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BIOECONOMIC POTENTIAL OF VALORIZING BLACKCURRANT (*Ribes nigrum* L.) PRESS RESIDUES

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Abstract: *The concepts of sustainable development and circular economy require finding innovative ways for more efficient use of resources, produced raw materials, and waste. The aim of the research was to assess the economic and ecological justification of valorizing blackcurrant pressing residues. For this purpose, a semi-structured interview was conducted with a blackcurrant*

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producer, as well as with three potential service providers for the processing of pressing residues. The results show that the valorization of blackcurrant pomace is an ecologically and economically responsible approach to production. There are several ways to valorize blackcurrant pomace, and in this study, the emphasis is on extracting oil from the seeds and obtaining flour from the dried pressing residues. The economic justification of valorizing blackcurrant pressing residues has been identified, as the produced oil adds value to the pressing residue by 2.87 €/kg, and the flour produced by all three processors by 6.60 €/kg, 5.87 €/kg, and 5.57 €/kg, respectively. It was unequivocally established that value chains for blackcurrant pressing residues exist and that it is possible to add value to a currently worthless by-product, thereby increasing profits, removing waste from the production chain, and making the agricultural enterprise more competitive. The paper points to the need to integrate bioeconomy principles into agricultural residue management practices.

Keywords: *bioeconomy, valorization of by-products, pressing residues, blackcurrant*

INTRODUCTION

In recent times, the concepts of sustainable development and circular economy motivate researchers and entrepreneurs to find innovative ways for more efficient use of resources, produced raw materials and waste. In this context, the bioeconomy, which includes the production and conversion of biological resources and waste into valuable products and energy, becomes a key factor in the transition to more sustainable economic models. Ribeiro et al. (2022) point out that one of the segments of the bioeconomy is the valorization of agricultural waste, i.e. the use of all by-products created in the processes of agro-food production. Well-organized practices through the involvement of employees will lead to the achievement of internationally competitive performance indicators in waste management (Aremanda et al., 2022).

Black currant (*Ribes nigrum* L.), although little represented in the Republic of Serbia, represents an important agro-industrial resource, not only because of the fruits, which are used for the production of juices, but also because of the potential that its remains provide. After the pressing process, a significant amount of biomass (pomace) remains, which is often not adequately utilized (Mäkilä et al., 2014).

Valuing blackcurrants in different value chains can significantly increase the producer's income. Blackcurrant processing is an opportunity for business diversification, specialization in the production of juices and other products, along with the valorization of residues. During processing, one-third of raw materials can be lost, which can be expensive for the producer and have a negative impact on the environment (O'Shea et al., 2012). A large amount of blackcurrant pomace ends up on agricultural land, which causes environmental problems, because the pomace is acidic in nature (Imge et al., 2017).

One of the ways to solve environmental problems is the valorization of by-products which are created during the processing of agricultural raw materials. During the processing of fruit into juices, pressing residue or biomass is created, which can be valued. With the development of bioeconomy and technology, there are more and more opportunities to add value to production residues. These opportunities are linked to the circular economy strategy of the European Union, which encourages waste prevention and sustainable management of resources, maximizing their use (Friant et al., 2021).

Fruit growers should be motivated by the possibility of increasing additional value through the processing of pressing residues, as this can provide them with additional income. From an economic point of view, reducing production waste can have a positive effect on the well-being of suppliers and consumers. In this way, participants in the value chain can increase productivity, i.e. achieve higher profits (Rodriguez et al., 2021).

The use of residues from agricultural production to produce products with high added value can contribute to sustainability and is therefore part of the future of the bioeconomy.

LITERATURE REVIEW

In the context of sustainable development, bioeconomy is emerging as a key concept, which promises the reinvention of industrial processes in a way that is in line with the principles of environmental protection. Bioeconomy represents an approach that integrates biological resources, such as plants, animals and microorganisms with economic processes and technologies in order to create sustainable industrial and economic systems (Wei et al., 2022). The main goal of bioeconomy is to stimulate economic growth while conserving biodiversity and ecosystem services, thereby contributing to global efforts to achieve sustainable development (Ferraz and Pyka, 2023).

Within bioeconomy, special emphasis is placed on value chains, which include the use of biological resources and remaining materials from production, as raw materials for new products. Black currant, as a valuable agricultural product, finds its place in the bioeconomy, especially when it comes to the use of pressing residues.

