Reducing environmental impacts in the food chain for sustainable development of megacities

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Abstract. Today about a third of food produced for human consumption in the world is lost or wasted. The huge amounts of resources used for food production are wasted and the carbon footprint of food that was produced and lost reaches 3.3 billion tons of CO$_2$ per year. In monetary terms, the losses are estimated at $7.5 trillion. The importance of reducing food loss and wastage is reflected in the Sustainable Development Goals (SDGs) and commits to cut in a half food waste. Based on the available statistics, the paper analyses the food losses in the food chain as well as related environmental impacts and possible economic savings.

1. Introduction
It is estimated that today about a third of food produced for human consumption in the world is lost or wasted [1]. It is about 1.3 billion tons per year [2]. It also means that the huge amounts of resources used for food production are wasted and the carbon footprint of food that was produced and lost reaches 3.3 billion tons of CO$_2$ per year. In monetary terms, the losses are estimated at $7.5 trillion. The importance of reducing food loss and wastage is reflected in the Sustainable Development Goals (SDGs) and commits to cut in a half food waste. It will be a vehicle for achieving other SDG targets in the fields of food security, nutrition, and environmental sustainability [1].

The population is growing, the urbanization of countries and cities is increasing, the speed of economic development is increasing too. The rate of worldwide waste generation will only increase. For megacities, waste management issues are of high priority, especially with municipal solid waste, because the decomposition of food waste generates major problems in urban landfills: organoleptic discomfort, landfill gas and spontaneous combustion, soil and groundwater pollution, and synanthropic species at the landfills. Food waste attracts many synanthropes to urban landfills, including rats, cockroaches, flies, and birds. Their vital activity poses a threat to human health: insects become carriers of various diseases.

Reducing the volume of food waste and losses in the existing food chain is becoming an important condition for sustainable urban development.

The aim of the work is to identify the causes of the occurrence and find the most effective solutions to stimulate the reduction of food waste.

2. Methods
The existing food chain was analysed in this article based on available statistical sources. Data from the World Bank, Rosstat, the Higher School of Economics, and the Moscow School of Management “Skolkovo” were used for this. The collected data allowed us to estimate the volume of municipal solid waste produced in Russia and the share of food waste and losses in it. This will help reducing the
environmental impact of this waste. Data from the World Resources Institute (WRI) were used to assess the cost-effectiveness of reducing the amount of food waste produced.

The chain of creating food products for megacities (Fig. 1) includes the stages of growing food raw materials of plant and animal origin, storage, processing, transportation, sale, and consumption of finished food products in households and public catering organizations [3]. At each of these stages, a part of the products is lost for various reasons, CO₂ emissions are produced, and resources are consumed for transportation. More food is lost and wasted in the longer production chains. The longer the chain, the more food is lost and wasted. The closer to the stage of consumption food is lost and wasted, the higher the environmental impact becomes, because it has been accumulated at each of the previous stages of the supply chain.

![Figure 1. Environmental impacts in the food chain.](image)

Food losses – decrease in the quantity or deterioration of the quality of food for human consumption, expressed in nutritional value, economic value, or food safety.

Food waste – portion of food losses that arises from the discarding or alternative (non-food) use of nutritious and safe food for human consumption throughout the food supply chain.

Determination of the structure of food losses and the formation of food waste largely depends on the country, region, and products. The causes of food losses are complex. In developing countries food is lost to a greater extent at the stage of agricultural production, collection, and storage, because of technical, financial, and structural constraints – about 54% of world food waste.

In developed countries, in megacities, food is thrown away mainly at the stage of retail trade and consumption. The losses arise from decisions and actions in the chain of producers, food suppliers, retailers, food service providers, and consumers – about 31-39% of world food waste. The main driving force behind the generation of food waste here is consumer behaviour.
Retailers need to satisfy customers, that is why there are high standards of quality and appearance of food products, too large assortment of goods, and an excess of perishable goods in warehouses. In turn, the consumer increases the amount of waste due to improper purchase planning and food handling.

Experts note that the volume of food losses in various sectors of the economy are difficult to estimate due to the lack of reliable statistical information. Information based on data from the Ministry of Agriculture of the Russian Federation tells us that about 8.22 % of food products is lost during the agricultural production stage, 3.41 % – during transportation to the place of processing, and near 8.72 % – during processing [4]. At the stage of retailing, the volume of losses is about 5%, during storage and logistics – 4.33 %. The biggest losses, almost 12 %, are at the consumption stage, in households. About 41.3 % of the total food turnover in the Russian Federation falls on losses. More than 20 % comes from agricultural production, processing, and transportation of products, 9.2 % is lost at the stages of storage and sale of the original volume of food, and 11.8 % is thrown away by consumers (Fig. 2).

![Food waste and losses in total food turnover in Russia](image)

According to the Retail Trade Association, about 700,000 tons of food waste per year are overdue from stores. Losses of food products are on average estimated at 2–6% of retail turnover.

