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POTENTIAL FOR APPLYING CIRCULAR ECONOMY PRINCIPLES IN COMPOST PRODUCTION IN SERBIA

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Abstract: *Changes in today's socio-economic systems highlight the importance of addressing environmental issues, applying the principles of sustainable development, increasing the significance of renewable energy sources, and reducing resource exploitation. The concept of sustainable development represents a new long-term development approach, strategy, and philosophy of social progress, based on the Green Deal (2019) adopted by the European Commission. The circular economy represents the most significant model of sustainable development in Serbia, offering solutions for resource optimization, waste reduction, and increased economic efficiency. As one of the priorities of the Western Balkans Agenda (2020), its development can contribute to strengthening environmental awareness, improving industrial processes, and creating new jobs through innovative and sustainable business models. The implementation of the circular economy involves investments in green technologies and education, as well as the adoption of appropriate measures to fully harness its potential in the context of Serbia's economic and environmental progress. Compost production can be one of the key applications of the circular economy in the Republic of Serbia, aiming to reduce food waste. Research indicates that domestic compost producers have access to approximately 180 tons of food waste. The total waste generated by the HORECA sector is estimated at 40 kt, with around 99% of food waste ending up in landfills, according to 2018 data. The potential of applying the circular economy to compost production lies in raising awareness about food recycling and redirecting larger amounts of food waste toward compost production, contributing to environmental protection and reducing the number of landfills with harmful effects. The aim of this paper is to highlight the potential applications of the circular economy in compost production in the Republic of Serbia. Based on this, the paper consists of three parts, in addition to the introduction and conclusion. The first part emphasizes the importance of sustainable development in Serbia, while the second part discusses the significance and opportunities of the circular economy. The third part focuses on the potential application of the circular economy in compost production. Finally, concluding remarks are provided.*

Keywords: *Potential, application, circular economy, compost, Serbia.*

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Classification JEL*: Q53, Q56, O13.*

1. Introduction

Instead of the traditional linear consumption model, the circular economy strives for more efficient use of resources through the reuse, recycling, and regeneration of materials (Tošković et. al. 2023). The implementation of the circular economy involves investments in green technologies and education, as well as the adoption of appropriate

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measures to fully exploit its potential in the context of Serbia's economic and environmental progress.

This concept enables waste reduction, more efficient use of resources and a transition to sustainable production models, thereby stimulating innovation and opening up new business opportunities. In addition, cooperation between state institutions, industry and the scientific community plays a key role in creating a favorable environment for the development of the circular economy, which contributes to overall economic growth and environmental protection.

The aim of this paper is to highlight the potential applications of the circular economy in compost production in the Republic of Serbia. Based on this, the paper consists of three parts, in addition to the introduction and conclusion. The first part emphasizes the importance of sustainable development in Serbia. The second part discusses the significance and opportunities of the circular economy. The third part focuses on the potential application of the circular economy in compost production.

2. The first part emphasizes the importance of sustainable development in Serbia

The circular economy represents the most significant model of sustainable development in Serbia, offering solutions for resource optimization, waste reduction, and increased economic efficiency. Sustainable development in Serbia (Đorđević et al., 2024; Ignjatović, Đorđević, 2023a) is of key importance for economic growth, environmental protection and improving the quality of life. Serbia faces challenges such as pollution, climate change and unsustainable use of natural resources, which is why sustainable development strategies are focused on environmental protection, energy efficiency and circular economy (Misija OEBS-a, 2017).

As one of the priorities of the Western Balkans Agenda (2020), its development can contribute to strengthening environmental awareness, improving industrial processes, and creating new jobs through innovative and sustainable business models. Furthermore, investing in green infrastructure, renewable energy sources and the digital transformation of the economy enables long-term economic stability and greater competitiveness of Serbia in the global market. The implementation of these measures contributes to improving the quality of life of citizens, preserving natural resources and achieving climate goals in line with international standards (European Commission, 2020).

