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Sanja Titin
Ph.D., Student
University of Novi Sad, Faculty of Economics in Subotica, Subotica, Republic of Serbia

sanja.titin.t012023@student.ef.uns.ac.rs

Rade Popović
Ph.D., Full Professor
University of Novi Sad, Faculty of Economics in Subotica, Subotica, Republic of Serbia

rade.popovic@ef.uns.ac.rs

Marija Jeremić
PhD, Associate Professor
University of Novi Sad, Faculty of Economics in Subotica, Subotica, Republic of Serbia

marija.jeremic@ef.uns.ac.rs

Participation (direct/virtual): direct
JEL: D24

TECHNICAL EFFICIENCY OF SERBIAN VEGETABLE OIL PROCESSING INDUSTRY

Abstract: The objective of this paper is to analyse the technical efficiency of the sunflower oil production sector in the Republic of Serbia using Data Envelopment Analysis – DEA methodology. The analysis is conducted on representative sample of 10 companies classified under code 1041- Production of vegetable oil and fats. The study utilized data for the year 2023. Results provide insight into how firm size affect the technical efficiency of oil producers. In addition the analysis identifies key sources of inefficiency, most commonly stemming from suboptimal utilization of inputs such as raw material, energy, labor and others.

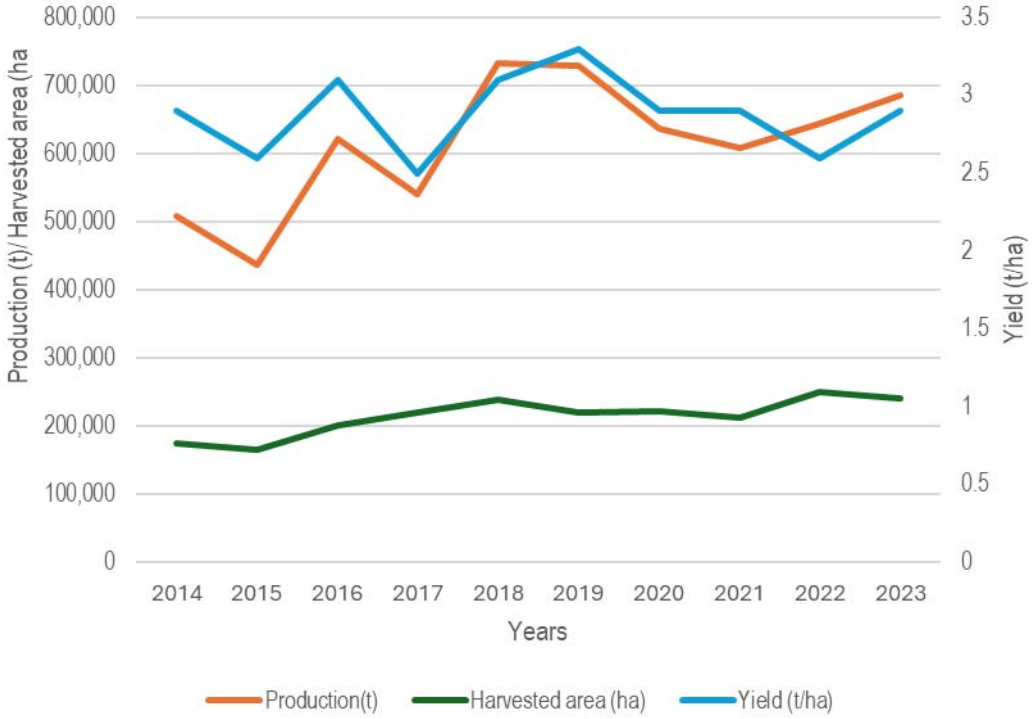
Keywords: technical efficiency, vegetable oil, DEA method, Serbia

