN: 1831-4732] can be found at: <https://efsa.onlinelibrary.wiley.com/journal/18314732>. The journal is indexed in the reference database of scientific journals Journal Citation Reports in the field of 'Food Science & Technology' in which in 2020 it is ranked as 53 out of 144 journals and belongs to the second quartile (Q2).

<sup>15</sup> Link: <http://www.fao.org/food-safety/en/>

<sup>16</sup> Link: <https://www.fda.gov/food>

<sup>17</sup> Link: <https://www.usda.gov/topics/food-and-nutrition>

<sup>18</sup> *Orig.* 'There is no food security without food safety'

as strange as it may seem to the average person, the fact that the whole story is not harmless is shown by the fact that a manual for training members of the terrorist organization al-Qaeda was found during a search of an apartment in Manchester (UK). Lesson 16 describes how contaminated food can be used as a weapon<sup>[71]</sup>. However, apart from intentional contamination of food caused by terrorist activity, often with a political motive, perhaps the most pervasive form of intentional contamination is to improve profits, ie to harm competition or to retaliate against competitors. In any case, the ‘motives’ of mentally disturbed people and local extremists should not be ruled out<sup>[72]</sup>.

The question is how to fight agro-terrorism and food terrorism?

The answer is simple; traceability and strengthening of food safety culture.

Therefore, each defense strategy essentially combines all the principles of ‘food security’, ‘food safety’ and the basic tool by which it is implemented is traceability in agri-food chains. Food defense is an extremely important security issue and must be an integral part of any well-designed *agri-food system*.

### 4.5 What are agri-food systems?

Agri-food systems, in terms of specifics that may relate to the type of product and/or the method of production and the number of stakeholders, become components of food systems. Although there is no single definition of food systems<sup>[73]</sup>, they are determined by a range of activities carried out on the establishment of agri-food chains, food security activities and other activities such as environmental protection and biodiversity<sup>[74]</sup>. What is being sought is the establishment of an *elastic, flexible and resilient* food system that is able to fulfill its functional goal – to ensure food safety – despite disturbances and shocks, whether economic or natural. The resilience of such a system consists of the following components:

- Robustness (impact resistance)
- Redundancy (ability to absorb interference)
- Flexibility or speed (recovery potential for lost food safety)
- Resourcefulness or adaptability (percentage of food safety lost: recovered)

However, the highest level in the organization of any system, including the food or agri-food system, is *sustainability*<sup>[75]</sup>.

According to the FAO, a *sustainable food system* is one that provides food security for all, without compromising the economic, social and environmental foundations for creating food security for future generations<sup>[76, 77]</sup>.

Unfortunately, today’s food systems are definitely not sustainable. There are the following reasons for this:

- Food supply based solely on market economic models that depend on steady growth in consumption.
- The agri-food system is dominated by a small number of large global companies that tirelessly strive for growth and monopoly, while eliminating trends toward sustainable and healthy food. This puts pressure on producers to produce food at low prices, and this is possible only with the use of agrochemicals and increasing the consumption of fossil fuels.
- High flow of production and consumption in the supply chain inevitably leads to waste, especially by retailers and consumers. This reduces the resilience needed to cope with global shocks and major disturbances caused by the effects of climate change, but also plant pests and diseases.
- Globalization of the food and agricultural raw materials market, which theoretically predicts poverty reduction due to the overall strengthening of international trade, in practice often redirects local agriculture and land use for food exports to developed countries has led to poor outcomes such as deforestation, pollution and biodiversity loss.
- Some of the positive policy measures of individual government countries, such as subsidies for agriculture or incentives for the food industry, aimed at addressing environmental and health issues, often fail due to conflicts with the interests of large corporations.
- The system of sanctioning environmental and health incidents is almost inefficient due to the activities of various lobby interest groups (individual stakeholders) in agri-food chains.



- Research and policy on the agri-food industry have a reductionist character that does not recognize the unbreakable link between environmental health and human health.

When we add to this the intensifying and faster climate changes and catastrophes they bring<sup>[78, 79]</sup>, as well as the latest pandemic of covid-19 virus<sup>[80]</sup> and also future pandemics, it is clear that radical changes in production methods and food consumption are needed<sup>[81]</sup>. Therefore, research and development of new sustainable technologies and education play a major role in the development of sustainable food systems based on sustainable agri-food chains<sup>[82]</sup>.

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