# AGRONOMIC AND ECONOMIC EFFICIENCY OF THE WASTE USE FROM THE PRODUCTION OF ALCOHOLIC BEVERAGES ON CAMBIC CHERNOZEM

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**Abstract**

Nowadays, the environment ecological status in the Republic of Moldova is deplorable in most natural and anthropogenic ecosystems. Wastes from the alcoholic beverages production is often stored chaotically presenting a major danger to the environment soil, water, air, flora and fauna. There is no waste processing and recycling company in the country. This waste contains a significant amount of biophilic elements necessary for the nutrition of agricultural plants and the increase of organic matter in the soil. About 100 thousand tons of waste is accumulated annually in the Republic of Moldova. Waste from the production of alcoholic beverages contains 28 thousand tons of organic matter, 180 tons of nitrogen, 80 tons of phosphorus and 260 tons of potassium. For this purpose, two field experiments were organized at the Technological-Experimental Station "Codru", Codru commune, Chisinau municipality, where the residues from the production of alcoholic beverages were studied: wine yeasts and vinasse (waste from wine production), distillers grains marc (waste from the production of rectified ethyl alcohol) on soil fertility and plant productivity. Research conducted in 2012-2019 showed that fertilizing the soil with cereal marc led to increased productivity of field crops. The increase in production on average is 868-1223 kg/ha of cereal units (30-42%) compared to the non-fertilized version with marc. Fertilization with waste from the production of alcoholic beverages increases on average over 9 years, the content of organic matter by 0.18-0.37% (4800-10000 kg/ha), mobile phosphorus by 0.3-1.0 mg/100 g soil (8.1-27.0 kg/ha), exchangeable potassium with 10-13 mg/100 g soil (230-300 kg/ha) for variants fertilized with waste. There was an increase in Sauvignon grape production of 0.9-2.3 t/ha (8-21%) on average for 9 years for wine waste variants. Wastes from the production of alcoholic beverages, applied to the soil as organic fertilizer have a significant economic effect, can be recovered and reintegrated into viticulture and phytotechnic sectors.

**Key words**: chernozem, yeasts, vinasse, grains marc, economic efficiency

Nowadays, in the case of land use in agriculture, the principle of restitution of the elements and fertility consumed for crop formation has been completely ignored. Since the agrarian reform (1990), plant production has been formed exclusively from soil reserves. These resources are depleted from year to year, and harvests become lower. It is necessary to return to the application of organic fertilizers as sources of environmental pollution. Therefore, a circle of matter and energy similar to that of nature would be established in agriculture.

According to this concept, waste from wineries (wine yeasts, vinasse) and waste from alcohol-producing sections (grain dumps) can serve as a source of organic fertilizer. 50-100 thousand $m^3$ of wine yeasts, 100 thousand $m^3$ of vinasse and about 50 thousand $m^3$ of grains marcs are accumulated in the country annually.

Accumulating and discharging without any legal norms, this wastes causes a serious polluting impact on the environment (Duca G. *et al*, 2006; Duca G., 2011). At the same time, the last ones contain nutrients very necessary for plants (Siuris A., 2017; Siuris A., 2018).

The main purpose of the research was to assess the fertilizing potential of the mentioned wastes, the productivity and quality of agricultural crops, the economic efficiency in order to capitalize them as fertilizers and the possibility of reintegration in viticulture and phytotechnics.

## MATERIAL AND METHOD

The researches and observations were performed in two field experiments founded in 2011-2012 at the “Codru” Technological-Experimental Resort, located in Codru commune, Chisinau municipality. As objects of study served the soil, vine and field plants and wastes from the production of alcoholic beverages (wine yeasts, vinasse, cereal marcs). The soil is deep cambic chernozem very strong, clay-loamy on clayey clay.

