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CHAPTER 1

Agricultural food chains

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1.1 Introduction

According to the definition that can be found in the Encyclopaedia Britannica[1], the term food means any substance that is consumed to ensure the nutritional needs of the organism. Food is usually of plant or animal origin and contains essential nutrients, such as carbohydrates, fats, proteins, vitamins or minerals. Food is taken into the body and absorbed in the cells of the body to provide energy, sustain life or encourage growth. Based on this definition, it is quite clear that in the history of human civilization, wars were fought to conquer new areas, and thus meet the nutritional needs of certain peoples. When we talk about food, we inevitably talk about food chains. In free nature, every food chain starts with herbivores, then carnivores and finally omnivores, including man. With the domestication of wild animals and the cultivation of the first economically important plant species, the period of agriculture begins, which lasts until today. With the introduction of agriculture, man changed his way of life and the first civilizations emerged, and with the emergence of the first civilizations the first cities, the first letters and the Anthropocene period began, which lasts to this day[2] and will stop when natural resources for food production are exhausted or no longer available[3]. The development of agriculture enabled the development of other activities, because with the development of civilization, the first *agri-food chains* were formed, which enabled the division of labor. Agri-food chains connect all parts of *food systems* that have developed more or less in proportion to the increase in human population, and as one after another, various innovations in agricultural production and logistics were implemented, the world trade also grew. However, today's agricultural production is very different from agricultural production only thirty years ago. Two moments were crucial for that, one of global and economical nature and the other in the form of a natural phenomenon. Namely, in May 1986, at the G7 economic summit in Tokyo, a major problem in world food trade was noticed, and four months later the Uruguay Round of negotiations on GATT (General Agreement on Tariffs and Trade) began. General Agreement on Tariffs and Trade), which was to devise trade and agricultural policy rules, bringing world agriculture under the effective rules of the GATT[4], with all the positive but unfortunately also negative consequences for food security and adequacy in many countries. Another moment that has disrupted the accounts of GATT creators is global climate change, which inevitably affects almost all socio-economic aspects related to food systems, from agricultural and livestock production to global trade, demography and human behavior, which all together affect food security and food self-sufficiency[5]. However, a third phenomenon has recently emerged that highlights the vulnerability of agri-food chains and food systems at the state level, the COVID-19 pandemic, which combined with global climate change is a serious threat to food security and food self-sufficiency in many countries of the world, and especially in the poorest ones[6].

1.2 What are agri–food chains and who are the stakeholders in them?

From a *socio-economic* point of view, the *agri-food chain is a system* created jointly by economic and social stakeholders involved in coordinated activities aimed at creating added value for a particular good or service, from its production to its arrival at the consumer. That chain or chains include input and service providers, processing, transportation, logistics, and other support services, such as financing. At the same time, from an *operational point of view*, the agri-food chain can be seen as an institutional tool for strategic planning, policy management, dialogue and consensus building among stakeholders or even as a social contract[7].

However, each agri-food chain has its two basic functions, namely:

a) Providing the necessary quantities of food, in order to achieve *food security* of the population of a particular country or region

b) Ensuring hygienic and healthy food, ie *food safety*, the consumption of which will not cause acute poisoning, nor chronic diseases of those who consume it.

When we talk about agri-food chains, we are talking about two forms of agri-food chains, and these are the *food value chain* and the *food supply chain*.

The food value chain is a term that refers to the movement of a food product along the supply chain and the identification of actors and their activities in order to create added value. *The food supply chain* is a process in which food reaches the end consumer, which includes all the different stages that food goes through in that process.

Understanding the agri-food chain as a food value chain is a prerequisite for the efficient management of all food production *resources*. By definition, *resources* are assets or wealth that countries, organizations, communities, or people can use to create new value or goods. Resources for food production available to a country or organization are divided into:

- *Natural resources*, including land, forests and water, and land-related assets such as soil, plants and animals.
- *Human resources* or in short people who contribute with their work, knowledge and skills create new goods, in this case food. It is natural resources that determine the possibility of providing the necessary quantities of food for the population of a country or *nutritional self-sufficiency*[8].
- *Capital resources*, ie money, infrastructure and equipment.

