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POTENTIALS OF GRAPE POMACE FOR COMPOST PRODUCTION ON THE TERRITORY OF THE THREE MORAVA REGION: A CASE STUDY

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Abstract. *Stems, skins, seeds, and pulp are grape pomace (GP) components formed as by-products during wine production. The GP share represents about 25% of the total amount of processed grapes, which is a significant amount of organic waste (OW) that can be treated in the composting process. The purpose of the paper is to consider the possibility of their use by presenting the basic characteristics and potentials of GP and other available fractions of OW of agricultural origin. First, based on the representation of vineyards by regions on the territory of the Republic of Serbia and locally available substrates, and using a previously developed mathematical model, the quantities of observed fractions and composts were calculated. After applying the mathematical model to the cities belonging to the Three Morava Region, it was discovered that the optimal mixture contains 40% of GP when the co-substrates are wheat straw (WS) and swine manure (SM). Next, using the mean values of the percentage of co-substrates and GP, the model was applied to the territory of the Republic of Serbia. The results showed sufficient quantities of all substrates and the model criteria were satisfied.*

Key words: composting, potentials, agricultural waste, grape waste, closing the loop

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1. INTRODUCTION

The wine industry and its accompanying agricultural branch, viticulture, have traditionally been among the most represented economic activities in the world. It is estimated that the annual quantities of grape production are higher than 77.8 million tons [1]. The most significant cultivation of grapes is in Europe, namely, Italy, France and Spain, amounting to about 40% of the total production globally, followed by America and Asia [2]. A significant amount of grape pomace (GP) waste is released during the winemaking process, representing about 25% of the total grapes [3], which can amount to tens of millions of tons of GP annually. The main components of GP are skins, seeds, stalks and a small amount of pulp formed during the process. Some GP parts are used to obtain other products in the food and pharmaceutical industries, such as grape seed oil or phenolic compounds. After grape fermentation in wine production, GP is used to obtain alcohol or cellulose-based compounds. After that, it remains a solid residue with altered characteristics, which in most cases is rejected [4]. However, this type of organic waste (OW) should not be dismissed primarily because of the significant content of essential nutrients, especially P and K. Some negative properties of this waste, such as low pH value and the content of polyphenolic compounds, can be eliminated by its biological treatment. The problem of the presence of polyphenol compounds that have a phytotoxic and antimicrobial effect for use as an organic fertilizer is solved by treating the GP process with composting [5]. The insufficiently good initial composition of GP can be solved by co-composting.

Composting is a biological treatment where mesophilic and thermophilic microorganisms are used to decompose complex compounds to obtain a stable end product that can be used as a natural fertilizer. During the composting process, easily degradable components such as proteins and sugars are first broken down and provide the necessary energy for the reproduction and physiological activities of microorganisms and the transition to the next phase. The second phase of the composting process is accompanied by high temperatures at which more complex compounds from OW decompose. In the last stage, the decomposition of more challenging to decompose compounds is completed, and after that, the process of maturing the product begins and later the obtained compost is used.

Numerous factors affect the composting process: physicochemical properties of the treated OW (pH value, moisture content, content of easily degradable compounds, particle size and carbon-nitrogen ratio, C/N) and environmental conditions if the treatment is not performed in controlled conditions [6]. The pH value changes during the process. At the beginning of the process, the pH value is low due to the intensive decomposition process and accumulation of organic acids. The process is slowed if the acid phase is too long. The pH value increases in the second and third phases and ranges from neutral to slightly basic [7]. Moisture content and particle size in the composting process are closely related. Too small particles and high moisture content lead to anaerobic conditions, i.e. the expulsion of air from the mass, and if the moisture content is insufficient, the process can be stopped. Therefore, the moisture content must be optimal, usually 40% to 60%, [7,8]. To provide energy for the development of microorganisms, raw materials treated by the composting process should contain compounds with sufficient amounts of carbon and nitrogen in their composition and other nutrients. The ratio of carbon and nitrogen (C/N) is the most critical factor in the composting process. For the smooth running of the process, the C/N ratio should be between 25 and 35. Higher values slow down the development of microorganisms (there are not enough building blocks for proteins) while losing nitrogen in the form of ammonia [9]. The final value of the C/N ratio plays a significant role if the obtained compost is further used as a fertilizer for soil treatment. A too high or too low C/N ratio harms the land on which it is used [10].