The literature dealing with bioeconomic value chains and the use of blackcurrant pressing residues shows multiple attitudes. First, there is a clear understanding that residues from the agro-food industry can be used as valuable raw materials for the production of biofuels, biochemicals and food additives (Singh et al., 2022; Pandey et al., 2022; Gutierrez-Macias et al., 2017; Faustino et al., 2019). Another important point concerns technological innovations, which enable more efficient use of these residues, which contributes to reducing waste and increasing the sustainability of production processes (Mashudi et al., 2023). Third, there is a growing awareness of the importance of the regulatory framework, which supports the development of the bioeconomy (Pender et al., 2024). Fourth, scientific literature emphasizes the importance of a multidisciplinary approach in research related to bioeconomic value chains (Lewandowski et al., 2019). Finally, there is a strong consensus on the need for further research to optimize processes and expand the application of blackcurrant pomace. Although significant progress has been achieved, researchers emphasize the need for new studies, which would consider the economic justification of using biowaste, the environmental impact and the acceptance of innovative products by consumers (Russo et al., 2019; Qyyum et al., 2022; Szilagyi et al., 2023).

AIM AND METHOD OF RESEARCH

The aim of the research was to evaluate the possibility of valorization, or the economic-ecological justification of using blackcurrant pressing residues. In order to achieve this aim, a semi-structured interview was conducted with a producer of black currants, as well as with three potential service providers of pomace processing.

Bioeconomic value chain of blackcurrant pressing residues

The berry provides the most opportunities for the valorization of blackcurrants. Valorization of the blackcurrant berry is a process of adding value through various processing methods, in order to make the most of its nutritional, health and aromatic potential.

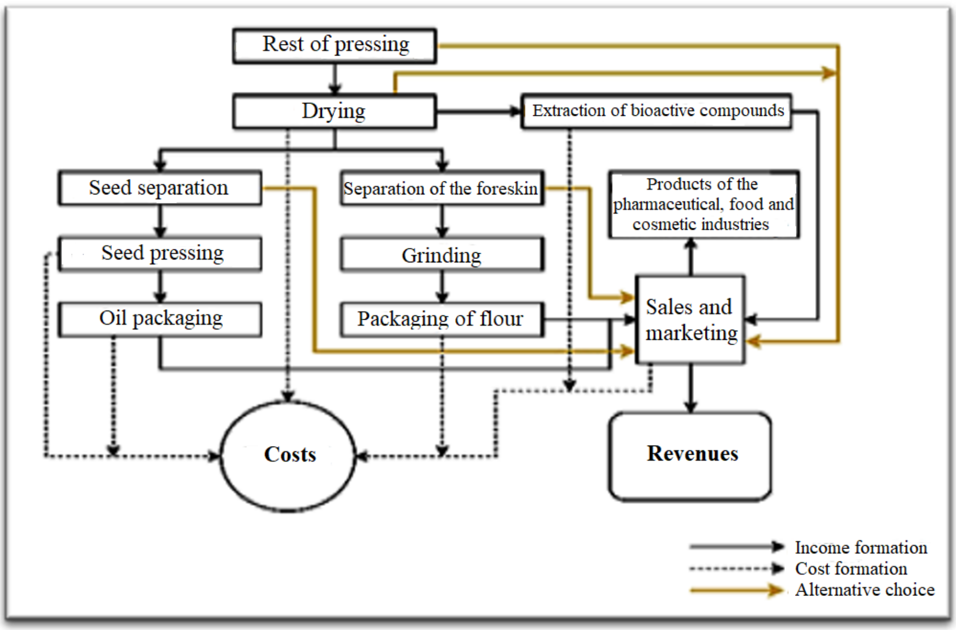
Blackcurrants are consumed fresh, dried and processed into other products (juice, jam, marmalades, syrups, wine and in the confectionery industry). Fresh berries are highly valued for their significant nutritional value. They are rich in nutritional components (vitamins, especially vitamin C, organic acids, pectins, sugars, phenolic compounds, anthocyanins and minerals), which are essential for the health of the human body or for the prevention of certain diseases. Berries are a real treasure trove of vitamin C, which together with bioactive phenolic components contribute to high antioxidant activity (Paunović et al., 2017).

