INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 07 Issue 10 October 2024

DOI: 10.47191/ijmra/v7-i10-47, Impact Factor: 8.22

Page No. 4962-4970

Challenges and Perspectives of Georgian Kvevri Wine Production

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ABSTRACT: This research examined the quality of Georgian Amber Kvevri wines produced in the last three years via sensory evaluation and identified common defects in Kvevri amber wines. The Georgian Wine Guild organized 32 tasting sessions, assessing 1,440 amber wines sourced from 149 cellars. Only 30.76% of the wines evaluated were free from faults. High levels of ethyl acetate, acetaldehyde, and volatile acids characterized the majority of faulty wines. Researchers collaborated with 18 local wineries to conduct a field study, revealing that errors in cellar planning, design, and winemaking contributed to defects in Kvevri Amber Wines. The identified mistakes comprised placing kvevries in close proximity, failing to adequately wash and sanitize the cellar, neglecting the use of sulfur dioxide and inert gases, fermenting wines at elevated temperatures, and excessively maturing wines with lees and solid grape components. Based on the obtained results, the study team developed a novel technique that integrates traditional and modern methods for the production of amber wine. The team implemented the traditional liming method for the installation of new wines, produced trial wines utilizing innovative approaches, and created control wines through the conventional method. Trial and control samples were prepared from Georgian endemic grape varieties Rqatsiteli, Kisi, and Khikhvi, which are typically employed in the production of kvevri amber wine. The accredited Wine Laboratory conducted the chemical analyses. The results indicated that the trial wine had three times lower levels of acetaldehyde, ethyl acetate, and volatile acids compared to the control samples. The study emphasizes the significance of reinstating authentic traditional Kvevri winemaking methods alongside contemporary practices. The research indicates that the application of the new technique enables winemakers to improve the sensory attributes of their wines and diminish off-flavors.

KEYWORDS: Kvevri Wine, Georgian Wine History.

JEL Classification Code-L66

1. INTRODUCTION

Georgian viticulture and winemaking tradition dates back 8000 years [1]. The Kvevri is a remarkable wine-making vessel that significantly influences the composition and organoleptic characteristics of the wine. The Kvevri winemaking method is unparalleled worldwide. UNESCO has even added the traditional method of Kvevri winemaking to its lists of intangible cultural heritage. The use of Kvevri in winemaking has been a longstanding tradition in Georgia, contributing to the unique character and quality of their wines. This ancient method involves fermenting and aging wine in large clay vessels buried underground, allowing for a natural and controlled process [2]. For the Georgians, wine is not just a drink. It is a significant part of Georgian culture, national identity, and heritage. Winemaking customs can be found in oral traditions, inscriptions on the walls of caves, churches, and dwellings, rites and songs, the calendar, the language, and people's common understanding. Myths, culture, art, and religious beliefs reflect the Georgian people's deep love and reverence for the vine [3]. The generations have passed down the traditional method of making kvevri vessels from clay, burying them in the ground, and using them to produce kvevri wine. However, during

the Soviet Union era, the rural population of Georgia faced additional challenges. The Soviet Union had a considerable wine market. Small and medium-sized wine producers prioritized quantity over quality and tradition preservation in order to maximize profits [4]. Consequently, they replaced numerous traditional methods. For more than 50 years, rural residents used the wine-making processes developed during this period [5]. As a result, people mistake this method for a conventional one. Contrary to popular belief, reestablishing true traditional Kvevri wine methods necessitates scientific research as well as the implementation of community-wide educational initiatives. Georgia, a small country, should grow its wine industry by producing high-quality wine. Kvevri wine, a traditional product from the wine's origin, piques the interest of wine lovers worldwide. The wine country's reputation and centuries-long history undoubtedly contribute to Kvevri wine's popularity. However, first and foremost, it must be of high quality and free of faults. The porous construction of the Kvevri wall increases the possibility of bacteria accumulation in this vessel. Using these wine vessels is fraught with complications, physical effort, and hazards. Despite these challenges, the unique flavor profile and cultural significance of Kvevri wine make it a valuable asset for Georgia's wine industry. With proper education and modern technology, Georgia can continue to produce exceptional Kvevri wine that stands out in the global market [6].

This study aimed to develop an effective method for producing Kvevri wine by combining traditional methods with modern winemaking techniques. The study concentrated on investigating the impact of Kvevri installation and operation techniques on wine composition.

2. METHODS AND MATERIALS

2.1. Preliminary study, sensory evaluation of Kvevri wines

This phase of the experiment was to investigate the quality of Georgian Amber Kvevri wines produced in the past three years through sensory evaluation and determine the prevalent flaws among them. For the sensory assessment, medium-scale and family wineries submitted wines from six distinct Georgian regions.