Due to its favorable properties, many studies have focused on monitoring the process of co-composting GP with additional co-substrates. Research that has investigated the advantages and disadvantages of composting GP and organic fraction of municipal waste (OFMSW) has shown that the presence of OFMSW contributes to increasing the content of P and N and reducing the acidity of the mixture [11]. A study conducted in Brazil examining the use of compost obtained from GP showed that the final product contains a high content of nutrients. Due to the presence of metals, it is necessary to include an additional fraction of OW in composting [12]. A similar study was conducted in Chile, where the parameters of quality and stability of compost obtained from GP and animal manure were examined. The results showed that the obtained compost satisfies the quality criteria through phytotoxicity, the absence of pathogens, and can be used as an organic fertilizer [13]. Research that has been conducted with composting certain parts of GP has shown that in the treatment of stalks and sludge, stalks contribute to achieving higher temperatures, and C/N ratio at the end and beginning of the process. These results were obtained for the case when the stalks were chopped [14].

This paper will present the potential of GP as a raw material for obtaining compost on the territory of the Republic of Serbia. In addition to the potential of GP, the potentials of other available fractions of OW are presented. According to their characteristics, they can be used as co-substrates, such as animal manure, crop residues, and OFMSW. By applying the previously developed mathematical model for obtaining the optimal mixture of various substrates for composting [15], and based on known quantities of OW and characteristics, it would be possible to determine the utilization of individual fractions of OW and the volume of compost that can be produced in the Republic of Serbia. During the application of the mathematical model, three criteria were introduced: the quantities and characteristics of the co-substrate and their territorial proximity. Four cities in the Three Morava Region were selected, with the most significant areas under vineyards and the most excrement that has other available raw materials. After applying the mathematical model, an optimal mixture was obtained, which consisted of 40% GP, 22.1% what straw (WS) and 37.9% swine manure (SM). By applying the model to the territory of the Republic of Serbia and based on the average values for the shares of substrates, it was shown that it is possible to satisfy the mathematical model and that there are large surpluses of substrates.

2. MATERIALS AND METHODS

2.1. Grape processing process

The scheme of the process of obtaining red and white wine is shown in Figure 1 [16] [17].

As shown in Figure 1, in both cases, the GP at the end of the process is composed of seeds, skins, stalks and small amounts of pulp. Table 1 shows some of the characteristics of GP components that are important for the composting process, above all, the content of carbon (C), nitrogen (N), pH and moisture content [19 - 30].

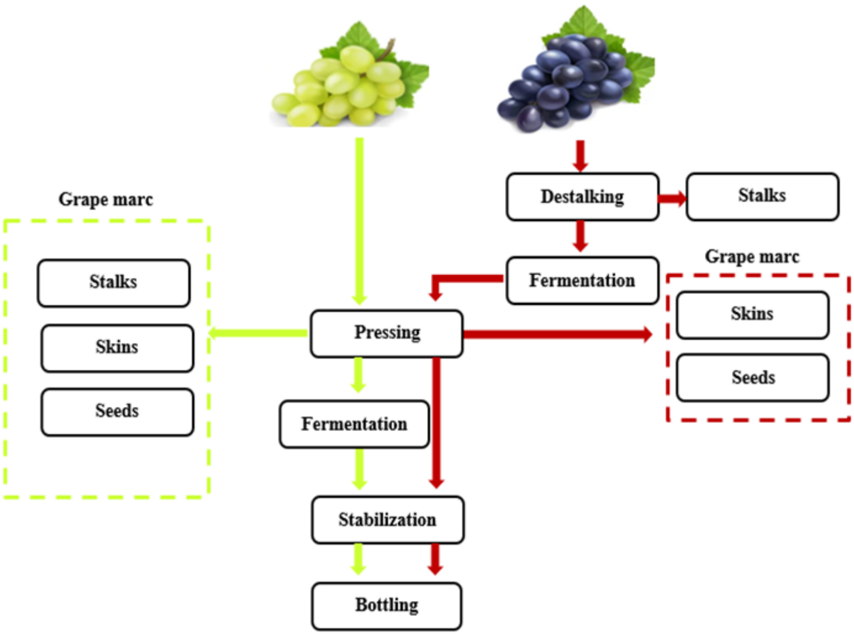

Fig. 1 Scheme of grape processing and separation of by-products [16,18]

