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Upravljanje otpadnom biomasom iz prehrambene industrije: Potencijala primena koštica breskve za prečišćavanje otpadnih voda

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Apstrakt: Biomasa koja preostaje kao otpad iz poljoprivredne i prehrambene industrije ima veliki potencijal da se, kao jeftina i lako dostupna sirovina, upotrebi za prečišćavanje otpadnih voda. Pokazano je da se, uz minimalan hemijski ili mehanički pretretman, otpadna biomasa može kosistiti za sorpciju teških metala, organskih i bioloških zagađivača kako u otpadnoj tako i u pijaćoj vodi. S obzirom da je biomasa obnovljiv resurs koji se kao otpad svakodnevno generiše i zahteva skladištenje, njeno uključivanje u održivi razvoj i cirkularnu ekonomiju predstavljalo bi višestruku dobit za celokupno društvo. Primena otpadne biomase za prečišćavanje otpadnih voda pozitivno bi se odrazila na ekološku, energetsku i ekonomsku dobrobit svake države, a posebno one u razvoju.

Ključne reči: Otpadna biomasa; prehrambena industrija; koštice breskve; tretman otpadnih voda.

Management of Waste Biomass from Food Industry: Potential Application of Peach Shells for Wastewater Treatment

Abstract: As available at low- or zero-cost, agricultural and food industry waste biomass has great potential to be used for wastewater treatment. It has been shown that, with minimum of chemical or mechanical pre-treatment, waste biomass has great adsorption capacity for different heavy metals, organic and biological pollutants from both drinking and wastewater. Since biomass is a renewable resource that is generated daily as waste and requires storage, its inclusion in sustainable development and the circular economy would have multiple benefits for society as a whole. The use of waste biomass for wastewater treatment would have a positive environmental, energy and economic impact on a country’s welfare, especially developing ones.

Keywords: Waste biomass; food industry; peach shells; wastewater treatment.

1. Introduction

The 2018 edition of the United Nations World Water Development Report specified that global water demand has increased by 600% over the past 100 years. The same Report predicted that until 2050 almost 6 billion people will suffer from clean water insufficiency (UNESCO, 2018). The gap between global water supply and increasing demand for water is the result of reduction of water resources, and increasing water pollution, driven by population growth, economic development and changing consumption patterns (UNESCO, 2018).

Approximately one-third of global drinking water requirement is attained from surface sources such as rivers, lakes, and canals. These water sources also serve as sinks for the discharge of industrial, agricultural and domestic wastewater containing heavy metals, organic and biological pollutants which are constantly contaminate the available water (Boretti & Rosa, 2019). In developed countries, strict environmental laws with *water*-related *legislation* and monitoring for compliance prevent undue pollution to freshwater sources. However, developing countries, like the Republic of Serbia, need both increased environmental protection awareness and good waste management technologies, while the removal of pollutants should be considered as a priority issue for drinking water and wastewater treatment.

A basic requirement for the human utilisation of water is the ability to remove chemical and biological pollutants quickly and efficiently at low-cost. Over the years, a plethora of technologies have been developed and proposed for water purification, among them are aerobic and anaerobic microbial degradation, chemical oxidation, sorption, coagulation, membrane separation, electrochemical treatment, dilution, filtration, flotation, softening, hydrogen peroxide catalysis, and reverse osmosis (Shaheen et al., 2016; Awasthi et al., 2019). The sorption is confirmed as a superior technology for wastewater treatment because of its cost-effectiveness, simplicity of operation, high sorption capacity toward pollutants, etc. (Marković et al., 2015). Due to their abundance, inexpensiveness, environmental safety and recyclability, natural materials such as clays (e.g. kaolin, bentonite, montmorillonite, smectite), zeolites, coal, etc., are the most commonly used sorbents for the removal of heavy metals, organic and biological pollutants from wastewater (Awasthi et al., 2019; Rosales et al., 2012). Since classical methods for wastewater treatment are energy (i.e. economically) demanded and generated secondary wastes (Lopičić et al., 2017a) there is an increased tendency to implement sustainable wastewater treatment through the utilization of biomass waste from agriculture and food industry. In the past two decades variety of waste biomass, such as coconut husks, cashew nut shell, peach nut shell, cork biomass, mango seed kernel, waste coffee powder, dried plant leaves, wool, cotton seed hulls, waste tea, orange peel, rice straw, and many others, has been tested as a (bio)sorbent for wastewater treatment (Kumar & Kumaran, 2005; Febrianto et al., 2009; Marković et al., 2015).