The Circular Economy Roadmap for the Republic of Serbia is a document of importance for circularity and sustainable development in the Republic of Serbia. The environment would through CE: reduce waste, reduce gas emissions, preserve natural resources and improve energy independence and the use of renewable energy sources (Ignjatović, Đorđević, 2023b). In addition to the environmental benefits, the development of a circular economy creates new economic opportunities by improving the competitiveness of domestic companies and creating new jobs in sustainable technology sectors. Investing in innovation, recycling and energy efficiency contributes not only to environmental protection but also to stable economic growth (Kalkan, 2022). In order to successfully implement this strategy, it is necessary to strengthen cooperation between the public and private sectors, as well as invest in educating citizens about the importance of responsible consumption and sustainable practices. Also, alignment with the goals of the United Nations Agenda for Sustainable Development contributes to European integration and the country's long-term prosperity.

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Figure 1. Circular economy – waste as a resource
Source: Kalkan, 2022

3. The second part discusses the significance and opportunities of the circular economy

The implementation of the circular economy principle contributes to the development of the agricultural and food market (Ignjatović et. al, 2024) in Serbia. In addition, it includes long-term sustainability, through the preservation of soil fertility, the protection of water and biodiversity, and the reduction of negative environmental impacts (Blagojević et al., 2024).

Agrarian policy in the field of agriculture and rural development is a complex system (Ignjatović et. al, 2024), which can use the circular economy and thus be competitive. However, agrarian policy needs to be strengthened and implemented first (Bajagić, Ignjatović, 2025).in order to follow Western trends. Only some of the recommendations for the development of the circular economy in rural areas in Serbia refer to:

- The existence of infrastructure prerequisites is essential for the quality of life and standard of living of residents in rural areas.
- The development and implementation of organic and circular agriculture is essential for the future development of rural areas in the Republic of Serbia.
- The high level of independent food production shows the potential of production in rural areas.
- Low level of independence and self-reliance of residents in the production of energy necessary for heating.
- It is necessary to increase the level of activity of the population in the work of the local community, groups of citizens or associations dealing with rural issues.
- It is necessary to increase the level of knowledge and awareness of the latest developments in agriculture and rural tourism, through the implementation of education.
- It is necessary to increase the quality of the environment through the reduction of waste, changes in transport and waste disposal.
- Increase the number of waste recycling facilities, which is crucial for environmental quality and local regional development.

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- Insecurity, lack of information and inadequate training of residents for investment, threaten the transition to organic agricultural production.
- Necessary reorganization of subsidy distribution at the state level.
- Introduction of the E-agrarian platform by the state.
- Increase the availability of preschool and school facilities in rural areas.
- Increase the availability of health stations in rural areas.
- Increase the availability of organized public transportation in rural areas.

3. The third part focuses on the potential application of the circular economy in compost production

Compost production can be one of the key applications of the circular economy in the Republic of Serbia, aiming to reduce food waste. Research indicates that domestic compost producers have access to approximately 180 tons of food waste. The total waste generated by the HORECA sector is estimated at 40 kt, with around 99% of food waste ending up in landfills, according to 2018 data. The potential of applying the circular economy to compost production lies in raising awareness about food recycling and redirecting larger amounts of food waste toward compost production, contributing to environmental protection and reducing the number of landfills with harmful effects.

Food waste is still a current topic that leaves many consequences, starting from food safety to environmental protection (Danon et al., 2019), resulting in the formation of waste and the creation of uncontrolled landfills. Today, waste is considered one of the leading environmental problems of the modern world. Due to the ever-increasing amount of waste generated as a result of human activities, one of the specific objectives of environmental protection is proper waste management. Acquainting citizens with the need for adequate waste management is necessary, because citizens are the largest producers of municipal waste (Ilić Krstić et al., 2018). According to the criteria of origin, waste is divided into: communal (household) waste, waste on public areas, industrial waste, construction waste, agricultural waste, sediments and sludge from waste water, sewage, septic tanks and street drains (Albanell et al., 1988). Also, waste is characterized as hazardous and non-hazardous waste.