The basis of the case study in this research is an organic blackcurrant producer, who mainly uses the berries of this orchard for juicing. As a result of this technological process, pomace is produced in the production chain, which is not recycled, but composted.

In particular, the focus is on the value chains of blackcurrant juice and the obtained pomace. Blackcurrant juice is expected to have many health benefits, and it is convenient for consumers to take high-value nutrients through the juice (Albuquerque et al., 2018). In addition, consumption of blackcurrant juice has been found to reduce oxidative stress and improve the condition of blood vessels (Khoo et al., 2017). Also, trends in the food and beverage markets are moving more towards natural and pure products, and consumers are increasingly appreciating products that do not use synthetic flavors (Bizzozero, 2020).

After the production process is completed, black currants are harvested, cleaned and frozen. "Fresh berries are not processed into juice. A frozen berry gives much better juice, because the freezing process breaks the structure of the berry." (Interview with farmer, 2024). As a rule, the harvest period is quite intensive, which does not allow for the simultaneous preparation of juice. It may happen that the producers do not have the equipment for juice production and the raw material needs to be transported to the business partner. After freezing, the berry passes through a mechanical press, which extracts the fuller juice, which is then pasteurized, packaged and marketed. Pulp or pomace remains from the entire processing process, which can be further valorized, thereby adding value and reducing waste. The value chain of blackcurrant pressing residues is shown in scheme 1.

Scheme 1. *Value chain of blackcurrant pressing residues*



Pomace valorization represents a responsible approach to production, which can add value and reduce waste. There are several ways to valorize blackcurrant pomace. One possibility is the extraction of bioactive compounds from the pressing residue. Blackcurrant skins are rich in antioxidants, pectins and essential fatty acids, which can be used in the food industry, and are known to have health-supporting properties (Azman, 2019). Blackcurrant pulp contains natural pigments, which can be used as an alternative to synthetic dyes in the food industry or in the production of natural textile dyes (Vega et al., 2023). Dried or fresh pulp can be used as an additive in the production of bakery products such as bread, cakes and biscuits, adding nutritional value, moisture and a unique taste to them (Bakowska-Barczak and Kolodziejczyk, 2011). The antioxidant-rich pulp can be useful in natural cosmetic formulations, such as face masks, lotions, and scrubs, due to its potential anti-aging and moisturizing properties (Plainfossé et al., 2020). Also, it can be used as a feed supplement due to its richness in fiber, antioxidants and other nutrients (Manju Wadhwa et al., 2015). Composting blackcurrant pulp is a simple way to turn waste materials into fertilizer (Hassan et al., 2023). Using pulp in anaerobic digestion for biogas production is a viable alternative for organic waste management. Biogas can serve as a source of energy, while the remaining digestate can be used as a quality organic fertilizer (Islam et al., 2009).

The valorization of blackcurrant pressing residues through extracting seeds and obtaining oil is an excellent example of how by-products can be efficiently used. By drying and washing it is possible to separate the seeds from the remaining mass. In the development of a solution for the production of oil from blackcurrant seeds, 19.67% to 20.94% of oil was separated during the experiments (Wójciak et al., 2022). Blackcurrant oil can have significant market value, especially if it is promoted as a natural product rich in omega-3 and omega-6 fatty acids, as well as antioxidants. Once the skins are separated from the dried pulp, they can be ground, resulting in fruit flour.

Residues (husks, pods, leaves, pieces of twigs) can still appear throughout the value chain. All this residue can be used in the production of thermal energy.

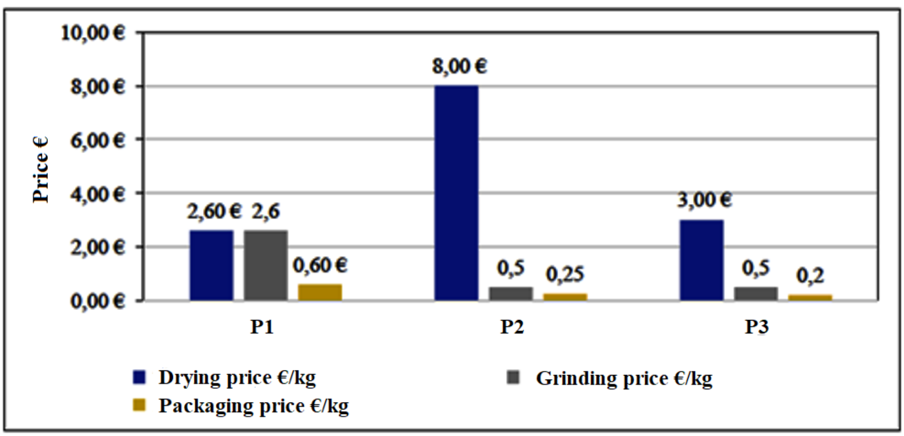
RESEARCH RESULTS AND DISCUSSION

The findings of the interviews with three potential service providers for the processing of blackcurrant pomace provide an overview of the possibility of adding value. Processing enterprises are coded as different variants P1, P2 and P3.