2. Waste biomass from agriculture and food industry

Biomass comes mainly from primary sources such as agricultural crops (51.5%) and their collected residues (9.9%), grazed biomass (11.7%), forestry (26.6%) as well as fisheries and aquaculture (0.3%). Secondary sources of biomass are recycled paper, by-products from wood processing and recovery of wood and other bio-waste (Colmorgen et al., 2020).

The agricultural sector is important for improving the availability of food and achieving food security (Pawlak & Kołodziejczak, 2020); furthermore, agriculture has a strategic role in the process of economic development of a country (Praburaj, 2018). As it is known, agriculture already made a significant contribution to the economic prosperity of advanced countries and it is of vital importance for the economic development of less developed ones. As Praburaj (2018) recently stated “where per capita real income is low, the emphasis is being laid on agriculture and other primary industries”.

Generally, a rapid growth of agricultural productivity has yielded a huge amount of waste; most of them is waste biomass, which has harmed the environment (Duque-Acevedo et al., 2021). In recent years waste biomass becomes a resource with great potential for the extraction of by-products with high added value under the approach of the circular economy and the bioeconomy. The bioeconomy, as a renewable part of the circular economy, promotes the use and sustainable recovery of agricultural waste biomass as an essential supply. This bio-based economic model has become one of the main tools for drawing up new development policies based on the Sustainable Development Goals. The circular economy and the bioeconomy are presented as the key of the circular economic production models for the transformation of the current food production system. Additionally, a special emphasis is placed in the management of the agricultural waste biomass and the alternatives for its valorization, which are promoted by the bioeconomy as circular and sustainable practices (Duque-Acevedo et al., 2021).

Figures 1 and 2 show average amounts of the most produced food commodities in the world (Fig. 1) and in the Republic of Serbia (Fig. 2), in the period 2010-2020. Increased production of food commodities simultaneously increases amount of waste biomass. One strategy to manage biomass more effectively is based on the concept of circularity in agricultural production, as proposed in food systems research by de Boer and Van Ittersum (2018). This concept aims to reduce food losses and food waste, using biomass for human consumption first, then for livestock, and finally to recycle any by-products back into the system (Muscat et al., 2020; van Zanten et al., 2016a; van Zanten et al., 2016b).

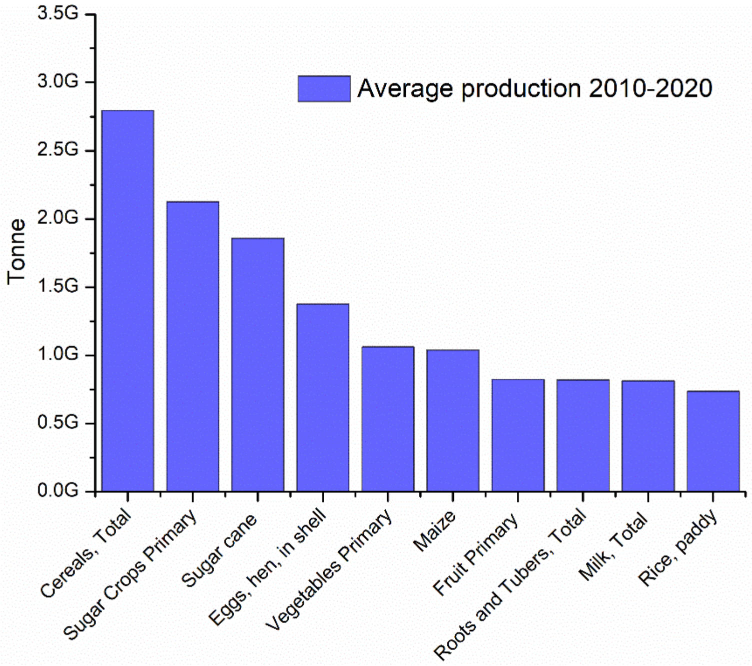

Figure 1: Most produced food commodities in the world; average in period 2010-2020
Source: (FAOSTAT, Retrieved February 27, 2022)

