

An Effective Method of Using Ozone Generator in Viticulture Instead of Pesticides

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Abstract: This study addresses the challenge of developing sustainable and environmentally friendly viticulture practices by proposing an alternative to conventional pesticide use based on ozonated water treatment. The method involves the application of ozone dissolved in water at controlled concentrations, adjusted according to environmental conditions such as rainfall and temperature. Field experiments were conducted over two years in vineyards of the Bolnisi region (Georgia) on different grape varieties, including Saperavi, Chinuri, and Rkatsiteli. The proposed approach demonstrates that ozonated water can effectively replace chemical pesticides while maintaining plant health and reducing environmental impact. Experimental results indicate that the method preserves the chemical composition of grapes, soil, and vine leaves, without increasing heavy metal accumulation. Moreover, an increase of approximately 30% in resveratrol content in vine leaves was observed, while quercetin levels remained stable. The findings confirm that ozone-based treatment represents a cost-effective, energy-efficient, and sustainable solution for viticulture. This approach is particularly suitable for small-scale farmers, as it reduces dependency on agrochemicals and supports the production of safer and nutritionally valuable agricultural products.

1 INTRODUCTION

To achieve global development goals, healthy, sustainable and inclusive food systems are critical, especially in the world's most fragile regions where agriculture and its development are one of the most powerful tools for poverty reduction and are also critical for economic growth.

Three billion kilograms of pesticides are used worldwide every year, while only 1% of total pesticides are effectively used to control insect pests on target plants. The large amounts of remaining pesticides penetrate or reach non-target plants and environmental media. As a consequence, pesticide contamination has polluted the environment and caused negative impacts on human health [1].

The numerous negative health effects that have been associated with chemical pesticides include, among other effects, dermatological, gastrointestinal,

neurological, carcinogenic, respiratory, reproductive,

and endocrine effects. Furthermore, high occupational, accidental, or intentional exposure to pesticides can result in hospitalization and death [2].

The background paper to The State of Food and Agriculture 2023 examines the annual hidden costs of agrifood systems across 2016-2023 for 154 countries. The expected value of hidden costs is around 13 trillion 2020 purchasing power parity (PPP) dollars [3].

Despite direct annual global pesticide costs, where In 2023, the volume of total pesticides exports (used here as a proxy for trade) decreased by 3 percent compared with 2022 to 6.7 Mt of formulated products, and their value decreased by 12 percent to USD 42.8 billion [4], as well as ongoing and growing "hidden costs", there is still no effective alternative to pesticides that could provide sufficient healthy agricultural products with the less losses for a growing population.

2 MATERIALS AND METHODS

2.1 Ozone Generation Technology

Ozone is approved for use as an alternative disinfectant in the United States and Europe. In the US, the FDA has granted it Generally Recognized as Safe (GRAS) status for use in food and food processing, including as a sanitizer. In Europe, ozone is widely accepted and used in wastewater treatment plants, particularly for disinfection and odor control. Ozone is a strong oxidant and potent disinfecting agent. Even though it is new for the US, it has been utilized in European countries for a long time [5].

The main problems of the mass distribution of ozone technology in the world are the high cost and the high energy consumption of the ozone generators (air; water).

In 2021, in Georgia (GE), was patented (P 2021 7302 B) [6] its own “Ozone Generating System” technology and began to use it in various areas of agriculture. An advantage of the present invention: “Ozone Generation System”: can operate reliably for a long time without damaging the electrode due to the current generated during the electric discharge; can operate at a reduced voltage of the power source; can operate efficiently with relatively less energy consumption; ozone generation is carried out by barrier and corona discharge and ultraviolet radiation simultaneously; ozone formation is regulated by air flow and by electric operation mode; the ozone generator operates on oxygen on demand.

2.2 Applications of Ozone Generation Technology for Vineyards

Grapevines are one of the most extensively grown fruit crops in the world and also one of the leaders in pesticide consumption. Worldwide, on average 35 % of all pesticides are used for viticulture [7].

This can be largely explained by the fact that grapevines host the highest number of pathogens of any woody species.

Recent studies have revealed that ozone (O₃) in aqueous solution is a promising candidate for limiting grapevine infection by *Phaeoacremonium aleophilum*, a fungus associated with esca. In the last few years, in fact, spraying grapevines with ozonated water for disease control is becoming more frequent among winegrowers. The reason lies mainly in the high oxidizing power of ozone and its spontaneous decomposition to oxygen without forming hazardous residues. The decomposition of aqueous ozone also leads to the production of reactive oxygen species

(ROS), which are more reactive but less selective than molecular ozone [8].