Almost all this volume of food waste ends up in landfills, where it becomes a source of soil, water, and air pollution. The specified volume of food waste, 17 million tons, emits about 2.4 million tons of methane, plus ammonia and hydrogen sulphide. The most important environmental impacts associated with food loss are: unsustainable land use, waste of energy, eutrophication of water bodies, excess water use, ecotoxicity from pesticides, and climate change associated with methane generation.

In Russia, about 60 million tons of municipal solid waste is generated annually [6]. In megacities, about 30% of their composition is food waste, this is about 17 million tons per year. The cost of these products is estimated at more than 1.6 trillion roubles. This is equivalent to 12% of retail food turnover in Russia and 1.58% of Russia’s gross domestic product (GDP) as of 2018 [4].

Reducing and preventing food waste throughout the food chain is essential to improving the efficiency of the food system. This directly affects the final cost of products for the consumer.
3. Results
The development of the most effective methods of dealing with the increase in the volume of food waste and losses requires identifying all the factors contributing to their formation at each stage of the food production chain.

These factors include:
- for the agricultural stage – losses from diseases, weather, or pests, inaccessibility of modern cultivation methods, backward collection technologies and associated mechanical damage, losses due to quality standards (shape, colour, size, and ripeness), overproduction of individual producers for guaranteed supplies, financial and structural constraints of farmers, and the impossibility of selling at market prices;
- for processing and transportation stage – long distance for transportation in the context of the globalization of trade, damage during storage and transportation (damage to packaging, non-compliance with storage conditions), backward warehouse and transport infrastructure;
- for storage and retail stage – staff’s mistakes while ordering and processing, products suitable for consumption, but with an expired shelf life on the label, the operation of inflated aesthetic and quality standards;
- for consumption in households and catering establishments – incorrect interpretation of expiration dates, improper purchase planning and mishandling, improper storage, leftover food waste (preparation of new food before the previous one is eaten) [2].

As the most perspective, we can highlight the following ways to reduce food losses and food waste:
- optimization of the entire food production chain: introduction of full-cycle technologies, maximizing the benefits from by-products of production;
- overproduction prevention – establishing communication and cooperation between farmers;
- optimization of the retail stage: reduction of the variety of goods in retail chains and government incentives for the transfer of unclaimed food for further use;
- localization of production of products and reduction of the length of the supply chain;
- educational campaigns to raise consumer awareness of food waste and financial losses from wasteful spontaneous shopping;
- private initiatives – distribution of food to people in need, instead of recycling;
- energy use of food waste: biogas production.

Reducing food losses will require the participation of government agencies and significant investments in improving production technologies, transport, and logistics infrastructure as well as organizational measures for accounting and control of material flows, working with manufacturers and consumers.

For truly positive impact, it is necessary to educate all participants in the food chain about the benefits they will receive from reducing food losses and waste.

The main advantages for farmers are increasing economic efficiency by reducing the amount of unused raw materials, sale of unclaimed by-products to interested market participants, an increase in the quality of food, and improving the reputation among investors and consumers. Increasing the availability of food products and improving their quality are the main interests for consumers [5].

According to the World Resources Institute (WRI), there are benefits for retailers also from investing in reducing food waste. Companies spend money on audits identifying the amount of losses and identifying problem links in production chains. They also invest in changes in the technological process (purchase of equipment to eliminate identified deficiencies, improvement of food storage systems, change in technology and techniques for packaging products to increase shelf life) and work with staff (training or hiring new staff in order to reduce product losses) [7].

Retailers will receive profit from refusing to purchase problem products, increasing the part of sold products, reducing the cost of disposing of garbage and waste, reducing staff’s cost, using new models of business process management, non-financial results, such as increased consumer loyalty, strengthening of corporate culture and communications with partner companies [8].
Financial gain is not the main factor that motivates companies around the world to develop their own food loss prevention programs. Several companies in different countries are developing their own programs to prevent food loss. The main reason is the desire to contribute to the achievement of food security and reduce the impact on the environment.

4. Conclusion
The need to solve and update the topic of food losses and develop activities for the management of organic waste requires a cross-sectoral approach. This approach should be based on complementary interventions in agriculture, ecology, healthcare, industry, trade, and other areas related to sustainable development. It is necessary to involve all stakeholders, including representatives of federal executive and legislative bodies, intergovernmental organizations, the private sector, the scientific community, and the public, as well as building active interaction between them.

Reducing environmental impacts in the food chain will require a set of measures, such as creation of educational programs in schools and universities, with an increased emphasis on the socio-economic and environmental components of sustainable development. Special attention should be paid to increasing the efficiency of agricultural sector, food and processing industries, development of transport logistics, farms near cities, improvement of ecological efficiency of restaurant industry, and the environmental modernization of the packaging industry. Such a comprehensive system of measures will reduce the pressure on the environment and ensure a positive effect in the economic and social sphere by saving money for farmers, companies, and households.

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