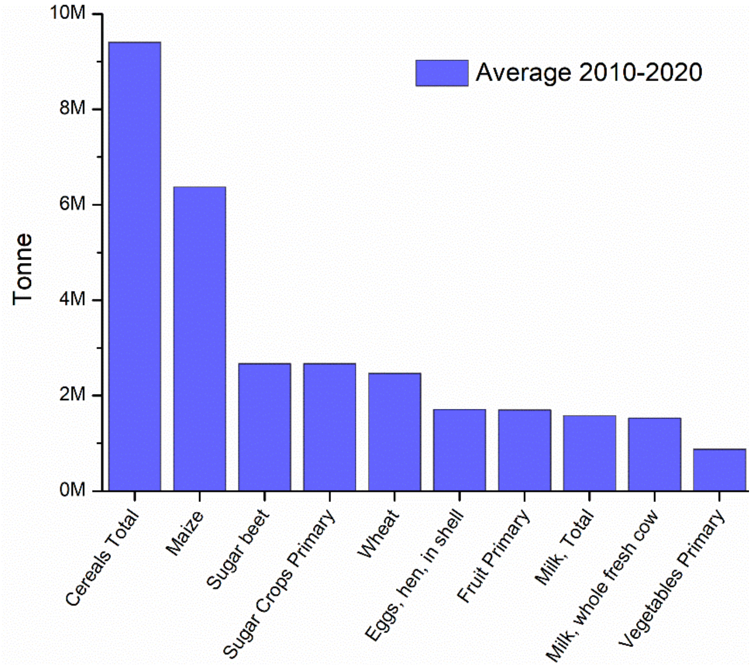

Figure 2: The most produced food commodities in the Republic of Serbia; average in period 2010-2020
Source: (FAOSTAT, Retrieved February 27, 2022)

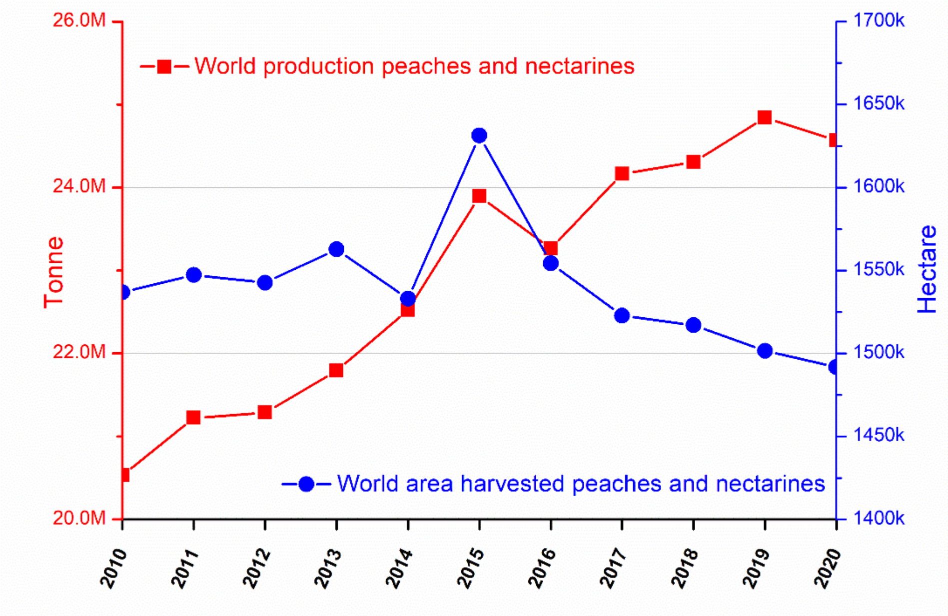

Figure 3: World peaches and nectarines production in the period from 2010 to 2020 (total amount and area harvested)
Source: (FAOSTAT, Retrieved February 27, 2022)