Ozonated water is being introduced as an alternative phytosanitary treatment to control grapevine diseases in a context in which the reduction of chemical pesticides has become an urgent necessity [9].

However, it has recently become clear that ozone exposition leads to another important benefit: in living tissues, the induced-oxidative stress triggers the antioxidant response, and, therefore, it enhances the production of antioxidant and stress-related secondary metabolites. As such, ozone can be considered an abiotic elicitor. The goal of the present review was to critically summarize knowledge about the possibility of improving bioactive compounds and, consequently, the health-related properties of grapes and wine, by using ozone [10].

2.3 Scientific Competence and Technical Equipment

Within the framework of the research grant project of the Shota Rustaveli National Science Foundation of Georgia with the support of the Technical University of Georgia, a target group of 11 participants was selected from the vineyards of the Bolnisi District Small Winemakers Association, with whom research was conducted over two years on the use of ozone in the form of an aqueous solution in different concentrations, under different natural conditions, on different grape varieties (*Saperavi*, *Chinuri*, *Rqatsiteli*).

Each participant, who provided at least 1 ha of vineyard, was equipped with 585 wat solar panels as a power supply, also by overheating protection systems, AC and DC stability protection, additional charging systems for other electrical appliances, batteries, etc. and 10 gr/h water ozone generators for 15 liters water sprayers, with which water was charged with soluble ozone up to 0.03-0.08 mg/l on demand. Concentration measurements were carried out using a “Hy bono” Dissolved Ozone Tester.

2.4 The Methodology of Application of Ozonized Aqueous Solution in the Vineyard Follows

The application of ozonized aqueous solution in the vineyard was carried out according to a structured treatment protocol developed based on environmental conditions and grapevine phenological stages. The methodology includes the following key steps:

- 1) Vineyard treatment began in late March - early April and was carried out during 9 phenological phases until the second ten-day period of August with an ozonized aqueous solution at a concentration of 0.03 mg/l. (For prevention of powdery mildew, ash, mites and grape moth (1, 2, 3 generations), scale insects, false scale insects, rot).
- 2) No treatments were carried out during the flowering period of grapes.
- 3) During the rainy season at a temperature of 20–29 °C, the vineyard treatment was not carried out, but was resumed out of turn immediately after the rains ended. After a period of 1–4 days of rain, the ozone concentration in the aqueous solution was 0.04–0.06 mg/l. After a period of 6–9 days of rain, the ozone concentration in the aqueous solution was 0.06–0.08 mg/l.
- 4) After the second ten-day period of August or at a temperature above 30 °C, on healthy and large, then on ripe and, finally, on very ripe large bunches of grapes, the treatment was continued only after rainy days, or for prevention only once, while the ozone concentration in the aqueous solution was 0.04-0,06 mg/l. and 0.03 mg/l. respectively.

During harvesting and visual inspection, the vineyard and berries looked healthy.

3 RESEARCH

The quality of grapes was assessed by the content of some mineral and phenolic components.

Resveratrol scavenges free radicals and enhances the activity of endogenous antioxidant enzymes. This action protects cellular components from damage associated damage and helps reduce oxidative stress, a significant factor in aging and the development of age-related diseases, such as cardiovascular diseases and diabetes [11].

Quercetin manifests antioxidant properties both in vivo and in vitro. Free radical scavenging activity of quercetin protects from various age-associated disorders. A diet rich in quercetin has various health-promoting benefits. It acts as an agent to lower coagulation, hyperglycemia, inflammation, and hypertension. Various clinical studies show that supplementation of quercetin is used to prevent and treat various chronic diseases such as cardiovascular disorders [12].

Since the two main types of antioxidants in grapes - Resveratrol and Quercetin neutralize the effects of

free radicals that can cause significant harm to the body, these two main phenolic compounds were analyzed from organic components.

Moreover, it was necessary to determine whether the chemical composition of vine leaves and wine changed as a result of replacing pesticides with ozonized water treatment, therefore, microelements were also determined in vine leaves.

From winemaking companies of the Bolnisi region, wines and grape leaves were used as objects - *Saperavi* and for comparison *Chinuri* and *Rqatsiteli*.