In the bioeconomic value chain of blackcurrant, it was important to investigate the regularity of pomace delivery, and whether it is important for processing service providers that there is a continuous supply of raw material for processing. The answers revealed that it is not important to them, because the given raw material is processed in batches, but it is important that the minimum quantities are guaranteed. Delivering press scraps below the minimum quantities is not reasonable, as the incidental costs will be prohibitive. P3 answered: "*The regularity of delivery is not important, if we only provide drying service. In case we market dried blackcurrant flour, it would be good to have regular delivery, which we need to agree on in advance*".

Furthermore, the cost of services for the processing of pressing residues were examined, in order to be able to estimate the price of the final products. For a better overview, the cost of processing services are shown in graph 1. In addition, the prices of packaging based on different packaging sizes (100 g, 1 kg and 5 kg) were examined. The responses revealed that the unit cost of packaging depends on the type and quantity of packaging. Packages were not included in the price. In the case of variants P1 and P3, there is a fixed price, 0.60 €/piece, or 0.20 €/piece. P2 says: "*The price of packaging depends on the raw material and scope of packaging work, i.e. whether the product can be packed by machine or by hand*" (P2). However, the price of packaging is calculated at 0.25 €/piece for option P2.

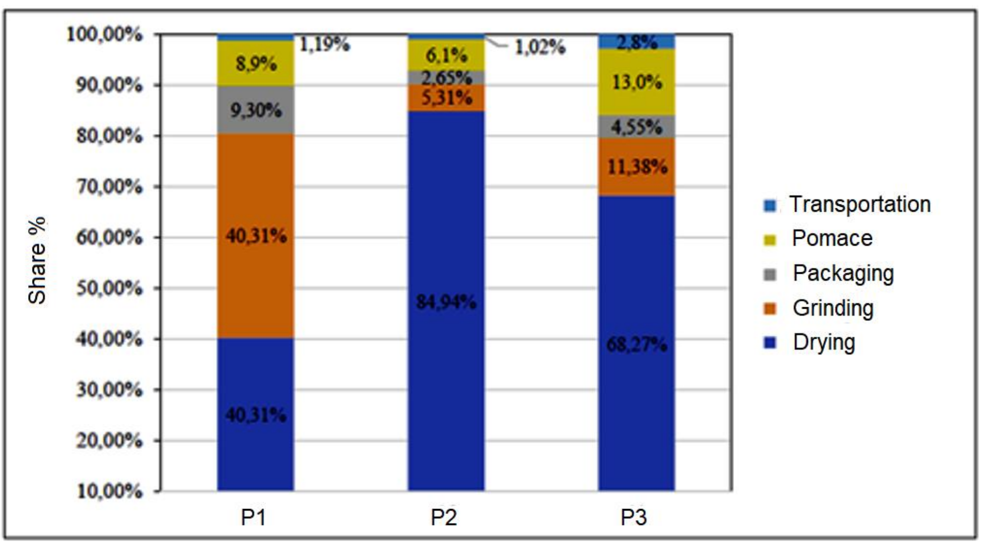
Chart 1. *Cost of services for the processing of blackcurrant pomace in the production of flour from residues*



The cost of processing blackcurrant pressing residues is calculated per kg of dried raw material. According to the data of the processing organizations, the yield of dried press residue in variant P1: 32.5%, P2: 25% and P3: 20%. The most expensive service is in the P2 variant, where the price of drying, grinding and packaging is 8.75 €/kg, then P1 - 5.8 €/kg and P3 - 3.7 €/kg. It is also worth noting the fact that P3 services are significantly cheaper than those offered by P1 and P2. P2 said: "*raw materials that are difficult to dry have a special price, among them are e.g. ordinary pomegranate, cranberry and black currant*." P2 also mentioned that dried blackcurrant residue: "*When grinding, it should be taken into account that part of the raw material remains in the mill, therefore the costs are around 400 gr for each grinding, regardless of the amount of ground mass*".

