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THE SUSTAINABLE CONSUMPTION OF FOOD PRODUCTS AS A COMPONENT OF MODERN ENVIRONMENTAL SECURITY

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Abstract. *The food system of the modern world faces difficult and large-scale challenges, among which the issue of sustainable consumption and reduction of food waste occupies a special place. The growth of the world population, climate change and high levels of consumer activity are putting natural resources and the environment at risk.*

This paper examines the use of sustainable practices in the agricultural sector, the food industry, logistics, retail trade and the catering sector to encourage more efficient use of resources at all stages of food production, transport and consumption.

The main approaches to sustainable food consumption include expanding composting practices, using food waste for biogas production, increasing the efficiency of processing food waste in agriculture and expanding food redistribution initiatives through charities and food banks, changing consumer behavior and raising their awareness of proper food storage, using food waste and conscious consumption, innovative food processing technologies.

Measures to reduce waste and promote sustainable consumption must become an indispensable and priority part of the strategies of governments, businesses and citizens.

Key words: *food waste, food losses, zero-waste production, shelf life of products.*

Introduction.

The rapid increase in food waste worldwide is a serious environmental problem that threatens the sustainable development of food systems and environmental protection [1, 2]. According to the European Commission, more than 88 million tonnes of food are thrown away in the EU countries annually, which leads to the irrational use of natural resources, significant economic losses and increased environmental threats. Food loss contributes to the growth of greenhouse gas emissions, as food waste forms methane during decomposition, which is one of the most powerful factors of global warming [3, 4]. At the same time, reducing waste will not only reduce the environmental burden, but also contribute to a more efficient distribution of food and strengthen global food security.

With 735 million people at risk of hunger [5] and 2.5 billion people living with



malnutrition [6], the food system requires an unprecedented transformation to feed the world's population, which is expected to reach 10 billion by 2050, on a fair and sustainable basis [7].

1. Key principles of the European Green Deal on reducing food waste

The European Green Deal (EGD) is a set of measures for Europe's green transition to a climate-neutral continent by 2050. These measures are driven by global challenges such as climate change, pollution and biodiversity loss, and, consequently, the EU's positioning as a global leader. [8]

The principles of the circular economy supported by the EGC aim to reduce waste and transition to a circular economy [9-11]. This involves the introduction of resource recovery technologies, the development of environmentally sound production models, and the implementation of strategies for sustainable consumption [11-13]. Responsible handling of food products and their residues can significantly reduce waste levels and help reduce the need to grow new food crops, which in turn reduces pressure on agricultural land.

The main objective of the Green Deal is to achieve a balance between economic growth and environmental responsibility, which entails the modernisation of all sectors of the economy, including industry, energy, transport and agriculture [9].

Although the Green Deal is not a legislative act in itself, it lays the foundation for future legal regulation of sustainable development in EU countries. In the food sector, this means a transition to more environmentally friendly and efficient production systems, encouraging the use of reusable packaging materials, supporting local producers who adhere to the principles of sustainable development, and promoting responsible attitudes towards food consumption among the population [11-16]. The application of the EGD principles in the food sector opens up new opportunities for reducing food waste, lowering the environmental impact and enhancing food security, making this strategy a vital tool for achieving sustainable development both within the EU and globally. The Ukrainian government has announced the country's intention to join the EGD [17], which is linked to Ukraine's relatively high level of integration into the European space in certain sectors of the economy.



2. Strategies for minimising production waste

The production of crops and livestock involves the use of significant amounts of natural resources, such as water, land and energy, as well as chemical fertilisers and pesticides, which can pollute the environment. Greenhouse gas emissions during food production mainly originate from methane, nitrogen oxides and carbon dioxide, which are generated during soil cultivation, animal feeding and the use of agricultural machinery [18]. All these factors place a significant burden on ecosystems, reduce biodiversity and lead to the degradation of natural resources.

The «Farm to Fork» strategy aims to reduce pesticide use by 50% and fertiliser use by 20%, while maintaining soil fertility at the same level. Another key objective is to ensure that crop yields per hectare are not reduced. These ambitious goals meet the requirements of environmental sustainability and economic efficiency in the agricultural sector.