Microelements were determined in wine, soil and grape leaves. Sample preparation and content measurement was carried out in the Atomic Absorption Spectrometry Department of the Academician Nodar Kekelidze Scientific Research Institute of Materials Research of the Faculty of Exact and Natural Sciences of Ivane Javakhishvili Tbilisi State University, on an atomic absorption spectrometer AAnalyst 800 (PerkinElmer Inc.) with software WinLab 32 and in the "Geoanalytic" laboratory of the Alexandre Tvachrelidze Mineral Resources Caucasus Institute. (The results of the analyses are presented below in Tables 1, 2, 3).

Chemical analyses were conducted according to the respective ISO and GOST. In particular, analysis of heavy metals carried out according ISO 8288-1986 standards.

Resveratrol and quercetin assays were performed using the highly efficient liquid chromatography method. We made chromatographic division on Agilent 1200 Technologies chromatograph CI8 HPLC 5mcm chromatographic column. For analysis, 20 ml of the sample was administered with an autosampler, acetonitrile-HPLC, >99.9 % (Sigma-Aldrich), acetic acid, bidistillate were used as eluents. Extraction used 60% ethanol. For chromatographic division, the following conditions were selected: gradient elution with acetic acid, acidified bidistillate, and acetonitrile. Total analysis time 50 minutes.

4 RESULTS AND DISCUSSIONS

As follows from the data in Table 1, the content of heavy metals in Saperavi wines from the ozonized and control plots is almost the same and does not exceed the MAC (except for copper and manganese). When comparing the amount of heavy metals in wine and soils of the studied plots (Tables 1 and 2), it was found that almost a thousandth part of each heavy metal contained in the soil passes into the wine.

Table 1: Heavy metal content in bottled wine, mg/l.

N	Element	Cu	Zn	Pb	Cd	Co	Ni	Mn
1	Saperavi from non-ozonized site	1.114	0.912	0.120	0.00	0.022	0.072	0.836
2	Saperavi from ozonized site	0.136	1.200	0.113	0.00	0.017	0.107	0.152
3	MPC (maximum permissible concentration)	1.0	5.0	0.3	0.001	0.2	0.5	50.0

Table 2: Content of mineral microcomponents in soil, mg/kg.

N	Element	Cu	Zn	Pb	Cd	Co	Ni	Mn
1	Non-ozonized site	297.2	820.8	55.3	2.3	9.4	32.6	895.4
2	Ozonized site	312.7	80.3	46.9	1.3	6.1	32.9	820.8
3	MPC (maximum permissible concentration)	3.0	23.0	6.0	0.5	5.0	4.0	60-700

Table 3: The content of some mineral micro components in the vine leaves, mg / kg.

N	Grape	Ni	Cd	Cu	Pb	Mn	Co	Zn	Cr	Fe total
1	Saperavi	27.32	0.56	9.32	1.38	564.5	2.64	7.77	1.75	352,8
2	Chinuri	25.46	0.52	9.41	4.82	120.75	2.44	4.95	2.34	560.0
3	Rqatsiteli	26.98	0.55	9.65	4.84	61.0	2.35	5.75	1.95	266.0

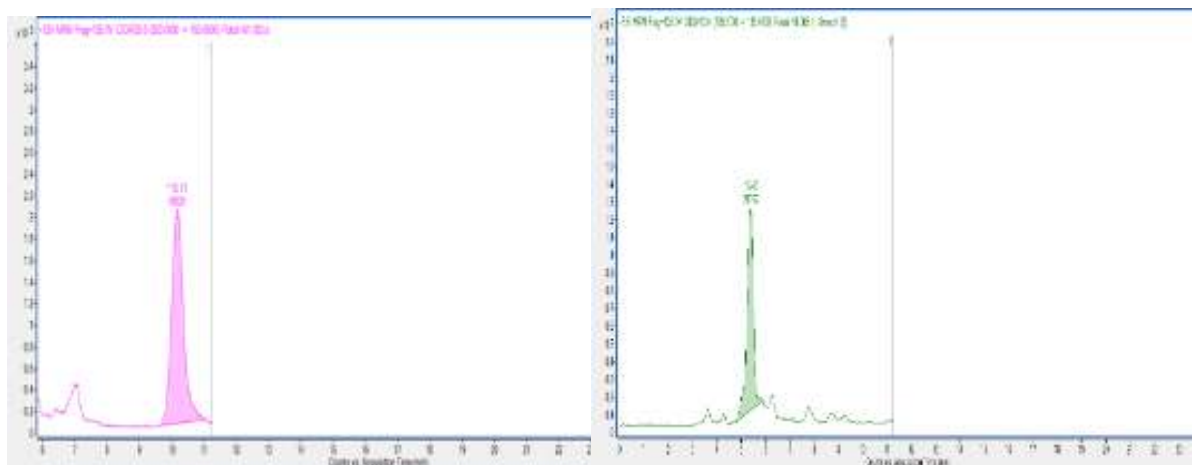


Figure 1: Chromatograms of resveratrol (at the left) and quercetin in leaves from non-ozonated site.

