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WASTE FROM THE WINE AND ETHYL ALCOHOL PRODUCTION INDUSTRY - AN IMPORTANT SOURCE FOR INCREASING SOIL FERTILITY AND CROP PRODUCTIVITY

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Abstract

The Republic of Moldova generate approximately 100 thousand tons of wastes each year. These contains 28 thousand tons of organic matter, 180 tons of nitrogen, 82 tons of phosphorus and 257 tons of potassium. Fertilization with waste from the production of alcoholic beverages led to a significant increase in the content of organic matter by 0.17-0.41%, nitric nitrogen - 0.45-5.80 mg/kg, mobile phosphorus - 0.22-0.68 mg/100 g and exchangeable potassium by 7-16 mg/100 g of soil. The application of solid wine yeasts ensures a significant increase in grape (Sauvignon) production on average over eight years of 1.4-2.4 t/ha. The average harvest increase when incorporating vinasse over eight years was 1.0-1.1 t/ha. The cereal mash applied to the soil determined the achievement of average increases in plant production over ten years of 1.100-1.700 kg/ha cereal units or 50-65% compared to the unfertilized variant. Based on the research, innovative technologies for the valorisation of waste from the production of alcoholic beverages as local organic fertilizers are developed.

Key words*: grapevine, field crops, solid wine lees, vinasse, grain mash.*

INTRODUCTION

At the current stage in the Republic of Moldova, the ecological state, in most natural ecosystems of the environment is deplorable. Pollution with organic waste of different origin represents a major danger, both for human life and for the environment (Duca & Covaliov, 2001; Duca & Ţugui, 2006).

The Moldova`s primary natural resource is its soil, particularly chernozems, which require ongoing care and attention from the government, specialized institutions and every individual resident. Although there are various types of waste that should not be disposed chaotically in landfills, the country lacks a facility for their processing or recycling. Among these is waste from the wine industry, which is estimated to hundreds of tons annually and represents a significant source of environmental pollution. When these wastes reach the soil in large quantities, they percolate into water bodies, leading to eutrophication and disrupting the balance of these ecosystems (Duca, 2011).

The main purpose of the research was to assess the chemical composition and fertilizer potential of alcoholic waste (wine yeast, vinasse and cereal dregs), to utilize them as fertilizers.

MATERIALS AND METHODS

The research focused on the soil (cambic / leached chernozem), grapevine, field crops and by-products from the production of alcoholic beverages (wine yeast, vinasse and grain dregs), which were applied in two field experiments (Table 1) conducted at the Technological-Experimental Station "Codru" in the commune of Codru, Chisinau Municipality. The experiments were carried out during 2011-2022. Waste was applied manually each year.

Table 1. Field experiments with waste

Wineries waste		Cereal waste	
Variant	*Dose*	*Variant*	*Dose*
Control	unfertilized	Control	unfertilized
Wine yeast (N_{100})	13 t/ha	Grain mash (N_{120})	47 m^3/ha
Wine yeast (N_{200})	26 t/ha	Grain mash (N_{240})	94 m^3/ha
Vinasse (K_{450})	300 m^3/ha	-	-
Vinasse (K_{900})	600 m^3/ha	-	-

Prior to the application of the tested waste materials, the following parameters were analyzed: moisture content, humus content, mineral nitrogen, phosphorus and potassium and the ionic composition of the aqueous extract. Soil samples analyses were conducted using established classical methods.

Solid wine yeast is a by-product of the wine industry, generated during the fermentation of grape juice by yeast. Typically, approximately 10-15% of the volume of juice undergoing fermentation results in the formation of wine yeast, which is in a semi-solid state and has a dry matter content of 12-13% (Plămădeală et al., 2016).

Vinasse is a waste product generated during the distillation of wine to produce wine distillate. However, the treatment and ecological management of the liquid remaining after distillation lack effective technological solutions for its recovery or neutralization in accordance with environmental standards.

Grain mash. In ethyl alcohol production plants, grain mash (wheat, barley, maize), potato mash and molasses are formed as a by-product. In most cases, these products are discarded, causing a polluting impact on the environment.

RESULTS AND DISCUSSIONS

Solid wine yeast. Currently, in wine factories, depending on the existing equipment, ethyl alcohol is extracted from the yeast by distillation. At the same time, the yeast can be dehydrated on filter presses. With or without dehydration, the yeast is evacuated or discharged as waste. The research carried out on the possibility of using them as nutritional additives in animal feed is quite interesting (Chiseliţa, 2010; Duca, 2011).

Wine yeasts are characterized by an acidic status. The average pH value is 3.5. Humidity varies from 42.0 to 58.9%, averaging 48.0%. The chemical composition demonstrates that solid yeasts constitute an important source of organic matter for the soil and nutrients for plants. Calculated from the mass with natural moisture, the organic matter content constitutes an average of 46.8% (Table 2).

Among the primary elements, total potassium predominates with a share of 2.5%, followed by total nitrogen - 1.5%, total phosphorus - 0.70%.