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The scheme of experiments and the main biophilic elements incorporated into the soil with wine wastes and those from the production of rectified ethyl alcohol are presented in *tables 1 and 2.*

*Table 1*

**The scheme of experience and the main biophilic elements incorporated in the soil with wine wastes**

| Fertilization variant | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| | kg/ha | | |
| 1. Unfertilized witness | - | - | - |
| 2. Wine Yeasts, ($N_{100}$), 13 t/ha | 100 | 16 | 300 |
| 3. Wine Yeasts, ($N_{200}$), 26 t/ha | 200 | 32 | 600 |
| 4.Vinasse, (K450), 300 $m^3$/ha | 21 | 18 | 450 |
| 5.Vinasse, (K900), 600 $m^3$/ha | 42 | 36 | 900 |

Table 2

**The scheme of experience and the main biophile elements incorporated in soil with corn marc**

| Fertilization variant | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| | kg/ha | | |
| 1. Unfertilized witness | 0 | 0 | 0 |
| 2.Corn marc, 47 $m^3$/ha | 120 | 47 | 38 |
| 3.Corn marc, 94 $m^3$/ha | 240 | 94 | 76 |

The following methods of determination were used in the soil analysis: humus-Tiurin method; mobile phosphorus-by colorimetric dosing after Macighin; exchangeable potassium in extract after Macighin by flame photometer. The following methods were used for waste analysis: humidity - GOST 26713-85; organic substance - GOST 27980-88; pH –GOST27979-88; total nitrogen - GOST 26715-75; total potassium-GOST 26718-85. Statistical processing of the results obtained in the investigations was performed after B.A. Dospehov (1990).

## RESULTS AND DISCUSSIONS

In the country annually are accumulated about 100 thousand wastes from the production of alcoholic beverages (*table 3*).

They contain 28,000 tons of organic matter, 211 tons of nitrogen, 95 tons of phosphorus and 257 tons of potassium.

**Characteristic of the chemical composition of waste discharged from wineries**

**Solid wine yeasts.** Are characterized by an acidic environment. The average pH value is 3.5 (*table 4*). The humidity varies from 42.0 to 58.9%, making up an average of 48.0%.

Table 3

**The quantity and content of organic matter and main fertilizers in wastes from the production of alcoholic beverages, tonnes/year**

| Index | Waste | | | | |
|---|---|---|---|---|---|
| | Liquid wine yeasts | Solid wine yeasts | Vinasse | Distillers grains marc | Total |
| Annual quantity | 16000 | 2000 | 33000 | 50000 | 101000 |
| Organic subst. | 544 | 935 | 439 | 25700 | 27618 |
| N | 34 | 31 | 6 | 40 | 211 |
| P | 16 | 13 | 6 | 60 | 95 |
| K | 120 | 51 | 66 | 56 | 293 |

Table 4

**The chemical composition of solid wine yeasts from wineries, reported to the mass with natural humidity (2011-2018), n = 10**

| Index and unit of measurement | x | min | max |
|---|---|---|---|
| pH | 3.5 | 3.2 | 3.7 |
| Humidity, % | 48.0 | 42.0 | 58.9 |
| Organic substance, g/l | 46.8 | 38.3 | 50.3 |
| Cinder, % | 5.3 | 2.8 | 8.8 |
| Carbon, % | 23.4 | 19.2 | 25.5 |
| Total azote, % | 1.50 | 0.77 | 1.81 |
| $N\text{-}NO_3$, mg/100 g | 1.60 | 0.71 | 2.80 |
| $N\text{-}NH_4$, mg/100g | 32.9 | 26.9 | 51.7 |
| Total phosphorus, % | 0.70 | 0.60 | 0.79 |
| Total potassium, % | 2.5 | 2.3 | 2.7 |

The chemical composition demonstrates that solid yeasts are an important source of organic matter for the soil and nutrients for agricultural plants. Calculated from the table with natural humidity, the content of organic substances is on average 46.8%.

Among the primary elements, total potassium predominates, averaging 2.5%, followed by total nitrogen - 1.5% and total phosphorus - 0.70%. 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 ton of solid wine yeast with natural moisture contains 47 kg NPK, with a ratio between these elements 1: 0.5: 1.7 which corresponds approximately to the nutritional needs of the main cultivated plants. So, we can see that solid wine yeasts are concentrated fertilizers that can economically justify their transportation over long distances, over 10 km from wineries (Golban A., 2016; Golban A., 2017).

**Vinasse.** Vinasse is the liquid left after distilling the alcohol from the wine. The amount of vinasse represents 75-85% of the volume of wines subject to distillation. Vinasse is an opalescent or slightly cloudy liquid, of a golden-reddish color, with a specific heat treatment odor and a sour taste.