1. INTRODUCTION

The production of the sunflower and sunflower oil represent a very significant part of the global oilseed market (Knežević & Popović, 2011). Sunflower and rapeseed, as well as sunflower and rapeseed oil produced from them, along with palm and soybean oil, belong to the group of the most important and widespread oilseeds and edible vegetable oils throughout Europe and the world. (Premović, Ilić, & Krmpot, 2024). On global scale, Russia and Ukraine dominate in sunflower seed production, and together account-51.3% of global supply. The European Union is also one of the major producer, with 9.83 million tons, followed by Argentina and Turkey (FAOSTAT, 2025). Considering that the Black Sea region presents production and trade center of sunflower and its derivates, changes in these markets have a direct impact on global prices. The oilseed market in the Black Sea basin (which is also a reference point for the Republic of Serbia) is currently facing challenges due to a low oil price, which have dropped below USD 900 per ton. This is a significant drop compared to April 2022, when the price exceeded USD 2,000 per ton, as well as compared to October last year, when the price was USD 1,300 per ton. (Ministry of Agriculture, Forestry and Water Management, 2023b). According to Premović, Ilić, & Krmpot (2024) in Europe the maximum sunflower production was in Ukraine (14,000,000-14,160,000 t), and the minimum in Portugal (22,000-23,000 t). Serbia ranks as the 7th largest sunflower producer in Europe, with total output of 650,000 t.

According to SORS data in 2023 there was a growing trend in the sunflower harvested area, ranging from 166,192 hectares in 2015 to 251,155 hectares in 2022. Average yields have fluctuated significantly due to the impact of variable weather conditions. The highest yield was recorded in 2019 (3.3 t/ha), while the lowest was in 2017 (2.5t/ha). The overall increase in sunflower production in Serbia is primarily driven by expansion of sown areas.

Figure 1. Production, harvested area, and average yield of sunflower in Serbia in the period from 2014 to 2023



Source: SORS,2025

In period between two agricultural censuses the area under sunflower and the number of farms increased by 26.6% and 69.8% respectively. At the same time, the average area under sunflower per farm decreased from 6.6 ha to 4.9 ha (Table 1). This indicate that significant number of small and medium-size farms decided to introduce sunflower into their crop rotation, which has resulted in a decline in the average area under this crop.

Table1. Number of farms and area under sunflower in Serbia

Year	Area [ha]	Number of farms [number]	Average area per farm [ha]
2012	186,361	28,307	6.6
2023	235,905	48,055	4.9

Source: Authors based on data from the Agricultural Censuses 2012 and 2023

According to the Ministry of Agriculture, Forestry and Water Management (2023a), the largest number of farms engaged in sunflower production cultivate between 10 and 20 hectares of utilized agricultural land (UAA), with a total area of 44,915 ha, representing 19% of the total sunflower cultivation area. They are followed by farms with 5 to 10 ha, which account for 25.3% of the total sunflower-producing farms, cultivating 23,753 ha in total, or 10.1% of the overall sunflower area. Farms which cultivate more than 10 ha represent only 1.9% of all sunflower producers yet manage the largest share of sunflower-planted land (25% of the total area). Structural changes in number and size of farms have occurred under the influence of specific agrometeorological conditions and market dynamics. In general, agrometeorological conditions during the 2023/2024 production season in the Republic of Serbia were mostly favorable for sunflower cultivation. Compared to the previous drought year, the season was notably more humid. However, storm winds, heavy rains, and hail in the northern regions during the grain-filing phase caused lodging and breakage of plants, albeit on limited area (Republic Hydrometeorological Institute of Serbia, 2024). The fact is that the domestic sunflower market reflect the situation on the global oilseed market, which is currently saturated with inexpensive Ukrainian supply and at the same time is experiencing downward price trend. During the sowing period, input prices were high. In the meantime, input and final product prices have fallen, which currently burdens producers the most. In the long term, these cost reductions are expected to benefit consumers as well. Following the introductory section, which provides a brief overview of developments in the global and Serbia's sunflower market, the study proceeds with the methodology section. The third section presents a literature review regarding the application of the DEA method for analyzing the efficiency of agricultural sector participants. This is followed by the discussion of research results, while the final section is devoted to concluding remarks.

2. METHODOLOGY

The efficiency of enterprises engaged in the production vegetables of oils and fats in the Republic of Serbia was analyzed based on data from the database Serbian Business Register Agencies, for the 2023 year, specifically using financial reports – balance sheets and income statements. In addition, information was gathered from company websites, business reports, and relevant research sources. Initially, the research encompassed 93 enterprises classified under the activity code 1041 – Production of oils and fats. However, the analysis revealed that only 58 companies held an" active" status. A significant number of these companies are not exclusively engaged in sunflower oil production, indicating a broad range of production activities within this industry. The analysis shows that only 21 companies are specifically involved in the production of sunflower oil. For the purpose of this research, data was processed for a representative sample of 10 oil-producing companies.