Table 1 Characteristics of grape pomace

Parameter Component	C, %	N, %	C/N	pH	Moisture, %
Skins	49.82 – 47.36	2.08 –2.36	23.98	6.80	60.90 – 64.40
Stalks	48.23 – 41.58	1.93 – 1.18	24.98	9.58 – 7.77	68.90 – 44.40
Pulp	/	/	/	3.65	79.15
Seeds	55.44 – 57.60	2.47 –2.40	22.44	4.60	6.93 – 10.60

From Table 1, it can be seen that the C/N ratio of all components is higher than 20, with stalks having the highest content, followed by skins and then seeds. If the moisture content in the individual components is observed, all parts except the seeds are in the required range, 40-60% (pulp has the highest moisture content, while seeds have the lowest moisture content). Except for the stems (9.58), GP is also characterized by a pH value (3.60 - 6.8).

Based on the characteristics shown in Table 1, it can be seen that if GP is considered raw material for composting treatment, it does not have good initial characteristics. The negative characteristics are, first of all, the low pH value, which slows down the process. Also, the C/N ratio, which is higher than 20 for all components of GP, still does not meet the lower limit of the minimum value of 25 for the smooth running of the process [8]. Furthermore, vineyards' seasonal presence and diversity are another negative feature of GP as a raw material for composting.

Due to the previously described properties, additional components are added to GP – co-substrates, to achieve optimal conditions for the smooth running of the composting process.

2.2. Potentials of OW suitable for composting on the territory of the Republic of Serbia

For the needs of compost production that has a quality such that when returning to nature, it can meet the needs of plants, it is necessary to mix different substrates. Preliminary theoretical and experimental research has shown that GP can be combined with different types of substrates such as OFMSW [11, 13, 31] and crop residues such as WS and maize silage (MS) [32].

Keeping in mind that there are many of them, the available potentials on the territory of the Republic of Serbia were considered so as to be included in the composting process. Therefore, in addition to viticulture, agricultural waste from the countryside (wheat and maize residues), livestock (poultry, cattle, and pig manure), and municipal waste from the city (food waste and green waste) were also taken into account.

2.2.1. Vineyard potentials

Viticulture in the Republic of Serbia is an essential agricultural branch that has constantly grown in the last few decades.

On the territory of the Republic of Serbia, there are three wine-growing regions: the region of Central Serbia, the region of Vojvodina, and the region of Kosovo and Metohija.

Within these three regions, there are 22 regions with 77 vineyards and several wine-growing oases. According to the data from the 2012 census of agriculture on the territory of the Republic of Serbia, the area under vineyards is about 25,000 ha [33]. Based on the distribution of vineyards the most significant areas are located in the territory of Central Serbia, about 17,118 ha, and in the region of Vojvodina 5,032.00 ha. The data for the part of Kosovo and Metohija are not available.

Table 2 shows the distribution and areas under vineyards by regions in the Republic of Serbia.

Table 2 Distribution and areas of vineyards in Serbia [33]

Region	Area [ha]	Grape yield [t]	GP quantity [t]
Subotica region	312.18	2,497.44	624.36
Telečka region	115.23	921.84	230.46
Potiski region	227.37	1,818.96	454.74
Banat region	132.03	1,056.24	264.06
Južni banat region	1,730.69	13,845.52	3,461.38
Bačka region	18.87	150.96	37.74
Srem region	2,215.55	17,724.40	4,431.10
Beograd region	1,129.55	9,036.40	2,259.10
Pocersko – valjevo region	190.62	1,524.96	381.24
Šumadija region	1119.79	8,958.32	2,239.58
Mlava region	814.37	6,514.96	1,628.74
Negotin region	978.04	7,824.32	1,956.08
Knjaževac region	1,076.47	8,611.76	2,152.94
Tri Morave region	7,528.76	60,230.08	15,057.52
Čačansko – kraljevo region	64.88	519.04	129.76
Niš region	1,311.85	10,494.80	2,623.70
Nišava region	470.88	3,767.04	941.76
Toplica region	764.73	6,117.84	1,529.46
Leskovac region	1,459.27	11,674.16	2,918.54
Vranje region	421.31	3,370.48	842.62
Total	22,082.44	176,659.52	44,164.88