Table 2. Chemical composition of solid wine yeasts, reported to the natural humidity mass (2011-2022), n=12

Index	x	Min.	Max.
pH	3.5	3.2	3.7
Humidity, %	48.0	42.0	58.9
Organic matter, %	46.8	38.3	50.3
Ash, %	5.3	2.8	8.8
Carbon, %	23.4	19.2	25.5
Total nitrogen, %	1.5	0.8	1.8
N-NO_3, mg/100 g	1.6	0.7	2.8
N-NH_4, mg/100g	32.9	26.9	51.7
Total phosphorus, %	0.7	0.6	0.8
Total potassium, %	2.5	2.3	2.7

Compared to conventional manure, solid wine yeasts contain 2.7 times more nitrogen, 1.6 times more phosphorus, 2.4 times more potassium and 2.7 times more organic matter. On average, 1 tone of solid wine yeasts with natural moisture contains 47 kg of NPK, with a ratio of these elements of 1:0.5:1.7, which approximately corresponds to the nutritional needs of the main cultivated plants.

Vinasse. The amount of vinasse represents 75-85% of the volume of wines subjected to distillation. Vinasse is an opalescent or slightly cloudy liquid, of a golden-crimson color, with a specific smell of heat treatment and a sour taste and contains all the compounds originally found in wine: organic and mineral compounds, proteins, coloring compounds, etc. It is characterized by an acidic status. The average pH value is 3.4 units (Table 3).

The dry residue varies from 7.5 to 24.7 g/l, averaging 15.2 g/l. The organic matter content averages 13.3%, varying from 6.3% to 21.7%.

Mineral compounds average 1.9 g/l. Of the primary elements, total potassium predominates in the composition of vinasse with an average value of 0.12%. The total nitrogen and phosphorus content averages 0.02%. Of the total nitrogen content, ammonia constitutes approximately 34%. In the aqueous extract, monovalent potassium cations (579 mg/l) and sodium (172 mg/l) predominate. The concentration of bivalent calcium and magnesium cations averages 106 mg/l and 84 mg/l. Among the anions predominate sulphates. Their concentration ranges from 79 mg/l to 280 mg/l with an average value of 155 mg/l. The chlorine content varies from 69 to 122 mg/l, averaging 90 mg/l (Table 3).

Table 3. Chemical composition of vinasse (2011-2022), n=12

Index	x	Min.	Max.
pH	3.4	3.0	3.7
Dry residue, g/l	15.2	7.5	24.7
Fixed residue, g/l	1.9	1.2	2.9
Organic matter, g/l	13.3	6.3	21.7
Total nitrogen, %	0.02	0.007	0.05
Total phosphorus, %	0.02	0.006	0.039
Total potassium, %	0.12	0.048	0.157
$N\text{-}NH_4$, mg/l	67.0	52.0	86.0
$N\text{-}NO_3$, mg/l	9.3	0.31	23.8
Ca^{+2}, mg/l	106.0	72.0	120.0
Mg^{+2}, mg/l	84.0	49.0	146.0
Na^{+}, mg/l	172.0	125.0	210.0
K^{+}, mg/l	579.0	335.0	1127.0
Cl^{+}, mg/l	90.0	69.0	122.0
SO_4^{-2}, mg/l	155.0	79.0	280.0

Grain mash (Cereal porridge). The grain dregs are characterized by an acidic medium. The pH value is 3.4-4.2 units and they have a varied content of primary elements: total nitrogen - 0.21-0.33%, total phosphorus - 0.06-0.19%, total potassium - 0.09-0.13%.

Among the cations, the monovalent ones of potassium and sodium predominate (783 mg/l and 450 mg/l). The concentration of the bivalent cations of magnesium and calcium is on average 97 mg/l and 234 mg/l. Among the anions predominate sulphates. Their concentration varies between 188 mg/l and 533 mg/l, the average being 367 mg/l.

The average chlorine content is 299 mg/l (Table 4).

Table 4. Chemical composition of grain mash from ethylic alcohol production enterprises (2012-2022), n=12

Index	x	Min.	Max.
pH	3.7	3.4	4.2
Dry residue, g/l	66.3	40.5	72.0
Fixed residue, g/l	14.9	9.3	21.4
Organic matter, g/l	51.4	16.2	62.1
Humidity, %	93.4	92.1	97.0
Total nitrogen, %	0.28	0.21	0.33
Total phosphorus, %	0.12	0.06	0.19
Total potassium, %	0.11	0.09	0.13
$N\text{-}NH_4$, mg/l	143.0	71.0	224.0
$N\text{-}NO_3$, mg/l	5.8	2.9	11.0
Ca^{+2}, mg/l	97	60	100
Mg^{+2}, mg/l	234	183	224
Na^{+}, mg/l	450	185	550
K^{+}, mg/l	783	649	850
Cl^{+}, mg/l	299	138	321
SO_4^{-2}, mg/l	357	188	533

From above, we conclude that the dregs from ethyl alcohol production must be included in the agricultural circuit and used as fertilizer.