Unfortunately, losses inevitably occur in the food production and supply chain. It is estimated that the total losses are about 1/3 of the total food produced in the world. Unfortunately, losses in agri-food chains are higher in third world countries compared to developed countries. According to some estimates, only in the Middle East and North Africa losses in production, distribution, and losses in households and restaurants of tubers and root crops are about 26%, cereals 14 - 19%, oilseeds 16%, meat 13%, 45% fruit and vegetables, 28% fish and seafood and 18% dairy products[9].

Therefore, the management of all resources is a prerequisite for the establishment and development of sustainable food value chains[10]. Today, one of the important components of the overall management of agri-food chains is waste management in the agri-food chain[11]. Of course, all standards of hygiene and health when it comes to reusing or recycling this waste, for example in the production of animal feed must be met. In doing so, one must take into account not only the terminological but also the semantic difference between the two terms, namely *food loss* in the agri-food chain and *food waste*[12]. Namely, the term food loss refers to the reduction of the amount of food maintained in the food supply chain after harvest before it reaches the state in which it is delivered to the consumer. Food losses occur already during the harvest, and continue in all phases of transport, storage, processing of agricultural raw materials into food products, transport and storage of food products. On the other hand, food waste refers to food of adequate quality for food that is discarded before it is consumed, either at the retail outlet, or in a restaurant, or in the household of the final consumer[12].

Stakeholders in agri-food chains, from agricultural producers to the food industry, logistics and food retail chains, face major challenges, such as improving production and all business processes to ensure sufficient affordable food, and on the other foreign satisfaction of the quality of food products in accordance with the sensory preferences of consumers and the policy of overall health and hygiene of food[13]. Therefore, the conceptual framework of agri-food chain performance indicators[14] includes the following *indicators:*

- *Business efficiency* determined by cost management, profit, return on investment, value of assets and share capital.
- *Business flexibility* determined by customer satisfaction, flexibility in quantities and delivery of manufactured food products, number of withdrawn orders and late orders.
- *Business responsibility* determined by the order fulfillment rate, product delivery delays and delivery / delivery errors.
- *The quality of food* determined by the *quality of products* and the *quality of the processes* in which food products are made.

The quality of food products is determined by:

- Sensory properties of food products and shelf life.
- Hygienic and health safety of food products.
- *Reliability* or conformity of an agricultural and food product with its description and declared composition and *suitability* of a food product for use/preparation and consumption[15].

When it comes to agri-food chains in developed countries, *the main stakeholders* in this chain are *suppliers* of raw materials and equipment (both for agricultural producers and for processors of agricultural and food products), *agricultural producers* (farmers), *processors* (food industry), *distributors* (logistics), *shops* (wholesale and small shops), and finally comes the *buyer*, ie the consumer of the food product. Today, in most developed countries, the overall business efficiency of all stakeholders in the agri-food chain, measured by certain indicators, is achieved and improved by using the *Internet of Things* (IoT), ie its main component, *the blockchain*, as the main component of the system which contains all the business logics, implemented through the so-called *smart contracts* entered into the blockchain[16]. IoT and blockchain also enable complete *traceability* within the agri-food chain.

According to the FAO definition, *traceability* is the ability to distinguish, identify and track the movement of food or substances intended to be incorporated into food through all stages of production, processing and distribution[17]. Establishing traceability in the agri-food chain and the food supply chain reduces the frequency of *product recall. Product recall* is defined as the act of removing food from the market at any stage of the food chain, including that held by consumers[18]. This is the ultimate measure implemented to achieve *food safety* and consumer health. Unfortunately, every withdrawal of food products from the market creates food waste. Therefore, in developed countries, especially in EU member states, a *Farm to Fork Strategy* has been created, which includes the disposal of food waste and its use in *the circular bio-based economy*[19, 20, 21]. Thus, agri-food chains, 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[22], 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[23, 24].