From Table 2, it can be seen that the most significant areas under vineyards are represented in the Three Morava region, where the areas under vineyards are 7,528.76 ha. The average grape yield is about 8,000 kg/ha [34]. Based on that amount, the amount of GP for each region can be estimated. The total amount of GP on the entire territory of Serbia is 44,164.88 t (Table 2). Therefore, the GP quantities in the Three Morava region are 15,057.52 t. At the same time, in the other areas, the amounts are significantly smaller.

2.2.2. Livestock potentials

Livestock is the leading branch of agriculture in the Republic of Serbia. About 77.5% of agricultural farms in Serbia are engaged in livestock production. According to the number of conditional throats (CT) of all animals, the regions of Šumadija and Western Serbia (39.8%) and the region of Vojvodina (34%), respectively, have the highest percentages of livestock. It is less distinct in Southern and Eastern Serbia (20.7%) and Belgrade (the smallest percentage).

The average density of livestock production, according to the 2012 census, was 0.6 CT/ha. According to the structure of CT, the most represented are pigs (36.7%) and cows (34.7), while poultry is slightly less represented (18.1%), with the other CT amounting to about 10% [35].

In Western Serbia and Šumadija region, cattle breeding accounts for 45.5% of livestock production while swine breeding accounts for 33.8%.

In Vojvodina, livestock is represented by 27% of cattle breeding and 41% of swine breeding. In Southern and Eastern Serbia, cattle and swine breeding is represented by about 20%. The lowest prevalence is in the Belgrade region, with about 6% for both species. What characterizes poultry farming is a small number of farms with many CT concentrated in different parts of Serbia. The highest concentration of poultry is in Vojvodina and Central Serbia in the area of the Three Morava region.

2.2.3. Wheat and maize potentials

According to the 2012 census of agriculture, there is 3,347,423 ha of arable land on the territory of the Republic of Serbia [36]. The structure of agricultural land is made up of arable land and gardens, meadows, vineyards, orchards and backyards. The area under cereals has the largest share in the structure of agricultural land, about 68%, i.e. 1,715,562 ha, of which corn is 39% (976, 612 ha of land) and wheat 24% (602,804 ha of land) [36]. The most significant areas under cereals are located on the territory of Vojvodina, namely 940,597 ha, and the smallest in the Belgrade region, 62,389 ha, Table 3 [36]. The average yield of wheat residues is 3.50 t / ha, while maize yield is 3.85 t / ha [37].

Table 3 shows each region's annual wheat and maize production based on these data.

Table 3 Areas of wheat and maize and biomass yield by regions of the Republic of Serbia

Region	Wheat		Maize	
	Area [ha]	Annual production [t/year]	Area [ha]	Annual production [t/year]
Belgrade region	26,523.00	92,830.50	35,866.00	102,113.55
Region of Vojvodina	330,293.00	1,156,025.50	610,304.00	1,271,628.05
The region of Šumadija and Western Serbia	117,478.00	411,173.00	185,952.00	452,290.30
Region of Southern and Eastern Serbia	128,549.00	449,921.50	144,490.00	494,913.65
Total	602,844.00	2,109,954.00	976, 612.00	3,759,956.20

2.2.4. Potentials of the organic fraction of municipal waste (OFMSW)

On the territory of the Republic of Serbia, the amount of municipal waste (MW) generated is 2,374,374 t, or about 0.87 kg per capita per day [38]. The largest share in the MW is the organic fraction of municipal waste (OFMSW) with 42.48%, on average for the whole of Serbia, which consists of garden waste (GW) (11.88% in the MW) and food waste (FW) (30.6% in the MW) [38].

Taking all the above into account, Table 4 shows the available quantities of organic matter on the territory of the Republic of Serbia that can be used for composting [33] [36] [37- 40].