Based on the results of drying, grinding and packaging of blackcurrant pressing residue, the authors prepared chart 2, which shows the cost structure of processing and transportation of blackcurrant pressing residue. In addition to the price of the processing service, the price of the remaining blackcurrant pressing was added to the structure, which in this study was calculated as 0.572 €/kg of raw material. 25% of the cost price of black currants was calculated as the cost price of the pressed residue, which in this research amounted to 2.29 €/kg.

Chart 2. *Structure of processing and transportation costs per 1 kg of blackcurrant pressing residue*



The largest share in the costs of processing blackcurrant pomace (79 - 91%) is the drying and grinding of the raw material. The costs of processing blackcurrant pomace with transport turned out to be the highest in company P2: 9.42 €/kg, followed by P1: 6.45 €/kg and P3: 4.39 €/kg.

During the interview, there was a discussion about the possibilities of squeezing and packaging blackcurrant seed oil. We have learned that only the processing service provider P1 has this capability. The first question was related to the price per liter of oil, produced in a quality intended for the food industry?: „*We have a screw press that can press approx. 2-6 kg of seeds per hour. So it's a very small device and therefore a pressing service would be very expensive. First of all, we provide testing and development services, so it is not reasonable to compare with production. The average oil yield in the tests was 8.4%. The service costs 12 €/h. To obtain oil of appropriate quality, it is only necessary to filter it and pack it into bottles.*“ (P1).

According to calculations, the capacity of the screw press is 2-6 kg of seeds per hour, which is an average of 4 kg/h. From the tests, it was determined that the yield of oil during pressing is 8.4%, which means that the amount of oil obtained per hour would be 4 * 0.084 = 0.336 liters, and the price would be 12 € / 0.336 l = 35.71 €/l. In addition, the interviewee was asked what would be the indirect additional fixed costs of pressing the oil per hour (10 €, 20 € or 30 €)? „*It is difficult for me to specify it, because I have not calculated the price calculation (12 €/h). This price is based on the assumption that the operator is not constantly present on the device and can deal with other things. When calculating the price of other services, I took into account the time/cost of work required to use the device + the cost of electricity (on the device) + the cost of amortization of the device + 35% of general costs.*“ (P1). Although the interlocutor could not accurately predict the additional costs, it is reasonable to increase them by 50%. Therefore, the price of pressing the oil would be 35.71 + 17.85 = 53.56 €/l.

The next question was: What will be the price of a package of blackcurrant seed oil in the following quantities: 50 ml, 0.5 l, 1 l and more?: „*We bottled the oil in 50 ml packaging, which is purchased by the processing organization at a price of 0.255 €/ piece. We did not pack other quantities of oil*“ (P1).

In this research, the packaging of oil in a 50 ml tare is considered. When bottling the oil, a glass container of 50 ml is used at a price of 0.25 €/piece, and the price of a stoppered dropper is 0.16 €/piece. A glass jar with a price of 0.35 €/piece is used for packaging blackcurrant flour, with a capacity of 100 g of flour and a lid at a price of 0.09 €/piece (Cider Mill, 2024).

The bioeconomic value chain of blackcurrants begins with the establishment of plantations, and ends with the valorization of the residues after processing. The price of 1 kg of black currants is 2.29 € (Interview with a farmer, 2024). 6 tons of black currants were used for the production of juice. Based on the purchase value of black currants, the incurred cost is 13,740 €. When producing juice, it is important to freeze the berries immediately after harvesting. The cost of freezing was 0.14 €/kg, and the cost of storage was 0.18 €/kg. Transport to the processor is 0.13 €/kg. The price of processing black currants into juice was 4.26 €/l, from 6,000 kg of fruit, a total of 4,500 l of juice was obtained, the processing costs of which were 19,167.79 €. As a result of juice production in 2023, 1,500 kg of pomace was produced, and the cost price of pomace was 0.572 €/kg, a total of 858 €.