According to the legal status, the companies' structure include: one join-stock company, 40 limited liability companies, 16 entrepreneurs, and one cooperative. In order to analyze the efficiency of the sunflower oil production sector in Republic of Serbia Data Envelopment Analysis (DEA) method was used. DEA is a non-parametric technique based on linear programming, which allows decision-makers to evaluate multiple inputs and outputs simultaneously. The efficiency of each Decision Making Unit (DMU) is assessed in relation to the most efficient unit (a production frontier), rather than to an average performance (Zhang, Huang, Lin, & Yu, 2009). The DEA method used in this study can be calculated under the assumption of Constant Returns to Scale (CRS), representing Technical Efficiency (TE), as well under Variable returns to scale (vrs), representing Pure Technical Efficiency (PTE). The efficiency scores for TE and PTE range from zero to one, where a score of one indicates full efficiency of the observed DMU, while values below one suggests the presence of inefficiency. Inefficient DMUs can improve their performance in two ways: by increasing their scale of operation (irs- Increasing Returns to Scale) or by reducing their scale (drs- Decreasing Returns to Scale) to an optimal level. The advantage of the DEA method over stochastic techniques lies in its ability to determinate the relative efficiency of each individual DMU in comparison with other within the selected sample, thus measuring efficiency internally (Popović & Đokić, 2019).

3. LITERATURE REVIEW

In order to analyze the efficiency of production several models have been developed. One of them is the Data Envelopment Analysis (DEA) method that can also be used to evaluate the efficiency of companies in agri-food sector. The literature review is organized into two sections. The first part considers the application of the DEA method in analysis of farm efficiency, while the second part addresses the efficiency analysis of companies in agri-food sector. Based on literature reviewed, it has been noticed that the DEA method is more frequently applied in the evolution of farms efficiency.

3.1. The application of the DEA method in evaluating farm efficiency

The next part of the paper examines numerous studies that consider the application of the DEA method in the analysis of the efficiency of agricultural holdings in different regions and sectors of agricultural production.

Günden, Miran & Unakıtan (2006) applied the DEA methodology with a constant return to scale assumption to measure the technical efficiency of sunflower production in the Trakya region of Turkey. In their study, the inputs included land, labor, tractor use, nitrogen, seeds, and pesticides, while the output was total sunflower production. The results revealed inefficiencies in sunflower production across the region, with an average technical efficiency score of 0.672, indicating that the same output could be achieved with a 32.8% reduction in input use.

Bojnec & Latruffe (2007) analyzed the efficiency of Slovenian farms across different production sector over the period from 1994 to 2003. Their study included 130 observations, and the results showed that five sectors (crop production, dairy farming, integrated livestock production (with on-farm feed), fruit cultivation, and forestry) were fully efficient. The results also indicate that these specializations have the highest potential to compete in the European and global markets.

Niavis & et al. (2018) evaluated the efficiency of 100 Greek farms specialized in olive trees cultivation using an input-oriented DEA method. The inputs included land, chemical inputs, labor, and energy, while the output was the revenue of each farm. The results indicated significant variations in efficiency score. The results also indicated the possibility of restructuring the production process in order to reduce cost and enhance efficiency.

Popović et al. (2019) used the DEA method with variable returns to scale (vrs) to evaluate the technical efficiency of farms across different regions of Serbia, based on sample of 1,420 farms. The analysis was conducted based on two criteria: region and production type. The results reveal that farms in region Serbia North are in average more efficient than farms in Serbia South. According to production type, in the case of plant production the results indicated higher

average efficiency rate for the indoor and outdoor horticulture farms, and fruit producers. On the other hand, when it comes to livestock production type, results showed higher average efficiency in poultry and pig production.
Popović & Đokić (2019) analyzed the technical efficiency of 520 farms in the region of Serbia North using input-oriented Data Envelopment Analysis (DEA) with variable return to scale (vrs). The output was the total value of agricultural production, while the inputs included intermediate consumption and depreciation, labor, and agricultural land. The results of the research indicated that above average levels of efficiency were achieved by farms engaged in poultry farming, indoor and outdoor horticulture, fruit growing and pig farming.