Table 4 Quantities of organic mass on the territory of the Republic of Serbia

	Type organic mass		
Vineyard	Area under vineyards [ha]	Amount of GP per area [t/year/area]	Total amount of GP per area [t/year]
Grape pomace	22,082.44	2.0	44,164.88
Animal Manure (AM)	Number of heads	Amount of AM per head [t/year/area]	The total amount of AM per head [t/year]
Cow	908,102.00	19.86	18,162,040.00
Swine	3,407,318.00	1.45	4,906,537.920
Polutry	26,710,921.00	0.06	1,736,209.865
Biomass waste (BW)	Area [ha]	Amount of BW per area [t/year/area]	The total amount of BW per area [t/year]
Maize	976, 612.00	3.85	3,759,956.20
Wheat straw	602,844.00	3.50	2,109,954.00
Organic fraction of municipal waste (OFSMW)	Number of inhabitants	Amount of OFSMW per inhabitant [t/year/inhabit]	The total amount of OFSMW per inhabitant [t/year]
FW	7,041,599.00	0.1045	736,055.90
GW	7,041,599.00	0.0404	284,924.80

Table 4 shows that on the territory of the Republic of Serbia, there are large quantities of OW derived from animal manure (cow, swine and poultry), biomass waste from agriculture (maize and wheat straw), organic fraction of municipal waste (food and green waste) and waste which occurs after processing grapes that can be composted. Most of that waste is not treated but discarded. On the other hand, it can be seen that the presented OW fractions are highly suitable when used as raw materials for the composting process because they are readily available locally, plentiful, and nutrient-rich. By applying composting to the presented fractions of OW, two goals are achieved: solving the problem of waste and returning nutrients to the soil, i.e. the principle of circularity is completed.

2.3. Description of the mathematical model

For this research, a previously developed mathematical model [15] was used based on multi-criteria optimization, which includes the lexicographic method applied in this paper. The application of this method enables the monitoring of several parameters simultaneously to obtain an optimal solution that will be within the range of given conditions. The formation of the model consists of several steps: the formation of equations, setting boundary conditions and criteria, and the choice of priority criteria that we want to achieve.

The formation of equations was performed based on OW characteristics, carbon (C) and nitrogen (N) content, as well as moisture content (M) and pH value.

Boundary conditions were formed based on the literature data related to mentioned parameters that influence the composting process and the attitudes of decision-makers.

The first boundary condition in the model was that the sum of the observed fractions is 1, i.e. that their sum is 100%.

The second boundary condition in the model is that the C/N ratio is 25 to 35, which is the optimal ratio to start the process.

The third boundary condition in the developed model was that the moisture content is 50% to 60%. *The fourth boundary* condition in the model was that all observed OW fractions participate in the optimal mixture for composting treatment.

The fifth boundary condition in the model was that the share of individual fractions moves in different ranges. This paper assumes that the percentages range from 0 to 1, i.e. up to 100%.

The criteria were set on the basis of optimal conditions for the beginning of the process. The requirements set by the mathematical model serve to achieve the maximum carbon content and the maximum pH value in the initial mixture for the given boundary conditions. In the first step of this method, a solution that only meets the first criterion (maximum content C) while adhering to the constraints is sought. After obtaining the solution to the problem, if the resolution of the issue is not unique, the problem is solved using another given criterion (maximum pH value), and an answer is obtained. As the goal of optimization is to get an optimal solution according to both criteria, the next step in the model is the choice of the priority function, i.e. which criterion is more important to us. The maximum pH value was chosen as an important function in this study. This choice was made based on considering the characteristics of OW and, above all, GP, whose share in the mixture was monitored.

3. Experimental Research

To determine which fractions result in the highest inclusion of waste, especially GP, the experimental research was done to address the issue of GP as the main component and the inclusion of other available types of OW (crop residues, animal manure, and OFMSW) as a co-substrate for compost production in a limited area.

3.1. Study area

The research was conducted on the territories of four cities, Jagodina, Kruševac, Trstenik and Aleksandrovac, which belong to the Three Morava region. Data related to the number of inhabitants, areas under WS and MS, and the numbers of CT are given in the Table 5. Cities were chosen based on whether there is an area under vineyards, agricultural areas under cereals, and animal farms in a particular area, in order to show that it is possible to get compost by combining all raw materials with an aim of achieving the best characteristics for the starting mixture and compost by using the previously developed mathematical model.