The cost of transporting the rest of the blackcurrant pressing to the processing service provider P1 is 0.08 €/kg, a total of 57.6 € (115.2 € / 2), which is calculated on two different products. The cost price of the rest of the press is 429 € (1500 kg*0.572 € / 2) per product. In processor P1, it is theoretically possible to make two separate products, namely oil from blackcurrant seeds and flour from the residues after drying. The oil yield from blackcurrant seeds is estimated at 8.4%, and the share of seeds in the rest of the press is 18.4%. It would be possible to separate and dry 276 kg of seeds from the rest of the blackcurrant press (1,500 kg), the price of which would be 14.12 €/kg, a total of 3,897.49 €. The amount of oil obtained would be 22.08 l, the price of squeezing was 53.56 €, and a total of 1,182.60 €. Company P1 bottled the oil only in quantities of 50 ml. From the analyzed quantities, a total of 441 bottles would be obtained. The price of bottling is 292.53 €, of which the glass bottle is 110.25 €, the dropper with lid is 69.68 € and the package is 112.60 €. The total cost price of blackcurrant seed oil is 265.36 €/l.

If the seeds are separated from the rest of the pressing of black currants, about 1,230 kg of raw material remains. When drying the rest of the press, 32.5% or 399.75 kg remains. The costs of both transport and raw materials are divided by product into two, 57.6 € and 429 €, respectively.

The price of the processing service is 2.6 €/kg for both drying and grinding, which in both cases amounts to 1,039.35 € according to the given quantity. During grinding, 0.4 kg of dried press residue is lost. In flour packaging, 100 g packages were taken into account, and 3,993 units were taken into account. The total price of glass jars was 1,397.55 €, lids 359.37 €, and packaging 2,395.8 €. The total cost price of blackcurrant flour was 16.82 €/kg.

The cost of transporting the blackcurrant pressing residue to the processing service provider P2 was 0.10 €/kg per 1,500 kg, a total of 144 €. The price of pomace is 858 €. The yield of the rest of the press after freeze drying is 25%, in the amount of 375 kg. The price of lyophilization per kg of dried raw material is 8 €, a total of 3,000 €. The price of grinding is 0.5 €/kg, a total of 187.5 €, and the loss is calculated at 0.4 kg for the total amount of grinding. During the packaging, quantities of 100 g were taken into account, there are a total of 3,746 packages, and the price is 2,584.74 €. Of which the price of glass jars is 1,311.10 €, the price of lids is 337.14 €, and the price of packaging is 936.5 €. The total cost price of blackcurrant flour is 18.08 €/kg.

The cost of transportation to the processing service provider P3 was 0.12 €/kg for 1,500 kg of blackcurrant pressing residue, a total of 183.20 €. The price of drying pomace was 3 €/kg, a total of 900 €, and the yield of dried pomace was 20%, a total of 300 kg. The price of grinding pomace is 0.50 €/kg, a total of 150 €. Total grinding loss is 0.4 kg. Packaging of berry flour is calculated in cans of 100 g. A total of 2,966 packages were used and the total costs for packaging were 1,898.24 €, of which glass jars 1,038.10 €, lids 266.94 € and packaging 593.20 €. The total price of berry flour is 13.45 €/kg.

The obtained prices are compared with the prices of products on the market (table 1), in order to assess the economic justification of the processing of pressing residues. Comparable market prices are taken from the Internet. Analyzing the differences in price, it follows that the products obtained from the remains of blackcurrant pressing can be sold profitably. The comparison does not include sales costs, which can be 10-30% of the market price of the sold products, which depends on the sales strategy.

Table 1. *Comparison of prices of products obtained from blackcurrant pomace*

Supplier of processing services	Product name	Quantity	Own price	Cost price x quantity	Market price	Market price x quantity	Possible profit
P1	Seed oil	22.08 l	265.36 €	5 859.23 €	460.00 €	10 156.80 €	4 297.57 €
	Flour	399 kg	16.82 €	6 718.02 €	41.60 €	16 610.88 €	9 892.86 €
P2	Flour	374.6 kg	18.08 €	6 774.24 €	41.60 €	15 583.36 €	8 809.12 €
P3	Flour	296.6kg	13.45 €	3 989.44 €	41.60 €	12 338.56 €	8 349.12 €

The price comparison shows that it is most useful to produce oil and flour simultaneously from blackcurrant pressing residues. The possible profit from that would be 14,190.43 €, which is 60% more than other processors. Also, it is important to point out that the total cost price of P3 in the production of flour is about 60% lower than the price of other processing service providers. The potential profit of P3 is about 6-18% lower compared to other processors. When processing blackcurrant pomace, the proportion of residues remaining after drying is important. By dividing the possible profit (table 1) with the amount of press residue, it follows that the oil produced at P1 (4297.57 €/1500 kg) adds value to the pressing residue by 2.87 €/kg, the flour produced at P1 (9892.86 €/1500 kg) for 6.60 €/kg, flour produced at P2 (8809.12 €/1500 kg) for 5.87 €/kg and flour produced at P3 (8349.12 €/1500 kg) for 5.57 €/kg.