3.2. The application of the DEA method in evaluating efficiency of company in various food industries sectors

Ali (2007) analyzed the productivity and efficiency of the meat processing industry in India using the DEA method for the period from 1980-81 to 2002-03. To measure changes in total factor productivity (TFP), the author applied Malmquist TFP index. An output was the value of production, while input variables included cost of capital, labor, raw materials, and energy. The results indicated that the industry should modernize its production system in order to improve input utilization, particularly of raw materials, capital, and energy.
Jarzębowski & Bezat-Jarzębowska (2014), conducted an efficiency analysis of dairy processing companies in Poland, covering the period from 2006 to 2011. The sample ranged between 103 and 160 companies, depending on the year. The authors employed two approaches to evaluate efficiency: a parametric (on the example of the SFA method, Stochastic Frontier Analysis) and non-parametric (on the example of the DEA method, Data Envelopment Analysis). Authors used one output variable, sales revenue and two input variables, operating costs and assets value. The result showed an exponential relationship between technical efficiency scores obtained using SFA and DEA methods for the analyzed dairy processing sector during the observed period. The SFA method indicated that the efficiency of dairy processing companies was around 0.4 suggesting low level of technical efficiency.
Popović & Panić (2022) analyzed the technical efficiency of dairies in Serbia using DEA method for 77 dairy companies with 6 identified business strategies. In this analysis, operative revenue was selected as the output, while the inputs included material costs, average number of employees, fuel and energy costs, and another operating expenses. The results showed that dairy companies focused on long term coordination activities with dairy farmers, and those companies oriented on purchase and distribution of dairy product processed on farms, achieved above average levels of efficiency. The lowest level of efficiency performs dairy companies with business strategy focused on full vertical integration.
Pervan (2020) assessed the overall technical, pure technical and scale efficiency of large firms operating in the Croatian food industry using the DEA method. The sample included 64 companies (14 very large and 50 large companies). A total of five variables were used in the analysis (total assets, number of employees, material costs, business revenues, and profit). The results revealed a high level of overall technical, pure technical and scale efficiency among the analyzed firms.
A summary of reviewed DEA based efficiency studies is provided in Table 2.

Table 2: Overview of studies on the efficiency of the agri-food sector using DEA method

Author(s) and Year	Sector	Method	Sample	Output	Inputs	Conclusion
Ali (2007)	Meat Processing Industry, India	DEA	59 meat processing plants	Gross output	Capital cost, raw material costs, labor costs, energy costs	Modernization of the production system is needed to improve the utilization of raw materials, capital, and energy.
Jarzębowski & Bezat-Jarzębowska (2014)	Dairy Processing Industry, Poland	DEA, SFA	103–160 dairy processing companies	Sales revenue	Operating costs, asset value	Dairy processing companies show a low level of technical efficiency.
Pervan (2020)	Food Industry, Croatia	DEA	64 companies (14 very large, 50 large)	Operating revenue, profit	Total assets, number of employees, material costs	The results revealed a high level of overall technical efficiency, pure technical efficiency, and scale efficiency.

Popović & Panić (2022)	Dairy Processing Industry, Serbia	DEA	77 dairies	Operating revenue	Material costs, number of employees, fuel, other costs	Long-term coordination with agricultural producers and a focus on selling dairy products sourced from these producers lead to above-average efficiency.

Source: Authors based on the literature review, 2025

4. RESULTS

In this study, as the single output variable is selected the revenue from sale of products and services, adjusted for changes in the value of inventories of semifinished and finished products. The reason for choosing adjusted sales revenue as the output lies in the fact that in 2023, the most observed oil producers evidenced a decrease in the value of inventories of semifinished and finished products, due to specific market conditions. Sunflower is a commodity traded on the stock market, with prices determined by global supply and demand. A specific feature of oil producers' operations is that sunflowers are purchased in August of one year, while processing and sale of final products occur mostly in the following year. As a result, the inventory value in 2022 was relatively high, given that the average purchase price of sunflower was 57.86 RSD/kg in 2022, whereas in 2023, it dropped to 35.37 RSD/kg (Statistical Office of the Republic of Serbia, 2025). However, in 2023, the value of inventories was subject to a double effect. Additionally, to the lower procurement price of sunflower seed, the market also experienced a decline in final product prices in the second half of the year, which further reduced the value of inventories reported in the income statements. Until the end of March 2023, the Government passed Decision on the price limitation of basic foodstuffs was in effect, which reinstated prices to the level of November 15, 2021. This regulation was a response to the behavior of European countries that closed their markets, and the Republic of Serbia followed similar measures to protect the populations living standard by limiting the prices of oil and other essential food items.