One approach gaining popularity in the field of sustainable production is the optimisation of production processes to minimise resource losses and waste, using all components of the product as efficiently as possible [19, 20]. This approach involves avoiding the wastage or disposal of resources, thereby reducing the negative impact on the environment and improving economic efficiency.

For example, in the production of juice or canned fruit, not only the pulp can be used, but also the peel, seeds and other parts of the fruit [21]. Fruit peel, which is usually discarded, can be used as a raw material for the production of various desserts, beverage additives, and organic flavourings. This allows for the most efficient use of all parts of the product, reducing costs and, importantly, reducing the amount of waste that ends up in landfills.

The concept of zero-waste production has been widely promoted as part of the Cradle to Cradle initiative [22], according to which all products can be either recycled or regenerated without harming the environment.

Studies [2, 13, 23, 24] have shown that optimising material use in production processes and reducing waste are important aspects for improving efficiency and reducing costs in the long term.



Another aspect of zero-waste production is the use of waste recycling technologies. For example, biomass generated during food production can be used to produce biofuels or fertilizers [25, 26]. The processing of biomass into biofuels can also become an important element in the fight against global warming, replacing traditional fuels that contribute to carbon dioxide emissions.

The use of organic waste as fertiliser reduces the need for synthetic fertilisers, thereby lowering soil and water pollution.

Integrating circular approaches into production processes contributes to a significant reduction in CO₂ emissions and improved resource efficiency in industry [1, 4, 11].

Managing the agri-food supply chain, which has become more complex and multi-layered, requires an integrated approach to decision-making. Researches [14, 27–29] emphasize the need to optimise transport routes, improve logistics and refine packaging to minimise losses during transportation.

The paper [30] highlights the potential of using the latest digital technologies, such as artificial intelligence, blockchain and the Internet of Things, to improve the management of food supply chains. These technologies enable the monitoring of storage conditions, predicting product shelf life and managing inventories more effectively.

When formulating management strategies, it is important to take into account the specific shelf life of processed products. Indeed, products may have different storage lifespans, which significantly influences logistics and storage strategies [31]. In particular, there are long-life products (e.g. cereals, pulses, etc.) and perishable products (e.g. fruit, vegetables), for which different storage and transportation methods must be applied.

As for the types of agri-food supply chains, they can be both raw material-based and processed. The choice of strategy for each specific case depends on a number of factors, including economic and environmental constraints. In the case of processed food products, value is added through preservation, portioning and further processing of the products.



One of the key aspects is the concept of «food losses», which refers to food products lost during production, post-harvest handling and processing. This may include unnecessary losses caused by inefficient use of resources or improper storage of products, leading to spoilage before they reach the consumer.

On the other hand, food losses at later stages of the supply chain are referred to as «food waste». This refers to food that is discarded after it has reached the end consumer or the retail sector, even if it is still safe to eat. Food waste arises due to various factors, such as incorrect storage, products exceeding their use-by date, inefficient meal planning, and low consumer awareness regarding the correct interpretation of product use-by dates.

Such losses and waste have serious environmental consequences, in particular affecting the use of resources such as land, water and energy expended on food production and transportation [32].

The authors in studies [33, 34] emphasise the importance of implementing comprehensive programmes and policies in the service sector aimed at reducing food waste.

Food waste in the service sector, particularly in restaurants and cafes, consists largely of leftovers from plates after meals. One of the main causes of this waste is customers ordering excessively, often ordering more than they can consume, as well as the large portion sizes offered by restaurant operators. This situation is the result of a specific marketing strategy, whereby large portions are served for almost the same price as smaller portions. This allows restaurants and cafes to create the impression that consumers are getting more food for their money, which, in turn, often attracts more customers.

At the same time, many consumers view the large-portion strategy as a good deal, as they believe they are getting more product for the same money. However, this approach does not always meet customers' actual needs, as not everyone is able to consume such a quantity of food in one sitting. As a result, a large portion of the food remains on plates, leading to significant food waste. As studies show [33–35], some of this waste is not only lost but also results in unnecessary costs for restaurants.



Furthermore, this practice of increasing food waste causes environmental problems, as this waste is often not subject to effective recycling and disposal, thereby increasing the burden on the environment.