1.3 Characteristics of conventional and organic agricultural production according to food properties

Organic agriculture is determined by basic principles such as health, ecology, equity and care for the environment, animals and food consumers[25]. The key principle of organic agricultural production, also called organic farming in Europe, is that only healthy ecological systems can promote the development and sustainability of agriculture[26]. On the other hand, conventional agricultural production systems, which involve intensive cultivation and intensive use of pesticides and mineral fertilizers, tend to impair soil health as they lead to its poor biological, chemical and physical properties[27]. With the increase in environmental awareness, the consumption of organic or ecological food is growing more and more, especially in the highly developed countries of the northern hemisphere, primarily in the EU[28]. The best and most precise definition of organic agricultural production is given in EU Regulation 2018/848 of 30 May 2018[29] and it reads:

"Organic production is a complete system of farm management and food production that combines the best environment of mental and climate action practices, high levels of biodiversity, conservation of natural resources and the application of high animal welfare standards and high production standards in line with growing consumer demand for products natural substances and processes. Organic production thus plays a dual social role, where, on the one hand, it provides a specific market that suits consumers, demand for organic products, and on the other hand delivers publicly available goods that contribute to environmental protection and animal welfare, as well as rural development.

From the preamble of that document, which sets out the basic definition of organic production, it is clear that the terms organic and ecological production are essentially synonymous. This very comprehensive document specifies all the measures and procedures that are allowed in organic food production and clearly defines the measures and procedures that may be implemented in all aspects of organic/ecological food production. It also defines the concept of welfare of domestic animals and bees, reduction and even ban on the use of agrochemicals, especially pesticides and mineral fertilizers, etc.

Unlike organic, conventional agricultural production is a classic agricultural production, exclusively market-oriented, highly intensive, involves the use of pesticides that are allowed for use and the use of GMOs. Propagators of organic agriculture often point out many shortcomings of conventional, industrial and agricultural practices. They require a number of benefits allegedly provided by organic farming. Namely, organic agriculture eliminates chronic and acute exposure to toxic pesticides among agricultural workers, consumers, as well as surrounding aquatic and terrestrial ecosystems. Organic products have higher nutritional value with higher content of vitamins and minerals. It is also claimed that organic products taste better due to higher sugar content, and last longer due to high metabolic integrity and superior cellular structure. Organic cultivation maintains soil health and encourages the development of soil microorganisms, thus facilitating the availability of nutrients to plants. In organic agriculture, mutations that lead to insect resistance to some of the widely used insecticides are reduced. In addition, by reducing the cost of many inputs – including insecticides, herbicides and synthetic fertilizers - organic farming costs less and is economically competitive. Finally, relying on the inputs that exist in nature, organic agriculture offers a more harmonious orientation towards the natural world and as such represents a desirable ethical strategy for humanity. The fact is that some of these claims have been confirmed. In particular, the results of 12 out of 15 meta-analyzes confirm that agricultural products produced in organic agriculture contain more antioxidants, vitamin C and Ω-3 fatty acids than those produced in conventional production. On the other hand, it is an indisputable fact that yields in organic agriculture are up to 34% lower compared to conventional[30, 31].

The question is, can organic farming reduce vulnerability and strengthen the resilience of the European food system?[32]. The answer is simple, not in itself, because none of the appropriate food production strategies need full implementation, but their combined implementation brings sustainable food production and meets the nutritional needs of the population[33]. Namely, the development and wider application of information technologies such as *machine learning (ML)* and the development and application of *artificial intelligence (AI)* in conventional agriculture greatly reduces the use of mineral fertilizers by increasing their effectiveness[34, 35]. In this way, conventional agriculture is transformed into *precision agriculture*[36] in which equal fertilization with mineral fertilizers and application of phytopharmaceutical preparations is not performed on all parts of the production area, but it is carried out selectively according to actual treatment that a certain part of production area needs. In this way, the intake of harmful substances into both soil and crops is reduced and soil contamination and accumulation of residues in agricultural products are greatly reduced.