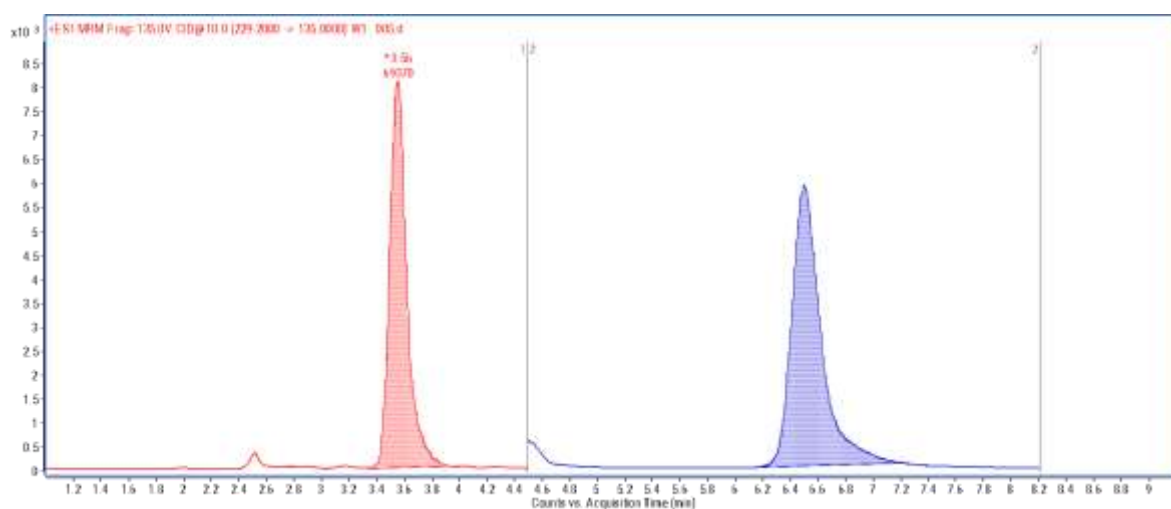


Figure 2: Chromatograms of resveratrol (at the left) and quercetin in leaves from ozonized site.

The content of heavy metals in the vine leaves of three wine varieties is almost the same order of magnitude (except for iron and manganese) and indicates their partial migration from the soil to the vine leaves Tables 2 and 3.

About 3% of copper and lead, 9.7% of zinc, 24% of cadmium, 28% of cobalt and about 80% of nickel passed from the soil to the leaves. According to the data, a study in field vegetation chambers to determine the effect of ozone and simulated acid rain (SAR) on the content of heavy metals in the soil [13].

This indicates high mobility of mobile forms of nickel and cobalt, and such a spread is apparently due to the presence of a large number of mobile forms of some elements and a smaller number of others in the vineyard soil. This was observed both for the ozonized plot and for the control one.

According to the obtained chromatograph mass spectrometric data (Fig. 1), the amount of resveratrol in the leaves of the *Saperavi* variety from the non-ozonized area is 3.4 mg/kg, and quercetin is 13.5 mg/kg (Fig. 1); in the leaves of *Saperavi* from the ozonized vineyard, the content of resveratrol reaches 5.3 mg/kg, and quercetin is 14 mg/kg (Fig. 2).

That is, the amount of resveratrol increased by 30% compared to the vine leaves from the non-ozonized area. In the wine, an inverse relationship with the treatment with ozonized water was observed: 1.64 mg/kg of resveratrol in the ozonized sample and 2.5 mg/kg in the control. The content of resveratrol in this case decreased by 30%.