Municipal waste consists of a variety of waste that is created as a by-product in households, institutions, shops, and stores. It appears in different forms, such as waste (from animal and plant sources), ash, paper, fabric, cardboard, objects made of rubber, wood, glass, leather, porcelain, furniture, household appliances, etc. (Ilić Krstić et al., 2018). According to the Statistical Office oft he Republic Serbia, in 2022 the amount of waste generated in the Republic of Serbia was 1,746,539.29 tons, while in 2023. year it was 1,801,838.46 tons, originating from agriculture, forestry, fishing, mining, processing industry, construction, the service sector, etc. (Statistical Office of the Republic of Serbia, 2023).

The utilization of food waste can be improved for energy production, composting, as animal feed, for donations to food banks and as a last, and least desirable, reaction disposal in landfills (Danon et al., 2019). The reduction of waste and its utilization is influenced by the circular economy (Rajković et al., 2020). The concept of the circular economy, which is increasingly accepted, overcomes the outdated concepts of the linear economy, which implies the uncontrolled exploitation of natural resources and the flow of materials from the factory, to the user, and finally to the landfill (Drljača, 2015). Circular economy, in terms of waste, implies less waste and more efficient use (NALED, 2021). A

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comparison of the concepts of linear and circular economy is given in a graphic representation in Figure 2.

Figure 2. Concept of linear and circular economy

Source: https://www.aandapackaging.co.uk/how-is-a-circular-economy-different-from-a-linear-economy/

By replacing non-renewable energy sources with renewable ones, the circle is closed: product - waste - product. Thus, industry is expected to function as a natural ecosystem, and waste from one industry (output) becomes raw material in another (input), i.e. it imitates circulation, which is where the name "circular" comes from (Zavargo, Jokić, 2010). Separation of waste is a necessary condition without which there is no application of the circular economy (NALED, 2021). The food reuse hierarchy model indicates the ways in which waste can be used, after its separation (*Figure 2*). The model is based on the legislative system, practice and model hierarchy developed by the EPA (United States Environmental Protection Agency).

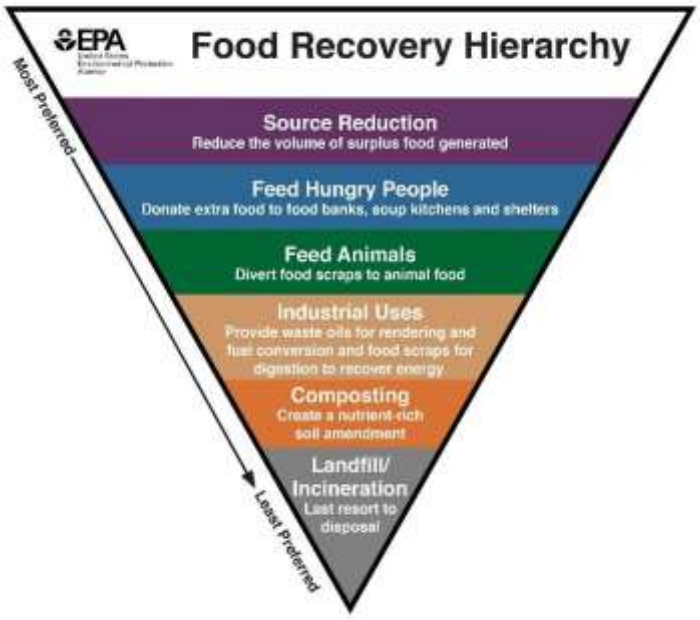

Figure 2. Food reuse model hierarchy

Source: https://19january2021snapshot.epa.gov/sustainable-management-food/food-recovery-hierarchy .html

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Based on Germany's long-term experience in introducing a circular economy, 5 stages were defined in the process of improving the waste management system (OSCE Mission, 2017):

Phase 1 – disposal of waste in uncontrolled landfills;
Phase 2 – reliable waste collection and improvement of landfills;
Phase 3 – introduction of separate waste collection and sorting;
Phase 4 – improvement of the recycling industry;
Phase 5 - circular economy - waste as a material and source of energy.