The main specifics of organic/ecological food production compared to conventional[13] are the following:

- prohibition of the use of GMO seeds,
- prohibition of the use of mineral fertilizers,
- prohibition of the use of synthetic pesticides,
- prohibition of the use of growth promoters,
- maximum allowable annual amount of nitrogen in organic fertilizers of 170 kg N/ha.

Therefore, organic/ecological agricultural production has a clearly defined system of control and certification of agricultural products of organic/ecological origin[29], and *it is necessary to ensure that mixing and processing of organic products after harvest does not interfere with conventional agricultural products.* Otherwise, it will not be possible to ensure traceability in the agri-food chain of organic/ecological products, and thus food products will not meet *the compliance criteria*, which is why they will not be labeled as organic/ecological[37].

1.4 Post-harvest management of agricultural products in agri-food chains

Post-harvest management of technological products is carried out in order to meet quality standards for fresh and processed products in order to meet the prescribed quality standards for agricultural and food products[38] and preserve their shelf life[39]. Therefore, post-harvest management of agricultural products in agri-food chains is an integral part of the overall food *value chain* of a particular agricultural product on the way from the farm to the consumer's table[40].

Post-harvest management measures for agricultural products vary depending on the type of agricultural product. However, depending on the storage conditions of agricultural products after harvest, the texture, taste, color and nutritional composition of a particular agricultural product may change. These changes can progress even to the complete deterioration of certain agricultural products and food products in the further stages of agri-food chains. Spoilage is essentially a process in which all the properties of food quality deteriorate to a level that makes that agricultural or food product inedible for human or domestic consumption[40]. The causes of such spoilage can be:

- harmful microorganisms, which in inadequate storage conditions lead to contamination by bacteria and mold;
- storage pests, most often insects and mites;
- rodents and birds.

Cereal crop products of cereals and legumes after harvest go through the following stages:

3. Transport from the field to the silo.
4. Cleaning the batch of granular field product from post-harvest residues of chaff, spindle, pods, remnants of stems and seeds of weeds, dust, etc.
5. Drying of a batch of granular product (if necessary) in flow dryers[41].
6. Cool the batch of granular product after drying.
7. Charging silo cells.
8. Storage and monitoring of granular field product in silo cells during storage.
9. Exclusion of a batch of granular agricultural product from silo cells and transport to the processor, ie the mill industry and the feed industry.

However, it should be noted that due to the specifics of organic/ecological agricultural production, farmers are greatly limited in the application of storage pest control measures. Physical methods of storing storage pests such as the use of CO_2 and/or inducing low temperatures in silos that do not favor the development and reproduction of storage pests are most commonly used[42, 43], while chemical methods of controlling storage pests may be used in storage of granular products, produced in conventional breeding.

In fruit and vegetable production, post-harvest management includes:

- cleaning,
- washing,
- selection,
- ranking,
- disinfection,
- storage of batches of agricultural products most often in ULO (*ultralow oxygen*) cold stores[44],
- packaging and transport to consumers,
- or drying or deep freezing, and packaging of dried or frozen product and transport to consumers.

Also, in the preparation of fruits and vegetables for the storage process as well as during storage, mixing of lots of fruits and vegetables produced in organic or conventional cultivation may also occur.