Vinasse contains all the compounds, initially found in wine: organic and mineral compounds, proteins, coloring compounds, etc. As a result of the research carried out so far, it has been found that the vinasse contains such valuable compounds as: nitrogenous substances, phenolic substances, which can positively influence the biological and organoleptic qualities of alcoholic beverages or can serve alongside other compounds as a nutrient medium. sterile in the process of fermentation of molasses and production of refined ethyl alcohol. Vinasse is characterized by an acidic environment. The average pH value is 3.4 units (*table 5*).

Table 5

**The chemical composition of vinasse from wineries (2011-2018), n = 10**

| Index and unit of measurement | 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 substance, g/l | 13.3 | 6.3 | 21.7 |
| Total azote, % | 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 | 52 | 86 |
| $N\text{-}NO_3$, mg/l | 9.3 | 0.31 | 23.8 |
| $Ca^{+2}$, mg/l | 106 | 72 | 120 |
| $Mg^{+2}$, mg/l | 84 | 49 | 146 |
| $Na^{+}$, mg/l | 172 | 125 | 210 |
| $K^{+}$, mg/l | 579 | 335 | 1127 |
| $Cl^{+}$, mg/l | 90 | 69 | 122 |
| $SO_4^{-2}$, mg/l | 155 | 79 | 280 |

**Distillers grains marc**. Distillers grains marc is characterized by 93.4% water and 6.73 dry substances (*table 6*), the average value of pH constitute 3.7 units. From primary elements in composition of distillers grains marc dominates the azote – 0.28%, the phosphorus and pottassium constitutes on average 0.12% and 0.11% and the organic substances constitute 54.4 g/l.

Among the cations, the monovalent ones of potassium and sodium predominate (783 mg/l and 450 mg/l). The concentration of bivalent calcium and magnesium cations is on average 97 mg/l and 234 mg/l. Among the anions, the sulphate content predominates. Their concentration is from 188 mg/l to 533 mg/l with an average value of 367 mg/l.The chlorine content varies from 202 mg/l to 397 mg/l, averaging 299 mg/l

**Sauvignon grape harvest obtained on levigated chernozem when applying wine wastes.**

The phenomena described about the beneficial influence of waste from the production of alcoholic beverages on organic matter, phosphorus and potassium in the chernozemic soil, were also reflected on the crops of cultivated plants (*table 7*).

Table 6

**Chemical composition of the distillers grains marc from the ethyl alcohol industry (2010-2018), n = 10**

| Index and unit of measurement | 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 substance, g/l | 51.4 | 16.2 | 62.1 |
| Humidity, % | 93.4 | 92.1 | 97.0 |
| Total azote, % | 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 | 71 | 224 |
| $N\text{-}NO_3$, mg/l | 5.8 | 2.9 | 11.0 |
| $Ca^{+2}$, mg/l | 97 | 60 | 100 |
| $Mg^{+2}$, mg/l | 234 | 183 | 244 |
| $Na^{+}$, 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 the measurements and calculations performed during all years of experimentation, it was established that the application of wine yeasts at a dose of 13 and 26 t/ha ensured a significant increase in grape harvest on average (2011-2019) over nine years of 1.3 and 2.3 t/ha, by 14 and 24% more compared to the unfertilized control (9.3 t/ha). Significant actions on the productivity of the vine plants were also incorporated in the vinegar in the dose of 300 and 600 m/ha annually. The average crop increase over nine years was 0.6-0.7 t/ha or 7-8% more than the control. It should be mentioned that when applying the grape in the years 2016-2019, statistically significant values of grape growth were not registered. The reason is that in recent years the vinasse has not been administered. The largest grape harvest was in the first four years of experimentation (2011-2014). Vinasse should be incorporated after every 4 years of action.

## Oenological researches

Grapes from all three variants were harvested for oenological researches on the quality of wine from the experienced vine plantation. The sugar and acid content of the juice extracted annually was determined (*table 8*).