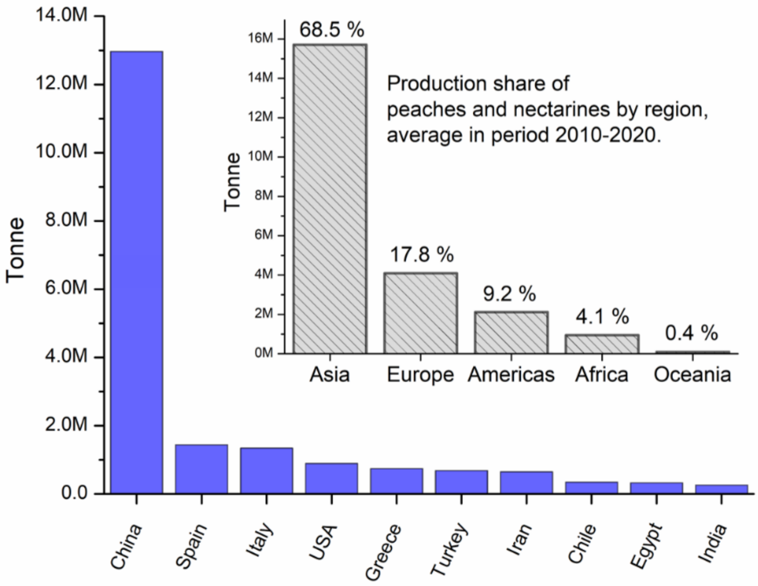

Figure 4: Peaches and nectarines production from 2010 to 2020: Top 10 world producers; as inset picture: production share by regions.
Source: (FAOSTAT, Retrieved February 27, 2022)

According to United Nation Food and Agriculture Organization data (FAOSTAT) in the period from 2010 to 2020, fresh fruits production has growing trend all over the world. Figures 3&4 show world area harvested peaches and nectarines and average amount produced in the period 2010-2020. Stone of the fruits such as peaches, plums, apricots, represent about 20% of the total fruit mass. This unavoidable food industry waste should be managed in most appropriate way, minimizing harmful impact on the environment, avoiding greenhouse gasses emissions and helping in resource depletion by its renewable nature. In 2020, worldwide production of peaches was about 24.5 million tonne (FAOSTAT, February 27, 2022, Figure 3). According to the Statistical Office of the Republic of Serbia data, peach (*Prunus persica* L.) is the fifth most common fruit in Serbia after plums, apples, pears and cherries, with annual production of 60000 tonne in 2020 (FAOSTAT, February 27, 2022, Figure 5). Since approximately 20% of peach mass is its stone, it can be estimated that almost 12000 tonne of this potentially useful waste is generated in Serbia every year (Lopičić et al., 2019). This waste is usually disposed on open dumps in industrial facility area, presenting a potential risk to the environment and human health. According to available data, in 2011 the Fruit Processing Factory "Vino Župa" Aleksandrovac has generated about 14500 tonne of waste biomass, where about 2500 tonne include solid waste of peaches, cherries, apricots, and plums (Lopičić et al., 2017b). Within the *recent* past, this waste biomass material was ballast for the company because it was disposed of as waste, which led to economic and environmental burden on both the company and the environment. In recent years, efforts have been made to find new solutions for the use of this material, most often through direct combustion. Although peach and nectarine stones possess high caloric values enabling their usage as a fuel; high water (49-60%) and mineral (especially potassium) content significantly complicates the combustion process (Jenkins et al., 1998; Lopičić et al., 2013a) make them challenging and expensive.

Therefore, it is very important to develop new possibilities for the use of waste biomass and thus improve the ecological and economic balance of its life cycle, while relieving already formed open dumps and preventing the formation of new ones. A review of up-to-date literature shows that lignocellulose waste biomass from the food industry has been mainly used as a precursor for production of activated carbon which has further been used for the removal of water pollutants (Attia et al., 2003; Aygün et al., 2003; Guo et al., 2003; Ip et al., 2008). Due to a large amount of water (50-60%) which biomass contains, the pyrolysis process, necessary to convert lignocellulosic biomass to activated carbon, is energy-intensive. Thus, was essential to consider other possibilities where lignocellulosic biomass will be directly applied, with minimal investments. One of the possibilities was to use raw lignocellulosic biomass as a sorbent (Albadarin et al., 2014). The absorption capacity i.e. removal efficiency of raw biomass is lower than that of active carbon but it is an available and inexpensive material; simultaneously, the use of biomass as an agricultural solid waste resolve the environmental problem of its storage.