If it is a question of small production quantities, an expert assessment is necessary, whether it is economically justified to think about the valorization of blackcurrant pressing residues. On the one hand, short food value chains offer farmers a fairer price and support regional economic development. However, the scale of production and distribution is often limited and therefore prices are higher for consumers. To address these shortcomings, Fairchain contributes to the development of intermediate food value chains, which combine elements of both short and long value chains, in order to achieve more sustainable food systems from an ecological, social and economic perspective (Fairchain, 2020).

Klitkou et al. (2019) believe that the main strategy for the transition to the bioeconomy is better utilization of organic waste and by-products. This implies the creation of a circular economy in which the outputs of one value chain are used as inputs in another. Thus, production, which was previously considered waste in one sector, is transformed into an input of another sector, which represents a more sustainable way of using a limited amount of energy and raw materials.

CONCLUSION

The aim of the research was to evaluate the possibility of valorization, or the economic-ecological justification of using blackcurrant pressing residues. In this regard, blackcurrant seed oil and flour from dried pressing residues are targeted as the main products obtained from biowaste, which can improve the economics of agricultural operations and reduce the ecological footprint.

The economic justification of the valorization of blackcurrant pressing residues in this study was confirmed, since the produced oil adds value to the pressing residue by 2.87 €/kg, and the flour produced by all three processors by 6.60 €/kg, 5.87 €/kg and 5.57 €/kg, respectively. Thus, it was unequivocally established that value chains of blackcurrant pressing residues exist and that it is possible to add value to a currently worthless by-product and thus increase profits, eliminate waste, and make the producer more competitive.

Through innovative technological solutions, adequate regulatory support and a multidisciplinary approach to the bioeconomy, it is possible to significantly reduce waste from the agro-food industry and at the same time produce high-value products that contribute to better economic effects and environmental protection.

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BIOEKONOMSKI POTENCIJAL VALORIZACIJE OSTATAKA PRESOVANJA CRNE RIBIZLE (*Ribes nigrum* L.)

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Sažetak: *Koncepti održivog razvoja i cirkularne ekonomije nalažu da se pronađu inovativni načini za efikasnije iskorištavanje resursa, proizvedenih sirovina i otpada. Cilj istraživanja bio je da se proceni ekonomsko-ekološka opravdanost valorizacije ostataka presovanja crne ribizle. U tu svrhu obavljen je polustruktuirani intervju sa proizvođačem crne ribizle, kao i sa tri potencijalna pružaoca usluga prerade ostataka presovanja. Rezultati pokazuju da je valorizacija komine crne ribizle ekološki i ekonomski odgovoran pristup proizvodnji. Postoji nekoliko načina za valorizaciju komine crne ribizle, a u ovoj studiji akcenat je stavljen na ceđenje ulja iz semena i dobijanje brašna od osušenih ostataka presovanja. Ekonomska opravdanost valorizacije ostataka presovanja crne ribizle je identifikovana, budući da proizvedeno ulje dodaje vrednost ostatku presovanja za 2,87 €/kg, a brašno proizvedeno kod sva tri prerađivača za 6,60 €/kg, 5,87 €/kg i 5,57 €/kg, respektivno. Nedvosmisleno je utvrđeno da lanci vrednosti ostataka presovanja crne ribizle postoje i da je moguće dodati vrednost trenutno bezvrednom nusproizvodu i na taj način povećati profit, ukloniti otpad iz proizvodnog lanca, a poljoprivredno gazdinstvo učiniti konkurentnijim. Rad ukazuje na potrebu za integrisanjem principa bioekonomije u prakse upravljanja poljoprivrednim ostacima.*

Ključne reči: *bioekonomija, valorizacija nusproizvoda, ostaci presovanja, crna ribizla.*