The quantities of available fractions found on the territories of the observed cities are shown in Table 5.

Table 5 Quantities of available fractions on the territory of the observed cities

Type of OW / Cities	GP	Animal manure			Biomass waste		OFMSW	
		CM	SM	PM	MS	WS	FW	GW
Jagodina	620.12	108,455.46	36,145.60	35,405.21	24,428.25	14,616.00	6,623.00	2,560.47
Kruševac	3,911.80	335,693.58	71,261.70	26,211.12	33,949.00	17,724.00	12,439.15	4,809.01
Trstenik	4,398.40	97,472.88	29,723.55	13,006.23	15,053.50	5,390.00	878.43	1,529.62
Aleksandrovac	3,061.00	85,556.88	24,607.95	26,095.22	9,871.40	5,166.00	2,461.07	951.46

3.2. Optimization of the composting process

When optimizing the initial mixtures of substrates, the main goal was to use the available fractions of OW to obtain a mixture that provides the necessary conditions for the beginning and course of the composting process. Therefore, the mathematical model was formed with four OW factions. GP was taken as the main component, and other OW fractions were changed during the experiment. In each part of the experiment, one fraction from the group of excrements and one fraction from the OFMSW group were taken. Due to the similarity of WS and MS characteristics, only WS was observed.

Table 6 shows the basic characteristics of the above substrates in the observed cities to model the composting process [8] [11] [19] [41 - 45].

Table 6 Characteristics of OW on the territory of the observed cities

Parameter / Type of OW	C [%]	N [%]	C/N	pH	Moisture [%]
Vinyeard					
GP	48.59	2.48	19.60	3.50	59.30
Animal manure					
CM	39.90	2.40	16.62	7.90	78.20
SM	40.90	2.50	16.36	8.24	82.50
PM	43.83	5.02	8.73	8.17	71.10
Biomass waste					
MS	44.18	0.53	83.30	7.40	5.00
WS	48.80	0.60	88.88	7.10	10.80
OFMSW					
FW	48.00	2.60	18.46	6.70	70.00
GW	47.80	3.40	14.05	6.60	60.00

Based on the available OW quantities in the observed cities (Table 5) and their characteristics (Table 6), the optimal amounts of OW fractions in the compostable mixture were obtained by applying the mathematical model. On that occasion, mixtures containing GP, WS, PM and FW were considered (Table 7.1), and combinations in which GP, WS, PM and GW were present (Table 7.2). While food and green waste are taken into account in OFMSW, poultry, swine, and cow manure are taken into account in animal excrement. Additionally, physicochemical characteristics of the resulting mixtures, such as the C/N ratio, maximum pH values, and maximum carbon content are taken into account (Tables 7.1 and 7.2).

4. Results And Discussion

Considering the obtained results (Table 7.1 and 7.2), it can first be seen that the set conditions of the set model were achieved according to the criteria of C/N and pH values (C/N: 25-35, pH = 6).

Looking at the maximum share of GP in the mixture for the first substrate combination (Table 7.1), it is 40% when the optimal mixture is composed of GP, WS and SM on the territories of all observed cities.

If we observe the quantities of used fractions and the maximum share of GP in the optimal mixture, based on the results, Table 7.1 shows that this is present on the territory of the city of Kruševac with more than 30,000 t OW. In other cities, Jagodina, Trstenik and Aleksandrovac, these quantities are slightly more than 10,000 t OW.

Table 7.1 Composition of optimal mixtures of components in the first research group