On the input side, two variables were selected: first, the cost of materials, fuel and energy- which, according to financial statement, represent the dominant share of total across of all vegetable oil producers regardless of their size and second, other costs, which include labor cost, depreciation, service expenses, intangible cost, interest and miscellaneous. Three large companies – Dijamant doo, Victoria Oil, and Bimal record both revenues and cost above the sector average, while the remaining companies, classified as medium, small, and micro enterprises, report below-average values relative to the sector as a whole (Table 3).

The structure of companies registered under the activity code 1041 – Production of vegetable oil and fats, by size in 2023, is as follow:

- Large companies (5): Dijamant, Bimal Sunce, Vital Vrbas, Viktorija Oil, Banat
- Medium companies (1): Agrolek
- Small companies (2) Bach Oil, Dunavka
- Micro companies (2) Bački Dukat, Linum

Table 3. Descriptive statistics for variables of 10 DMU, used in DEA method (in thousands)

Variable	Average	Standard deviation	Minimum	Maximum
Revenue +/- inventory of semifinished and finished products change	43,304,760	52,549,754	162,093	136,456,099
Raw material, fuel and energy	37,615,056	45,283,152	109,913	122,166,586
Other costs (labor, depreciation, service, intangible cost, interest, and other costs)	7,635,904	10,700,436	42,276	30,589,002

Source: Serbian Business Register Agency database, 2025

The results of the correlation analysis (Table 4) confirm the existence of a strong correlation between the selected output and the defined inputs. It is expected, given that the oil and fat production sector is characterized by a relatively rigid relationship between the quantity of purchased sunflower seed and other inputs on one hand, and the output, which is expressed in terms of the value of produced products, on the other.

Table 4. Correlation analysis of input and output variables for 10 DMU

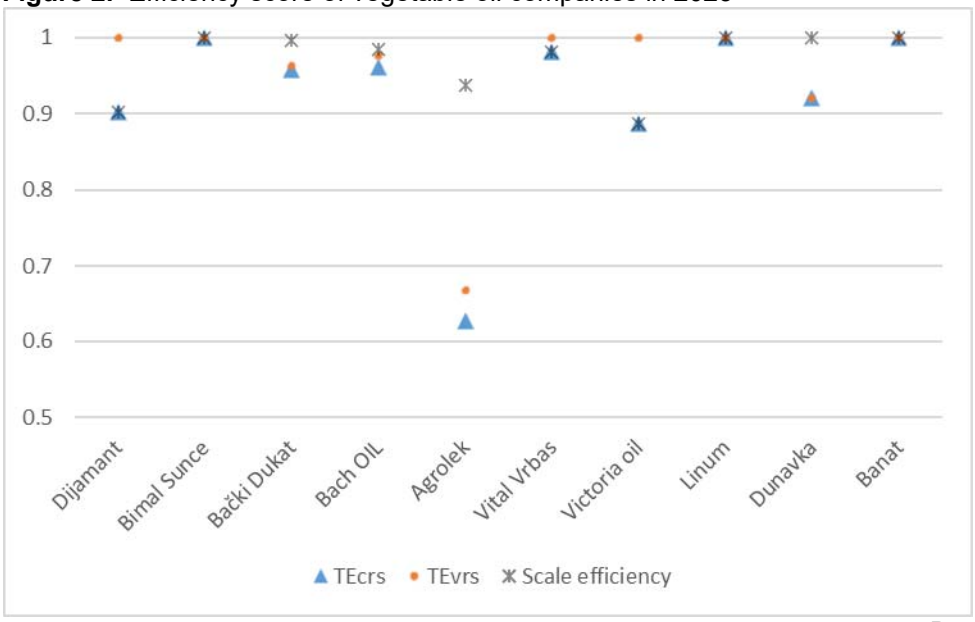
	Revenue +/- inventory of semifinished and finished products change	Raw material, fuel and energy	Other costs (labor, depreciation, service, intangible cost, interest, and other costs)
Revenue +/- inventory of semifinished and finished products change	1		
Raw material, fuel and energy	0.997371171	1	
Other costs (labor, depreciation, service, intangible cost, interest, and other costs)	0.967416192	0.950840324	1