5 CONCLUSIONS

The results of this study demonstrate the effectiveness of using ozonized aqueous solutions as an alternative to conventional pesticide treatments in viticulture. Based on the conducted experiments and analysis, the following conclusions can be drawn:

- 1) The use of ozone generators, available to smallholders, through above mentioned method of cultivation, reduces their annual costs for pesticides and toxic chemicals. Reduces the pressure on the environment;
- 2) Energy-efficient technologies are more flexible in switching to solar energy, especially for smallholders;
- 3) The use of an aqueous ozone solution for treating vineyards instead of chemicals and pesticides does not cause any negative impact

on the chemical composition of the leaves and the resulting wines from the *Saperavi* variety;

- 4) The content of heavy metals in the vine leaves indicates their partial migration from the soil through the root system and trunk into the vine leaves and in wine for both grapes, from the ozonized area and those obtained from the area treated with pesticides;
- 5) As a result of ozonation, an increase in the amount of resveratrol was observed in vine leaves from the ozonized area and a decrease in the amount of resveratrol in wine from the ozonized area;
- 6) As a result, replacing traditional pesticide treatment with ozonation and this method, reduces the overall content of toxic substances in the resulting wines, which is the positive effect of using an aqueous ozone solution through this method for spraying the vineyards.

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REFERENCES

- [1] [1] M. Tadić, H. D. Braun, L. Wang, J. Lyu, R. Sadler, D. Connell, C. Chu, and D. T. Phung, "Agriculture development, pesticide application and its impact on the environment," *International Journal of Environmental Research and Public Health*, vol. 18, no. 3, p. 1112, 2021, doi: 10.3390/ijerph18031112.
- [2] P. Nicolopoulou-Stamati, S. Maipas, C. Kotampasi, P. Stamatis, and L. Hens, "Chemical pesticides and human health: The urgent need for a new concept in agriculture," *Frontiers in Public Health*, vol. 4, p. 148, 2016, doi: 10.3389/fpubh.2016.00148.
- [3] FAO, "Hidden costs of agrifood systems and recent trends from 2016 to 2023 – Background paper for The State of Food and Agriculture 2023," FAO Agricultural Development Economics Technical Study, no. 31, Rome, 2023, doi: 10.4060/cc8581en.
- [4] FAO, "Pesticides use and trade – 1990-2023," FAOSTAT Analytical Brief, no. 109, Rome, 2025, doi: 10.4060/cd5968en.
- [5] Z. B. Güzel-Seydim, A. K. Greene, and A. C. Seydim, "Use of ozone in the food industry," *Food Science and Technology*, vol. 37, no. 4, pp. 453-460, 2007, doi: 10.1016/j.lwt.2006.10.014.
- [6] S. Burjanadze, J. Burjanadze, G. Burjanadze, and G. Tsivtsivadze, "Ozone generating system," Patent P 2021 7302 B, Official Bulletin of Industrial Property, no. 9, 2021.

- [7] S. Compant, G. Brader, S. Muzammil, A. Sessitsch, A. Lebrühi, and F. Mathieu, "Use of beneficial bacteria and their secondary metabolites to control grapevine pathogen diseases," *BioControl*, vol. 58, pp. 435–455, 2013, doi: 10.1007/s10526-012-9479-6.
- [8] A. Campayo, K. Serrano de la Hoz, M. M. García-Martínez, M. R. Salinas, and G. L. Alonso, "Novel endotherapy-based applications of ozonated water to Bobal grapevines: Effect on grape quality," *Agronomy*, vol. 10, no. 9, p. 1218, 2020, doi: 10.3390/agronomy10091218.
- [9] A. Campayo, K. Serrano de la Hoz, M. M. García-Martínez, M. R. Salinas, and G. L. Alonso, "Spraying ozonated water on Bobal grapevines: Effect on wine quality," *Biomolecules*, vol. 10, no. 2, p. 213, 2020, doi: 10.3390/biom10020213.
- [10] M. Modesti, M. Macaluso, I. Taglieri, A. Bellincontro, and C. Sanmartin, "Ozone and bioactive compounds in grapes and wine," *Foods*, vol. 10, no. 12, p. 2934, 2021, doi: 10.3390/foods10122934.
- [11] E. M. Morkovin, R. Litvinov, A. Koushner, and D. Babkov, "Resveratrol and extra virgin olive oil: Protective agents against age-related diseases," *Nutrients*, vol. 16, no. 24, p. 4258, 2024, doi: 10.3390/nu16244258.
- [12] Deepika and P. K. Maurya, "Health benefits of quercetin in age-related diseases," *Molecules*, vol. 27, no. 8, p. 2498, 2022, doi: 10.3390/molecules27082498.
- [13] P. A. Nouri and G. B. Reddy, "Influence of acid rain and ozone on soil heavy metals under loblolly pine trees: A field study," *Plant and Soil*, vol. 171, pp. 59–62, 1995, doi: 10.1007/BF00009565.