Component City	GP [%]	WS [%]	AM			OFMSW	C/N	pH	Quantity [t]
			PM [%]	SM [%]	CM [%]	FW [%]			
Jagodina	30.00	28.60	13.60	/	/	27.70	25.03	6.05	11,015.81
	40.00	18.40	/	41.50	/	0	28.39	6.10	17,537.34
	35.00	31.50	/	/	29.80	3.50	24.99	6.06	37,372.58
Kruševac	35.00	27.80	20.80	/	/	16.20	25.01	5.99	13,763.37
	40.00	20.70	/	39.29	/	0	25.00	6.10	33,232.20
	25.00	30.60	/	/	9.60	34.17	25.03	6.10	42,878.35
Trstenik	30.00	28.00	12.00	/	/	28.54	25.35	6.04	4,640.13
	40.00	27.50	/	32.40	/	0	24.87	6.02	12,872.00
	25.00	30.00	/	/	10.00	34.00	25.10	6.10	12,762.40
Aleksandrovac	25.00	29.30	5 .80	/	/	39.70	25.06	6.10	3,255.81
	40.00	24.00	/	35.30	/	0	24.80	6.06	11,150.80
	25.00	30.00	/	/	10.90	33.00	24.87	6.10	12,457.90

However, if we look at the quantities of mixtures obtained, based on Table 7.1, it can be seen that this is achieved when the share of GP is 35% in the city of Jagodina and when the percentage of GP is 25% in the city of Kruševac. In the other two cities, the maximum amount of components participating in the mixture is when the share of GP is 40%.

In the next group of experiments, GW replaced FW, and the other co-substrates remained the same, Table 7.2.

For the second combination of substrates, the maximum share of GP in the mixture is 40% when GP, WS and SM are included in the optimal mixture. This was achieved in all cities but for different proportions of other substrates.

Table 7.2, which examines the number of substrates used and the maximum share of GP in the optimal mixture, shows that this is the case on the territory of the city of Kruševac with more than 30,000 tons of OW. In other cities, Jagodina, Trstenik and Aleksandrovac, these quantities are slightly more than 10,000 t OW.

Table 7.2 Composition of optimal mixtures in the second group of mixtures

Component City	GP [%]	WS [%]	AM PM [%]	AM SM [%]	AM CM [%]	OFMSW GW [%]	C/N	pH	Quantity [t]
Jagodina	25.00	22.10	9.40	/	/	43.41	25.08	6.08	8,511.61
	40.00	18.40	/	41.50	/	0	28.39	6.10	17,537.34
	35.00	30.30	/	/	28.41	6.25	24.99	6.03	35.606.96
Kruševac	30.00	23.30	15.00	/	/	31.23	24.90	6.02	10,815.38
	40.00	20.70	/	39.29	/	0	25.00	6.10	33,232.20
	25.00	22.00	/	/	5.60	47.30	25.00	6.00	25,950.65
Trstenik	25.00	21.00	6.10	/	/	47.45	24.90	6.02	3,750.68
	40.00	27.50	/	32.40	/	0	24.87	6.02	12,872.00
	20.00	21.00	/	/	4.50	53.70	24.78	6.10	7,201.28
Aleksandrovac	20.00	20.00	3.4	/	/	55.70	24.63	6.10	3,062.59
	40.00	24.00	/	35.30	/	0	24.80	6.06	11,150.80
	25.00	22.00	/	/	6.80	45.70	24.84	6.02	8,154.41

However, if we look at the quantities of mixtures obtained, based on Table 7.2, it can be seen that this is achieved when the share of GP is 35% in the city of Jagodina. In the other three cities, the maximum amount of components participating in the mixture is when the share of GP is 40%.

Comparing the obtained results in Tables 7.1 and 7.2, it can be seen that the best results were achieved in both cases when the share of GP was 40% with the same co-substrates WS and SM.

Based on the data shown in Tables 7.1 and 7.2, it can be seen that GP and SM have the highest shares in the optimal mixture, with 40% and more than 30%, respectively. At the same time, WS has the lowest share. Suppose we observe the quantities of fractions that enter the optimal mixture (Tables 7.1 and 7.2). In that case, SM has the highest utilization, followed by WS, while GP has the lowest.

Application of the model to the territory of the Republic of Serbia

The mean values of the percentage fractions were determined based on the obtained results for the composition of the optimal mixture when GP participates with the largest share (Tables 7.1 and 7.2). After the calculation, the mean values for the observed fractions were 40% GP, 22.1% WS, and 37.9% SM.

Applying the average shares on the territory of the Republic of Serbia (RS), it was obtained that the optimal mixture includes 17,665.95 t GP, 466,299.83 t WS, and 1,859,577.87 t SM.