Considering the growth of the population on Earth, it can be concluded that the food industry will have a significant increase in production capacity, which also indicates an increase in waste. In this regard, the HORECA sector also joins in the generation of waste. In this paper, the emphasis on waste generation will be on the food industry, that is, the HORECA sector.

The food industry produces significant amounts of waste, which includes: fruit and vegetable residues, discarded items, molasses and flakes from sugar refining, bones, blood and skin from meat and fish processing, residues from wineries, distilleries and breweries, dairy waste such as whey, wastewater from washing, blanching and cooling (Arora et al., 2002). Food waste, according to the NALED guide, means any food or inedible part of food, intentionally or unintentionally removed from the supply chain and discarded without reuse. Food waste is classified into vegetable and animal waste. Waste of plant origin is classified according to the Law on Waste Management and the Rulebook on categories, testing and classification of waste in biodegradable kitchen and restaurant waste, as stated by NALED. Also, the waste generated can be unavoidable, potentially avoidable and certainly avoidable (NALED, 2021).

Most of the waste in the food industry is less hazardous waste due to its organic origin, however, it can have a negative impact on the quality of the environment. Waste in the food industry is generated in various sectors along the production chain, from farms, processing, packaging, transport, retail, services and households, with an estimated 18% of waste coming from food processing and packaging as a result of necessary operations such as washing, peeling, deseeding, separation, etc. (Yu, Brooks, 2016). By using the by-products of the food industry, the importance can be multiple (Rajković et al. 2020). With appropriate waste treatment, it can be used in the form of bioabsorbents, additives, new products that include functional food and bioactive ingredients, animal feed, substrate for the growth of microorganisms, materials for fertilizer after composting or as energy sources, for the production of biofuels (bio-hydrogen, biodiesel) (Kosseva, 2011; Dominquez-Perles et al., 2018).

When it comes to waste from the HORECA sector, compared to other categories of waste, there is the generation of unavoidable waste and waste that can be avoided. Unavoidable waste is formed through food preparation in the kitchen, and is mostly inedible parts of food. Avoidable waste mainly depends on the efficiency of the staff themselves. Facility guests also generate a mixture of these two types of waste. In 2018, the Center for Advanced Economic Studies (CEVES) estimated that the HORECA sector in the Republic of Serbia generates about 40 kt of food. About 25 kt is kitchen waste, which includes inedible parts of raw food, such as egg shells or banana peels. The waste left by guests in the HORECA sector is about 15 kt. Most of the waste, almost 99%, is deposited in landfills, and has a negative effect on the environment, which creates an

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unfavorable economic impact. The remaining part is used for composting and biogas production (Danon et al., 2019).

The Republic of Serbia has adopted a strategy of sustainable development and a series of important regulations, including regulations on waste that is present on the entire territory of Serbia and has a negative impact on the environment. A significant percentage of that waste is organic waste that can be seen as material for composting. Since the origin of organic waste, in addition to feeding the population, is mainly related to agriculture and forestry, where Serbia has significant resources and where large amounts of organic waste are produced, there is a need, both in the ecological, economic and social sense, to find opportunities to increase the volume of composting (Vemić et al., 2014). Composting helps reduce waste. Serbia, like other countries in Europe and the world, is trying to systematically solve the problem of waste (Komazec et al., 2011).

Composting is one of the possibilities for realizing the concept of sustainable development and a good way to deal with organic biodegradable waste. Composting increases cyclicality, i.e. circular flow of production, which is one of the goals of sustainable production. Sustainable production tends to move from linear systems (raw materials are used for products, by-products and waste) to circular systems (waste is reused as energy or raw material for another product or process) (Vemić et al., 2014).

Types of waste that can be composted (Albanell et al., 1988):

- bio-waste rich in nitrogen (50 %): fruit and vegetable residues, fruit and vegetable peels, coffee and tea grounds, grass clippings, weeds and plant residues in the garden, withered flowers,
- bio-waste rich in carbon dioxide (50 %): leaves, chopped branches, straw and hay, fruit and grape pruning residues, sawdust, coniferous tree needles.