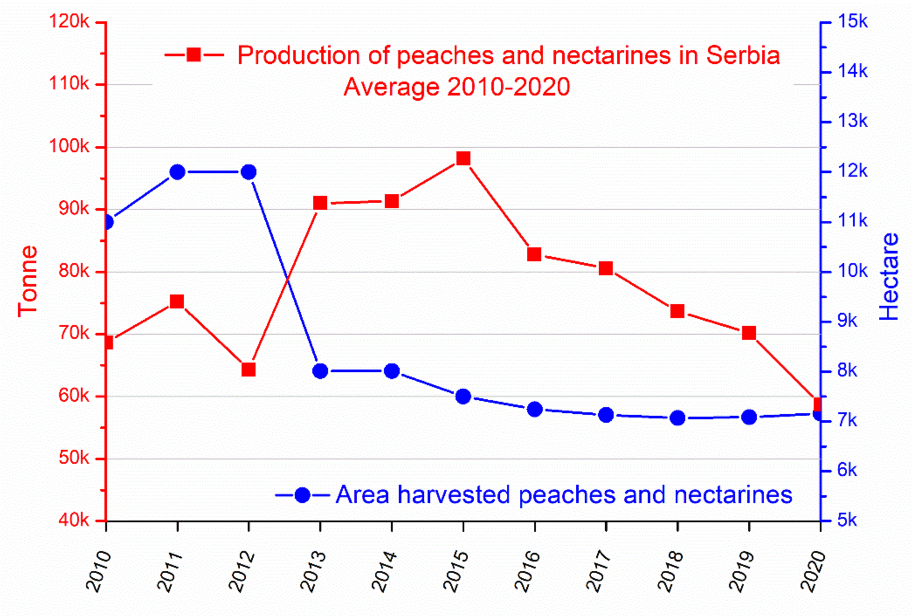

Figure 5: Production of peaches and nectarines in the Republic of Serbia in period from 2010 to 2020 (total amount and area harvested)
Source: (FAOSTAT, Retrieved February 27, 2022)

3. Application of peach shells for water treatment: Scientific approaches in the Republic of Serbia

Removing of dyes from a textile and dye industries

Colour is the first contaminant to be recognized in wastewater. Residual dyes are the major contributors to colour in wastewaters generated from textile and dye manufacturing industries (Mojsov et al., 2016). Contamination of drinking water by some dyes at even a concentration of 1.0 mg per L is highly visible and affects not only the aesthetic aspect and water transparency, but also the absorption and reflection of sunlight, interfering with aquatic life in lakes, rivers and other water bodies. Actually, colour impedes light penetration, decreases the efficiency of photosynthesis, inhibits the growth of biota, also has a tendency to chelate metal ions which result in micro-toxicity to fish and other living organisms (Mojsov et al., 2016). Thus, it is necessary to remove dye from wastewater before discharging it into sink; it could be done by decolorization or by degradation.

Wastewater decolorization can be performed using waste biomass from food industry as biosorbent for dye. Previously we have shown that raw powdered peach shells are a highly efficient biosorbent for removal of methylene blue (MB), a non-degradable cationic dye, as pollutant from water solutions (Marković et al., 2015). Waste peach shells have been supplied from Vino Župa, Aleksandrovac, Serbia, fruit juice factory. Prior to sorption experiments, the collected peach shells have been pretreated: to remove the adhering pulp, the peach shells were washed several times with boiled water and subsequently dried at room temperature. After drying, peach shells were manually crushed and separated from kernels; shells were milled in vibromill and sieved in different fractions. For the dye sorption experiments, the particles fraction smaller than 100 micrometer was used. Before the biosorption experiments, peach shells particles were washed with 0.01 M HCl to clean out surface impurities, subsequently washed with distilled water and dried for 24h.