Change in the main indicators of soil from applying waste from the alcoholic beverages production. Application of these waste on the cambic chernozem positively influenced the main agrochemical properties. Statistically significant increases in the content of organic matter and nutrients were recorded (Table 5).

Table 5. Influence of waste from the alcoholic beverages production on the organic matter and nutrients content in the arable layer of cambic chernozem, 2011-2022

Variant	Organic matter, %			P_2O_5, mg/100 g soil			K_2O, mg/100 g soil		
	Content	Increase over control		Content	Increase over control		Content	Increase over control	
		%	kg/ha		mg/100 g	kg/ha		mg/100 g	kg/ha
The experience with waste from wineries									
Control - unfertilized	3.90	-	-	2.11	-	-	28	-	-
Wine yeast, 13 t/ha	4.06	0.16	4200	2.81	0.70	18.5	39	11	252
Wine yeast, 26 t/ha	4.31	0.41	11000	3.23	1.12	29.7	43	15	344
Vinasse, 300 m^3/ha	4.01	0.11	3000	2.52	0.41	10.8	41	13	275
Vinasse, 600 m^3/ha	4.51	0.31	8000	2.69	0.58	15.4	45	17	389
Dl $_{0,5}$, %	0.11	0.15	5200	0.13	0.13	3.2	6.5	6.5	42
Sx, %	7.00	5.50	5.5	6.40	6.40	6.4	9.5	9.5	9.5
The experience with cereal waste									
Control - unfertilized	3.00	-	-	2.14	-	-	25	-	-
Grain mash, 47 m^3/ha	3.12	0.12	3000	2.45	0.31	6.09	29	4	78
Grain mash, 94 m^3/ha	3.26	0.21	6500	2.68	0.54	10.61	34	9	180
Dl $_{0,5}$, %	0.11	0.09	2041	0.12	0.19	0.38	2.8	3.8	62
Sx, %	8.10	8.10	8.1	7.20	7.20	7.20	10.4	10.4	10.4

Crop productivity from waste applying. The application of waste from the production of alcoholic beverages positively influenced the yields obtained. The application of wine yeast at a dose of 13-26 t/ha annually ensured a significant increase in grape yield on average over 12 years of research of 1.4-2.4 t/ha, which is 15-25% more, compared to the unfertilized control (9.5 t/ha).

Significant actions on the productivity of grapevine plants had a vinasse incorporated at a dose of 300 and 600 m^3/ha annually. The average yield increase was 1.0-1.3 t/ha or 11-14% more than the control. Starting from 2012, sunflowers were grown on the experimental plot, then winter wheat, sunflowers, corn, winter wheat, and in 2017 winter wheat again.

Cereal porridge applied at a dose of 47 and 94 m^3/ha (equivalent to N_{120} and N_{240}) resulted in average production increases in the years studied - 1.19-1.71 t/ha of cereal units or 23-31% more compared to the unfertilized variant.

Significant increases in grape yields (Table 6) and crop plants (Table 7) were presented.

Table 6. Influence of wine waste on the yield of Sauvignon grapes obtained on cambic chernozem, t/ha

Variant	Average for 2011-2022		
	Harvest, t/ha	Yield increase	
		tons	%
Control - unfertilized	9.5	-	-
Wine yeast (N_{100}), 13 t\ha annual	10.9	1.4	15
Wine yeast (N_{200}), 26 t\ha annual	11.9	2.4	25
Vinasse (K_{450}), 300 m^3\ha annual	10.5	1.0	11
Vinasse (K_{900}), 600 m^3\ha annual	10.8	1.3	14

Table 7. Influence of cereal waste fertilization on crop productivity, cereal units

Variant	Average for 2012-2017		
	Harvest, t/ha	Yield increase	
		tons	%
Control - unfertilized	3.62	-	
Grain mash (N_{120}), 47 m^3/ha annual	4.71	1.19	23
Grain mash (N_{240}), 94 m^3/ha annual	5.33	1.71	32
Dl $_{0,5}$, %	0.53	-	-
Sx, %	10.4	0	-

Based on the research carried out, technological models for the application of these wastes were developed (Siuris, 2017a; 2017b; Siuris & Ciolacu, 2019).

CONCLUSIONS

The research confirmed that the waste from the production of alcoholic beverages increased the content of humified organic matter in the soil by 0.2-0.4. A significant increase in mobile phosphorus was found (0.3-1.0 mg/100 g). The application of the waste did not change the content of exchangeable potassium. The wine yeasts application ensured a significant increase in grape Sauvignon production, on average for 2011-2022, of 1.4-2.4 t/ha. The harvest increase when incorporating vinasse was on average 1.0-1.3 t/ha. Cereal waste determined the achievement of average plant production increases of 1.2-1.7 t/ha cereal units or 23-32% compared to the unfertilized control.

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