In addition to the mentioned types, for composting, they are also used (Williams, 2005):

- residues from food processing: material for composting that results from the processing of fruits, vegetables, grains and meat;
- manure and agricultural by-products: generated in piglet barns, livestock farms, incubators, farms, greenhouses, plastic greenhouse covers, etc;
- residues from forestry and the wood industry: including bark, sawdust and fibrous residues from paper production;
- waste sludge or organic waste: created by biological treatment of waste sludge in wastewater treatment plants;
- leaves, bushes, twigs and other plant remains, as well as waste from yards, gardens and vegetable gardens;
- organic waste containing sorted compostable fractions of municipal waste.

Which sources of material will be used and in what proportions depends on the geographical region, economic structure, standards, lifestyle and eating habits of the population. The most important natural resources of the Republic of Serbia belong to agricultural land, followed by forests and forest land, where organic matter is mainly produced, while a large amount of biodegradable waste remains behind it (Vemić et al., 2014).

Composting, as a modern method of municipal waste treatment, is an exothermic process of biological oxidation, in which the organic substance undergoes aerobic biodegradation under the influence of microorganisms under conditions of elevated temperature and humidity (Ilić Krstić et al., 2018). It is usually defined as the rapid dissolution of wet, solid biodegradable organic matter: food waste, garden waste, paper,

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cardboard, using aerobic microorganisms under controlled conditions (Vemić et al., 2014). During the biodegradation process, the organic substance undergoes physical, chemical and biological transformations, creating a stable humic end product, which is called compost (Atiyeh, et al., 2001; Ilić Krstić et al., 2018).

The main goals of composting are (Vemić et al., 2014):

- transformation of biodegradable organic material into biologically stable material, while reducing the volume and weight of waste during the process;
- decomposition of pathogenic microorganisms, insect eggs and other unwanted organisms that may be present in solid municipal waste;
- retention of basic nutrients such as sodium (N), phosphorus (P) and potassium (K) in the greatest possible quantities;
- obtaining a product that can be used for growing plants.

Compost is a material similar to humus, which does not have an unpleasant smell and can be used to improve the soil or as an organic fertilizer important for agriculture, a means to control the temperature and humidity of the soil, or to prevent the growth of weeds, which results in the circulation of matter in nature (Vemić et al., 2014; Ilić Krstić et al., 2018; Danon et al., 2019). Compost can be used in agriculture, but only under the condition that all sanitary regulations are followed and that compost is controlled in terms of the presence of pathogenic microorganisms and harmful chemicals in it (Lješević, 2009). Domestic compost producers have about 180 tons of food waste at their disposal, while about 25% is lost in the composting process (Danon et al., 2019).

Compost can be used for:

- bioremediation and pollution prevention, restoration of contaminated soil, odor control or decomposition of volatile organic compounds;
- control of erosion and outflow of nutrients, as well as soil compaction;
- encouraging growth, controlling plant diseases and suppressing plant pests, which increases the yield in agriculture;
- afforestation, wetland restoration, habitat rehabilitation, etc.

4. Conclusions

The circular economy is a key step towards a sustainable future for Serbia, enabling the harmony of economic growth and environmental protection through innovation and responsible resource management. For starters, Serbia should adhere to EU advice on sustainable development but also adopt best practices for the circular economy. Food waste is still a current topic that leaves many consequences, starting from food safety to environmental protection, resulting in the formation of waste and the creation of uncontrolled landfills. The utilization of food waste can be improved for energy production, composting, as animal feed, for donations to food banks, and as a last and least desirable reaction, disposal in landfills. Composting is one of the possibilities for realizing the concept of sustainable development and a good way to deal with organic biodegradable waste. Composting increases cyclicality, i.e. circular flow of production, which is one of the goals of sustainable production. Compost can be used for: bioremediation and pollution prevention, erosion control, growth promotion, plant disease control and pest control, reforestation, wetland restoration, habitat rehabilitation, etc.

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