It has been shown that the efficiency of powdered peach shells for the removal of methylene blue, i.e. their adsorption capacity toward MB, depends on the initial dye concentration, biomass amount, contact time, and the pH value of the dye solution. Collected experimental results indicate that hydrogen bonding is the principal mechanism for the removal of methylene blue by powdered peach shells. Powdered peach shells with hydrogen bonded dye molecules can be easily removed from water solution by gravity-driven filtration or decanting, thus avoiding additional costs.

Removing of heavy metals

In the last more than twenty years many published journal papers concerned application of waste biomass as biosorbents for heavy metal ions as the most common pollutants in drinking and wastewater in modern societies. Besides, heavy metals are the most investigated due their high toxicity, persistence and bioaccumulation tendency (Arief et al., 2008). World Health Organization declared chromium, cadmium, mercury, lead, copper, aluminum, cobalt, nickel, zinc, magnesium and iron as the most toxic metals that induced human poisonings (Djeribi and Hamdaoui, 2008). For example, lead ions are powerful neurotoxins; over a hundred thousand deaths attributed to lead poisoning have been reported in 2016. Lead poisoning has also been correlated to the appearance of defects at birth and to cancer. Lead is commonly used in the infrastructures for water transportation and supply around the world, and the amount of metal dissolved in drinking water increases with time due to the progressive corrosion of the infrastructure. Furthermore, the recent practice to add chloramine for disinfection in water treatment facilities has led to even higher concentrations of lead ions in drinking water, because of the reaction of chlorine with lead in domestic pipes, which promotes the metal dissolution. Another major pollutant is cadmium, which is extensively used in electronic circuits, batteries, solar cells, paints and pigments, and can enter water sources through industrial waste. Consumption of water contaminated with cadmium can lead to severe gastrointestinal irritation and, potentially, to death.

Removal of heavy metal ions can be accomplished by exploiting the ability of materials with suitable functionality to bind the pollutants, whilst remaining insoluble in water. After binding, they form secondary contaminants and can be easily removed from water source.

The same group of authors examined an influence of pH on the biosorption capacity of lignocellulose waste toward copper (II) ions. They have tested biosorption at several pH values between 2 and 6; they have found significant influence of pH on the biosorption capacity and established pH 5 as the most prominent (Lopičić et al., 2013a). Removal of Cu (II) by biosorption on mechanically treated peach shells has been studied at different operating parameters in a batch sorption system, with special attention on temperature effect on sorption process (Lopičić et al., 2017a). According to collected results, the authors stated fast equilibrium and small amounts of energy enrolled in physisorption process which promoted mechanically treated peach shell particles as a good alternative for Cu (II) removal from aqueous solution. Additionally, the authors examined an influence of mechanical pretreatment on absorption capacity of peach shell particles toward copper (II) ions (Lopičić et al., 2019). Peach shell particles have been pretreated in vibratory disk mill and ultra-centrifugal mill, biosorption capacity has been determined, obtained results have been evaluated and compared. The collected results have shown that regardless of the type of mill used for pretreatment the average particle size and the size distribution are similar. However, the crystallinity index was lower for particles pretreated in vibratory disk mill than for those pretreated in ultra-centrifugal mill, which was also confirmed by lower crystalline thickness and hydrogen bond intensity index. It has been shown that particles pretreated in vibratory disk mill have lower absorption capacity for Cu (II) than particles pretreated in ultra-centrifugal mill. Different absorption capacity has been explained by different specific surface area and total pore volume influenced by pretreatment in different types of mills.

Beside methylene blue dye and heavy metals, powdered peach shell particles supplied from Vino Župa, Aleksandrovac, Serbia, have been tested as biosorbent of mycotoxins (Adamović et al., 2013; Lopičić et al., 2013b). The obtained results indicate that peach shell particles can be successfully applied as effective biosorbents of mycotoxins, while pretreatment of the particles by acid modification leads to the improvement of their biosorption capacity.

4. Conclusion

In the Republic of Serbia peach shells are widely available and renewable waste from agriculture and food industry, thus, their applicability as a biosorbent has a twofold significance: (1) as an economically viable solution for wastewater treatment and (2) the way to significantly reduce the mass and volume of food industry solid waste from storage places.

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