It should be noted that during post-harvest food management, most of the food losses in the production-process agri-food chain occur. These losses refer not only to losses of certain quality properties[38, 39], but also to quantity. Losses in the quantity/weight of granular agricultural products occur most often during the transport of agricultural products and in the case of poorly implemented monitoring measures of stored agricultural products, resulting in contamination of stored agricultural products with mycotoxins. Losses in the amount of agricultural products relate to the breaking of cereal grains and legumes, or to the sludge or loss of water in fruits and vegetables. However, mycotoxin contamination is a growing problem these days. Namely, depending on the conditions during the vegetation of a particular crop or plantation that may favor the development of harmful fungi, most often species of the genus *Fusarium* and *Apergillus*, there is the formation of their secondary metabolites called mycotoxins. Mycotoxins have a bad effect on the health of humans and domestic animals and can often cause acute poisoning in animals and also chronic poisoning in humans. Through the food chain from plant foods and products of animal origin mycotoxins end up in the human diet because *the mycotoxicological chain completely coincides with the food chain*[45]. However, proper post-harvest management, which includes analysis of batches of agricultural products coming from the field, prevention measures and the application of modern technological measures for successful storage of agricultural products, preventing the development of pathogenic fungi of *Fusarium* and *Apergillus*, the amount of mycotoxins can be reduced[46, 47, 48].

Therefore, post-harvest management in the agri-food chain is extremely important for ensuring hygienic and healthy food, for reducing food losses and thus for achieving business efficiency, because every loss of food inevitably means financial loss in the food value chain.

1.5 Animal welfare in the agri-food chain

Animal welfare has lasted since the domestication of domestic animals until today, and its basic intention has never changed. Animal welfare can be defined as the state of domestic animals without:

- pain,
- suffering
- and stress[49].

On the protection of animals kept for production purposes, the Council of the European Union in 1998 adopted Directive no. 98/58/EC on the protection of animals kept for agricultural production [50], and also the conditions for keeping and feeding animals are clearly described in the already mentioned European Commission Regulation no. 889/2008 on organic production[37].

Animal welfare is assessed on the basis of the following parameters:

- It is evident that the animals have access to water and food and are not malnourished.
- The animals have adequate housing conditions and the number of animals per unit of floor area does not exceed the prescribed limits.
- Animals have good veterinary care and prevention measures are implemented, and if necessary, treatments for injuries and treatment of diseases.
- Animals have enough space and adequate conditions to manifest their normal forms of behavior.
- Animals do not show fear of humans.

As already mentioned, animal welfare is of paramount importance in organic/ecological production[37]. However, it is given great importance also in conventional livestock production, entirely for economic reasons, ie to reduce losses such as animal deaths or transport to unplanned slaughter. Unfortunately, some livestock producers will not increase animal welfare, even if the lack of animal welfare directly causes losses in production[51]. However, depending on government legislation and customer requirements, large conventional farms will invest in animal welfare [52]. In particular, if stress conditions occur during animal loading, transport, and if animals do not recover adequately before slaughter, meat quality declines greatly as animal blood stress indicators increase, resulting in decreased muscle glycogen reserves and increased pH value[53].

One of the great challenges for conventional animal husbandry is the restriction of the use of antibiotics, ie their complete ban on their addition in the process of animal feed production[54]. Namely, since Sir Alexander Fleming discovered penicillin from 1937 until today, the consumption of antibiotics has been growing exponentially, and the consequence of this is the emergence of microbial resistance to antibiotics. Namely, for decades, antibiotics have been used as feed additives, which has led to the resistance of many pathogenic bacteria to them, and through animal products (meat, milk and eggs) antibiotics have accumulated in humans, resulting in the emergence of resistance of certain strains of pathogenic bacteria in the human population[55].

Examples of antibiotic resistance and the mycotoxicological chain best illustrate the importance of the link between the agri-food chain and food safety.

1.6 Traceability in the agri-food chain

There are several definitions of *traceability*, which refer to different types of raw materials, additives, food products, or processes[56]:

- *Lot traceability* involves identifying the lot and determining its origin (eg country of origin, location of producers and quantities) as well as tracking all information about the material (eg 'where' and 'where it is used'). The traceability of the batch strictly corresponds to the production costs and is easy to establish by following not only the product and/or raw material declarations, but also the incoming invoices, delivery notes, customs declarations and other documentation.
- *Food traceability* can be defined as a set of all the information necessary to know the history of the production of a particular food and to know each stage of the transformation that food has gone through from the grower to the consumer's table (from farm to fork).
- *Traceability* involves the monitoring of food, animal feed, food of animal origin and all substances through all stages of production and distribution.
- *Traceability* is the ability to track the movement of a food product and its ingredients up and down the food chain to prevent unsafe food from reaching consumers[57].