Calculating the amount of compost obtained

Table 8 shows the quantities of OW fractions that enter the optimal mixture for the case of the cities in the Three Morava region and the amounts for the entire territory of the country.

Table 8 Quantities of individual fractions entering the optimal mixture

Type of OW / Cities	GP Amount [t]	Biomass waste	Animal manure	Total Amount [t]	Amount of obtinred comost [t]
		WS Amount [t]	SM Amount [t]		
Jagodina	248.04	2,289.30	15,000.00	17,537.34	8,768.67
Kruševac	1,564.70	3,668.80	27,998.70	33,232.20	16,616.10
Trstenik	1,759.40	1,482.20	9,630.40	12,872.00	6,436.00
Aleksandrovac	1,224.40	1,239.80	8,686.60	11,150.80	5,575.40
RS	17,665.95	466,299.83	1,859,577.87	2,343,543.65	1,171,771.82

The amount of compost obtained at the end of the process for each city was calculated using the obtained quantities of OW that are part of the optimal mixture, and assuming that the mass of the initial mixture is reduced by 50%, after the composting process. Thus, the amount of compost obtained after treatment in Jagodina is 8,768 t, in the city of Kruševac 16,616.1 t, while in the cities of Trstenik and Aleksandrovac 6,436 t and 5,575 t, respectively. Therefore, the amount of compost that would be obtained on the territory of the Republic of Serbia is 1,171,771.82 t.

5. CONCLUSION

The Republic of Serbia has a significant potential for organic waste of agricultural origin. Large areas of arable land are represented on the country's territory, and there are many farms. GP, which is present in large quantities, represents a particular type of agricultural waste. The potentials of GP and other types of agricultural organic waste that are readily available and have qualities that make them suitable for composting such as animal manure, waste biomass, and organic fraction of municipal waste for producing compost are discussed in this paper. By applying the previously developed mathematical model for obtaining the optimal mixture on the territories of cities located in the Three Morava region, it was shown that the highest share of GP in the mixture is 40%. The composition of the optimal mixture includes WS with 22.1% and SM with 37.9%, on average. The resulting substrate mixture meets the required initial parameters, such as C / N 25, a pH value of 6.00, and a moisture content between 50% and 60%, which is a good initial condition. After applying the mathematical model to the territory of the

Based on the average participation of individual components in the optimal mixture, it was determined that there are sufficient amounts of observed substrates. Moreover, SM has the highest utilization, followed by WS, and then GP. It can be concluded that the previously developed model is favorable and acceptable because, in addition to GP, it includes all the listed and most accessible OW fractions. Further research will consider the possibilities of transport of the observed substrates.

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POTENCIJALI ISKORIŠĆENJA KOMINE GROŽĐA ZA PROIZVODNJU KOMPOSTA NA TERITORIJI REGIONA TRI MORAVE: STUDIJA SLUČAJA

Stabljike, kožice, semenke i pulpa su komponente komine grožđa (KG) nastale kao nusproizvodi tokom proizvodnje vina. Udeo KG predstavlja oko 25% ukupne količine prerađenog grožđa, što predstavlja značajnu količinu organskog otpada (OO) koji se može tretirati u procesu kompostiranja. U radu su prikazane osnovne karakteristike i potencijali KG i drugih dostupnih frakcija OO poljoprivrednog porekla sa ciljem sagledavanja mogućnosti njihove upotrebe. Prvo, na osnovu zastupljenosti vinograda po regionima na teritoriji Republike Srbije i lokalno dostupnih supstrata, a korišćenjem prethodno razvijenog matematičkog modela, izračunate su količine posmatranih frakcija i komposta. Primenom matematičkog modela na gradove koji se nalaze u oblasti regiona Tri Morave, pokazano je da najveći udeo KG u optimalnoj smeši iznosi 40% kada su supstrati pšenična slama (PS) i svinjski eksrementi (SE). Zatim je, koristeći srednje vrednosti procenta kosupstrata i KG, model primenjen na teritoriju Republike Srbije. Rezultati su pokazali dovoljne količine svih supstrata i kriterijumi modela su bili zadovoljeni.

Ključne reči: *kompostiranje, potencijali, poljoprivredni otpad, otpad od grožđa, zatvaranje petlje*