Food promotions, particularly «buy one, get one free» offers, as well as low food prices, can also contribute to increased food waste, as consumers purchase more food than they can consume, ultimately leading to a significant amount of unnecessary expenditure and waste [36].

Food labels can play an important role in promoting sustainable food consumption and reducing waste. Modern food labels often state only the date by which the manufacturer believes the product is best consumed, rather than the date until which the product remains safe to eat. However, most consumers lack sufficient knowledge and often assume that food is safe only until the stated use-by date. This leads to even products that are still edible often being thrown away [37, 38].

To reduce food waste, the authors [37, 38] propose improved consumer information regarding the actual shelf life of a product, based on scientific research into the preservation of product quality beyond the dates stated on labels.

3. Technological solutions that extend the shelf life of products

Research conducted by the authors [39–41] has shown that the correct use of preservation methods, such as freezing, vacuum packing, temperature control, modified atmospheric packaging, etc., can significantly reduce food waste. The use of these technologies allows the quality and nutritional value of products to be preserved for a longer period, which is critical for reducing losses in the supply chain.

Ultrasonic treatment involves the use of ultrasonic waves to destroy microorganisms and preserve the freshness of food products [42, 43]. Ultrasound is used to treat fruit, vegetables and juices, which significantly reduces the level of microbiological contamination and extends their shelf life. Ultrasonic treatment also helps to improve the texture and taste properties of products, whilst preserving their nutritional value.

The use of natural antioxidants is essential for prolonging the freshness of products [44]. Vitamin C (ascorbic acid) is an effective means of preventing oxidation



and spoilage of products such as fruit, vegetables and juices. It helps to preserve the taste, colour and nutritional value of products, reducing losses due to spoilage and decreasing the need for artificial preservatives.

Modified atmospheric packaging, replacing the air in the packaging with other gases, such as nitrogen or carbon dioxide, significantly extends the shelf life of products such as meat, fish, fruit and vegetables. This process helps to preserve the freshness of products by reducing their interaction with oxygen, which is the main factor contributing to the growth of microorganisms and spoilage [45, 46].

Cold pasteurisation uses high pressure to destroy pathogenic microorganisms in food products without using high temperatures. Cold pasteurisation includes a group of methods, such as cold plasma, pulsed electric fields, ionising radiation, ultraviolet irradiation, high hydrostatic pressure, and others. Cold pasteurisation helps to preserve the taste and nutritional properties of products, as it does not lead to the loss of vitamins or changes in the texture of the products [47, 48]. It also reduces the risk of spoilage and increases their shelf life without the use of preservatives.

Fermentation is a natural method of preserving food, which also enhances its health benefits [49, 50]. The use of enzymes in the production of foods such as yoghurt, sauerkraut and soy sauce not only extends their shelf life but also preserves their nutritional value. Fermentation also enhances the beneficial properties of foods, improving digestion and reducing waste, as a significant portion of the waste generated in this process is used to create new products.

The use of high-quality packaging materials is an equally important step in ensuring the preservation of the quality of food products [29, 31, 51]. The use of airtight, multi-layer and antibacterial packaging can significantly reduce product spoilage and extend shelf life. High-quality materials provide reliable protection against external factors such as moisture, air and microorganisms, which helps to reduce waste.

The application of nanotechnologies to improve packaging quality and preservation methods using nanoparticles enables the creation of more effective food preservation systems [52, 53].



Overall, the application of these technologies not only allows food quality to be maintained for a longer period but also reduces the level of waste resulting from food spoilage.

Conclusions.

Sustainable food consumption and waste reduction are key factors that determine the future of the food system. In the face of global environmental challenges, such as climate change and biodiversity loss, improving resource efficiency in the food industry is an essential step towards ensuring environmental sustainability.

To achieve sustainable food consumption, it is important to implement effective waste reduction methods at all stages of the supply chain – from production to consumption. This includes the application of modern technologies such as ultrasonic treatment, the use of natural antioxidants, modified atmosphere packaging, cold pasteurisation, fermentation and the use of high-quality packaging materials. These innovative solutions not only preserve the freshness and quality of food products but also significantly reduce the amount of waste that causes environmental stress. It is also important to note that these technologies promote resource conservation, reduce energy costs and lower emissions, making them economically advantageous.

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