In order for traceability to be successfully implemented, certain minimum requirements need to be met:

1. Identification of food business operators;

Namely, at the time of submitting an application for registration of food business for domestic or imported food, in accordance with the Food Safety Act, the food business entity must include the following information relevant to traceability, among other application requirements that may be prescribed:

- name of the food business operator and contact details,
- information on the identification and registration of the company,
- name and contact details of the person responsible for traceability,
- address and telephone numbers of all locations registered within the business,
- shelf life or product shelf life,
- methods of preserving and storing products,
- country of origin, in the case of imported food,
- manufacturer or exporter in the case of imported food,
- food traceability management plan of the food business operator.

Furthermore, each food business operator shall keep records to identify any party that has supplied the food business operator or to which the food business operator supplies food or any substance intended to be incorporated into the food business, and shall provide information for persons in charge of monitoring the traceability of food to the competent authority.

2. Identification and marking;

Food business operators need to determine what needs to be monitored. This is usually called a *traceable item / unit.* The following item can be:

- packaged product or item being traded (eg box / carton, consumer item),
- logistics unit (eg bucket, container),

- the shipment or movement of a product or trade item.

All traceable items must have a label affixed to the package with the following information in the latest, most accurate and legible form:

- food business identification number and brand name,
- a description of the type of article according to the brand name (if applicable) and according to the specific variety (eg brand: Trappist cheese, not only cheese; Roma salad, not only lettuce),
- product manufacturer, producer or processor,
- lot/batch number,
- code to indicate the date, as required by relevant legislation (eg best by, harvest, packaging, production or expiry date) and
- quantity.

3. Preservation of documentation;

All documentation involving the sale or transfer of a traceable unit must contain the following information:

- name and contact details of the supplier or customer or trading partner, including the food business identification number,
- a description of the traceable item, including the brand name, where applicable, and the specific variety or type of food,
- the batch or batch number or other specific identifier of the traceable unit, including the date of harvest or the standard bar code for products intended for retail sale,
- quantity and packaging information,
- price per unit or weight.
- date of business transaction.

4. Chain of custody[1]

Traceability system has to:

- enable identification of the product by product ID, batch/series and relationship to identification and batch / serial number of ingredients, raw materials and packaging in direct contact with food or packaging intended or expected to be in direct contact with food;
- be able to be tracked from the customer through all stages of processing to the supplier of ingredients, raw materials and primary packaging materials, including transport;
- be able to be tracked from suppliers of ingredients, raw materials and primary packaging material through all stages of processing to the customer, including transport.

Finally, if any non-compliance is identified in the agri-food chain, the last and most drastic phases follow, and that is.

5. Product recall

Product recall is performed according to the Product Withdrawal Strategy, which contains the following elements:

- the level of recall, which can be at the level of wholesale, retail or even households,
- the content of the public notices to be issued depending on the classification and the seriousness of the reasons for the recall,
- in emergencies, a public warning issued across the country or affected geographical areas,
- the level of verification of effectiveness, which includes the method to be used to verify the effectiveness of in – depth recall and
- disposal of withdrawn products.

The following factors must be taken into account when designing any product recall strategy:

[1] According to ISO 22095 - The storage chain is described as “a simple solution” designed “to increase the confidence of producers and consumers, reduce supply chain costs by addressing issues such as risk, loss of time and production conditions.” Link: https://www.iso.org/news/ref2574.html

- health risk assessment,
- type or use of the product,
- ease of product identification,
- the degree to which the lack of product is obvious to the consumer or user,
- the amount of product that remains unused on the market,
- distribution schedule and
- constant availability of basic products to consumers, in order to reduce the negative consequences through a drop in demand for the product in question.

Finally, it is quite clear that the traceability system is based on the entire consumer safety of a particular food product in the agri-food production and distribution chain, and the value chain, as described in ch. 1.2.

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