Table 7

**The influence of wine wastes on the Sauvignon grape harvest obtained oncambic chernozem, t/ha, technological-experimental resort "Codru"**

| Experiment variant | Grape harvest over the years | | | | | | | | | Average for 9 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Harvest. t/ha | Harvest growth | |
| | | | | | | | | | | | t | % |
| 1. Witness | 9.8 | 7.6 | 10.6 | 9.8 | 10.8 | 7.4 | 10.4 | 7.0 | 9.9 | 9.3 | - | - |
| 2. Wine yeasts 13 t/ha | 10.8 | 8.7 | 11.9 | 12.0 | 11.9 | 8.6 | 11.7 | 8.2 | 12.1 | 10. 8 | 1.5 | 16 |
| 3. Wine yeasts 26 t/ha | 10.9 | 8.8 | 14.1 | 13.9 | 12.8 | 9.0 | 13.2 | 8.8 | 12.5 | 11.6 | 2.5 | 27 |
| 4. Vinasse 300 $m^3$/ha | 10.8 | 8.7 | 11.2 | 10.5 | 11.4 | 7.6 | 10.0 | 7.2 | 10.0 | 9.7 | 0.4 | 4 |
| 5. Vinasse 600 $m^3$/ha | 10.6 | 8.5 | 11.4 | 10.6 | 11.6 | 7.6 | 10.3 | 7.4 | 10.1 | 9.8 | 0.5 | 5 |
| DL 0.5% | 0.60 | 0.64 | 0.94 | 0.73 | 0.67 | 0.92 | 0.82 | 0.53 | 0.60 | 0.65 | - | - |
| Sx | 14.3 | 15.1 | 17.2 | 16.2 | 14.6 | 15.3 | 12.4 | 14.1 | 12.7 | 13.4 | - | - |

Table 8

**Sugar content and accumulation of acids in Sauvignon grapes when applying wastes from the production of alcoholic beverages at technological-experimental resort "Codru", on average for the years 2011-2019**

| Variant of experiment | Sugar content, $g/dm^3$ | Acid accumulation, $g/dm^3$ |
|---|---|---|
| 1. Witness | 204 | 7.8 |
| 2. Vinasse ($K_{450}$), 300 $m^3$/ha | 212 | 7.2 |
| 3. Vinasse ($K_{900}$), 600 $m^3$/ha | 212 | 7.5 |
| 4. Wine Yeasts ($N_{100}$), 13 t/ha | 203 | 7.0 |
| 5. Wine Yeasts ($N_{200}$), 26 t/ha | 210 | 7.6 |

Table 9

**Physico-chemical indices of Sauvignon white wines on average for the years 2012-2018**

| Index and unit of measurement | Fertilization variant | | | | |
|---|---|---|---|---|---|
| | Witness | Vinasse ($K_{450}$), 300 $m^3$/ha anually | Vinasse ($K_{900}$), 600 $m^3$/ha anually | Wine Yeasts ($N_{100}$), 13 t/ha anually | Wine Yeasts ($N_{200}$), 26 t/ha anually |
| Alcohol, % vol | 12.57 | 13.46 | 13.42 | 12.99 | 11.68 |
| Titratable acidity, $g/dm^3$ | 5.3 | 5.5 | 4.8 | 5.8 | 5.4 |
| Volatile acidity, $g/dm^3$ | 0.37 | 0.38 | 0.49 | 0.32 | 0.29 |
| Sulphur dioxide, $mg/dm^3$ | 35.2 | 40.32 | 26.62 | 30.72 | 47.32 |
| Free Sulphur dioxide, $mg/dm^3$ | 11.52 | 17.92 | 14.08 | 15.36 | 14.08 |
| pH | 3.1 | 3.2 | 3.1 | 3.1 | 3.2 |
| Organoleptic note | 7.87 | 7.87 | 7.83 | 7.85 | 7.84 |