Source: Serbian Business Register Agency database, 2025

For the evaluation of the DEA efficiency model of the vegetable oil and fat production sector in Serbia for 2023, the DEAP 2.1. software developed by Coelli in 1996 (Coelli, Rao, O Donnell, & Battese, 2005) was used. The input-oriented model with variable returns to scale was selected for the analysis. Table 5 shows the efficiency coefficients by size, with the average technical efficiency for all oil producers in the sample being 0.924. The lowest value is found in the medium-sized vegetable oil producers (0.627), and the highest value is for the micro enterprises, 0.979. The maximum level of efficiency, represented by a TEcrs=1, was achieved by 3 oil producers in total (1 micro, 2 large). For TEcrs**,** decomposition was carried out into pure technical efficiency and scale efficiency, shown in the columns TEvrs and scale efficiency. Oil producers in the sample achieved lower levels of pure technical efficiency, with an average coefficient of 0.953. The oil producers that performed below average in terms of pure technical efficiency were medium-sized ones, while the micro and large performed above average. The efficiency level of 1 was achieved by 6 vegetable oil producers: 5 large and one micro. On average, the participation of oil producers with pure technical efficiency was highest among large, where the maximum level of pure technical efficiency TEvrc=1, was achieved, and lowest among medium oil producers (0.669).

Oil producers with a pure technical efficiency coefficient lower than 1 can improve their results by reducing their scale of operations (drs) to the optimal level. Out of the total number of 10 oil producers, 4 achieved the maximum level of technical efficiency in relation to their size (Figure 2): 1 micro (50% of all micro-oil producers), 1 small (50%), and 2 large (40%). A coefficient of less than 1 was achieved by 6 oil producers, and they can improve their operations by reducing the use of analyzed inputs (one or both) to the optimal level. A more detailed analysis obtained by the DEA method, using the example of the medium-sized enterprise Agrolek, which had the lowest values for TEcrs, TEvrs and scale efficiency, revealed that there is a room for improvement by reducing the second input, i.e., other costs, to achieve the optimal efficiency level. In general, for all oil producers with a scale efficiency coefficient lower than 1, their results can be improved by reducing the scale of operations (drs) to maximum average productivity.

Figure 2. Efficiency score of vegetable oil companies in 2023



Source: Results by using DEAP 2.1. software

Based on the analysis of average values (Table 5), it can be concluded that the biggest challenge lies with medium-sized oil producers due to the lowest values of TEcrs and TEvrs. On the other hand, large oil producers are technically fully efficient (TEcrs = 1) under optimal conditions, but their scale efficiency indicates room for improvement.

Table 5. Average technical efficiency of vegetable oil producers in Serbia according size

Size	TEvrs	TEcrs	Scale efficiency	Number of oil producer's
Micro	0.981	0.979	0.998	2
Small	0.949	0.941	0.992	2
Medium	0.669	0.627	0.937	1
Large	1	0.954	0.954	5
Average	0.953	0.924	0.969	10

Source: Results by using DEAP 2.1. software

5. CONCLUSIONS

The total production of sunflower in the Republic of Serbia is increasing due to the expansion of area in the sowing structure, i.e. oilseeds are becoming an increasingly common choice of farms, regardless of the size of the agricultural land used. Based on the efficiency analysis of the sunflower oil and fat production sector in Serbia in 2023, the average coefficient of technical efficiency was identified at level TEcrs = 0.924, which indicates high efficiency score in most of the companies in the analyzed sample. The pure technical efficiency (TEvrs) averages 0.953 and the coefficient of size efficiency averages 0.969. These results suggest that the sector in the observed period generally functions close to optimal conditions in terms of the combination of inputs necessary to achieve a given output. In terms of the size of the vegetable oil producers, micro oil producers, despite their smaller scale of operations, have achieved a very high coefficient (TEcrs=0.979). Large oil producers reached maximum pure technical efficiency (TEvrs=1), but the lower level of size efficiency coefficients indicates room for improvement, specifically by reducing the scale of operations (drs). Medium-sized oil producers are positioned the weakest with achieved coefficients of TEcrs=0.669 and TEcrs=0.627. The analysis has determined that these oil producers can improve their results by reducing input usage for the same level of produced output, particularly through a reduction in other costs. This paper contributes to the understanding of technical efficiency in the oil and fat production sector in Serbia. Considering that raw material prices, government regulations, and economic factors have a significant impact on enterprise efficiency in this industry, it opens the possibility for further research in this important but under-researched area. Therefore, future analyses in this sector will need to consider market specificities, as well as longer time intervals, to better understand trends and opportunities for further progress in the sector.

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