Table 10

**The influence of cereal marc fertilization on field crop productivity at technological-experimental resort "Codru", kg/ha**

| Experiment variant | Harvest of principal production | | | | | | | | On average for 8 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 sunflower | 2013 autumn wheat | 2014 sunflower | 2015 corn grain | 2016 autumn wheat | 2017 Soy beans | 2018 autumn wheat | 2019 autumn wheat | harvest, kg/ha | 32/5000 crop increase compared to witness | |
| | | | | | | | | | | kg | % |
| 1. Witness | 1230 | 3818 | 1170 | 2515 | 6100 | 1830 | 3925 | 3950 | 3619 | - | - |
| 2. Marc ($N_{120}$), 47 $m^3$/ha anual | 1840 | 5673 | 1790 | 3473 | 6700 | 2373 | 4813 | 4700 | 4714 | 1095 | 30 |
| 3.Marc ($N_{240}$), 94 $m^3$/ha anual | 2070 | 6183 | 1980 | 3750 | 7300 | 2568 | 5300 | 6533 | 5326 | 1707 | 47 |
| DL 0,5% | 223 | 520 | 172 | 653 | 573 | 241 | 504 | - | 531 | - | - |
| Sx, % | 10.4 | 12.3 | 11.6 | 12.4 | 11.2 | 10.7 | 11.5 | - | 10.4 | - | - |

The analyzes performed (2012-2019) show that the sugar content of the grapes in the fertilized variants was on average 203-212 g/dm$^3$ with an acid accumulation of 7.0-7.6 g/dm$^3$. In February-March 2012-2018 in the Laboratory "Hard drinks and secondary products" were carried out physico-chemical researches on the quality of wines obtained. In the wine samples were determined the alcoholic concentration, the mass concentration of volatile acids, the mass concentration of sulfuric acid, the pH of the wines. The obtained results are presented in *table 9*. Due to the advanced content in carbohydrates, the wines have a strength of over 13% vol. The concentration of sulfur dioxide and that free is 30.7-47.3 mg/dm$^3$ and 14.1-17.9 mg/dm$^3$. The pH values are equal to 3.1-3.2 units.

**Field crop productivity when applying grain marc**

The phenomena described about the beneficial influence on the organic matter, phosphorus and potassium in the chernozem soil, were also reflected on the crops of cultivated plants (*table 10*).

**The influence of grain marc on the qualitative indices of agricultural production**

A higher protein content was also synthesized in the harvest of the variants treated with cereal marc in the dose of 47-94 m$^3$/ha (equivalent to N120-N240) annually (*table 11*).

Given that the application of grain marc not only increased the concentration of vital substances in the crop, but also favored the increase of its mass, it was obtained that the harvested mass of protein and fat increased considerably compared to the reference variant. The total protein increase in eight years, compared to the reference plants, was 1716-1853 kg/ha. Regarding the fat content index, a significant increase was observed. The value of the fat increase in sunflower (2012) was 248-344 kg/ha (42.6-42.7%), in 2014 all sunflower - 266-358 kg/ha (48.7%). In 2017, soybeans were grown. The value of the fat increase was 135-176 kg/ha (22.6-22.7%).

## CONCLUSIONS

Wastes from wineries (wine and vinasse) and rectified ethyl alcohol production enterprises (cereal marcs), with their varied nutrient content and a significant amount of organic matter, must be included in the agricultural circuit by using them as fertilizers.

The average productions per hectare in the variants treated with wine wastes constituted 11.7-12.8 t/ha, being distinctly superior to the one obtained in the witness variant (10.8 t/ha). The increase in grape production in fertilized variants was 0.9-2.3 t/ha or 8-21%.

It was found that fertilization with wastes from wineries did not diminish the quality of the wines obtained. The physico-chemical composition agrees with the requirements for quality wines. The researched wines are distinguished by good organoleptic qualities and according to their typicality correspond to the normative acts.

The application of cereal marc led to an increase in the organic matter content in the soil by 0.12-0.22% (3000-5500 kg/ha) and mobile phosphorus by 0.24-0.47% (4.7- 10.4 kg/ha) on average for eight years. The value of the exchangeable potassium content has not changed.

The grain marc applied as fertilizer determined the obtaining of average increases of vegetable production over eight years of 1095-1707 kg/ha of cereal units or 30-47% compared to the unfertilized witness.

The grain marc used contributed to the synthesis and accumulation of crude protein in grain production. The total protein collected in eight years was 1716-1853 kg/ha.

The use of waste from the production of alcoholic beverages (wine yeasts, vinasse and cereal marc) is profitable. Expenses recover in 1-2 years.

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