The Georgian Wine Guild organized thirty-two tasting sessions, with 15 wine judges conducting each tasting. All participating wine judges are enologists and wine tasters with at least 5 years of experience, and they hold the appropriate certificates recognized by the state of Georgia. We evaluated 1,440 amber wines sourced from 149 wine cellars. The website www.topgeorgian.wine displays the outcomes of these sessions, featuring wines that have achieved scores over 80. We organized and implemented the tastings in accordance with OIV 332A/2009 resolution [9]. The wine judges evaluated samples using the following sensory descriptors: 1. Visual: The judges evaluated the samples for their limpidity and other aspects; 2. Nose: They assessed the samples for their genuineness, positive intensity, and quality; 3. Taste: They assessed the samples for their genuineness, positive intensity, harmonious persistence, and quality; 4. Harmony: The overall assessment. The tasting sheet also incorporates a section for wines that have undergone elimination due to a major defect. When a wine taster marks a wine as eliminated due to a major defect, he/she must write the detected flaw or fault. At least two tasters may eliminate a wine. The OIV Standard for International Wine Competitions and Spirituous Beverages of Vitivinicultural Origin delineates the globally recognized techniques and procedures that the Georgian Wine Guild consistently use for wine tastings. This organization adheres to stringent ethical guidelines; if a wine receives a score below 80 and any defect is detected, the sensory evaluation results are solely sent to the wine producer and remain inaccessible to others.

2.2. Field research and case study

The team of experimenters has visited 18 wineries that have received results indicating their wines are faulty. The visits were not only to implement the planned research but also to consult producers and help the wineries improve the quality of their wine. The team of experimenters studied the conditions in the wineries, learned about all the stages of winemaking, and, in individual cases, determined the various reasons for the development of faults in amber Kvevri wine. In a separate case, the team developed a strategy to prevent fault development and provided the producer with recommendations for making amber wine, including winery design, harvest date, equipment, cellar washing and sanitation, fermentation, kvevri closure, and opening time.

2.3. Winery design

Based on the field study results, the research team developed the Kvevri amber wine-making experimental technique by integrating traditional methods with contemporary approaches. The initial and essential step in this winemaking technique was the installation of new kvevries and the organization of the experimental area. The team opted for the traditional method of kvevri installation and operation.

Historically, ancestors placed kvevries in the yards of their houses rather than within the buildings. Traditionally, people covered them with a stone or wood lid, then with a layer of moist clay and soil [5; 7]. The contemporary rural population favors installing Kvevri underground within a winery building. Now, a glass lid is used. In certain wineries, elevated humidity levels in cellar

buildings, coupled with insufficient air circulation, create conditions conducive to bacterial proliferation. Exposing Kvevries to the open air enhances the drying process of empty Kvevri walls after washing and sanitation and prevents mold growth on the surfaces.

The experiment team installed 12 new kvevries, each with a capacity of 700 liters, in the yard of the winery, located in the Gurjaani district. The kvevries were purchased from the potter man, who made the kvevries, already installed in the winery building. The roof was constructed over the kvevries to protect them from precipitation and sunlight. The traditional liming method was applied for the installation of kvevries in the ground [5]. Concrete, cement, or other contemporary building materials were not used. Kvevris were positioned 3.5 meters apart to showcase their exceptional characteristics. The Kvevri necessitate an adequate quantity of soil around them to regulate the temperature of the wine during fermentation and ensure stability throughout maturation. At the special request of the research team, the walls of the kvevries were not covered with wax.

Covering the kvevri walls with wax has both positive and negative sides. Filling the kvevri pores with hot wax kills bacteria, deprives anaerobic microorganisms of oxygen, and prevents the development of microbiological diseases in the wine. This method is effective only for the first year of waxing the Kvevri walls. After decanting the wine, washing and sanitizing the kvevri removes part of the wax from the wall, which allows bacteria to grow between the wall and the wax layer. Removing the old wax and rewashing the kvevri before each season is technically very difficult, and wineries do not use this method. In addition, wax diminishes the wine's micro-oxygenation. That's why the research team decided not to cover the vegetables with wax [5; 8].

The old kvevries located in the cellar building were used to prepare the control wine samples. They were installed four years ago. The potter man who made both the new and old kvevries used the same clay and kvevri-making technique. However, it should be noted that the outer surface of the old kvevries was covered with cement, while the inner walls were coated with wax. Because there was not enough space in the winery, the distance between old kvevries was 0.5 m. Today, such cellar organization is typical. Regrettably, small and medium-sized wineries, belonging to the category of entrepreneurs who produce kvevri wine, typically place the kvevri in the ground close to each other, at a distance of 0.5 m, and do not re-wax them annually.

2.4. Grapes and Materials

In 2023, the Rqatsiteli, Kisi, and Khikhvi grapes were selectively harvested in the early morning and subsequently transported to the winery. The grapes underwent processing within a four-hour timeframe. Each grape variety was partitioned into six equal portions, destemmed, and in kvevries. For each grape sort were used 6 kvevries: three for trial and three for control wines. Following crushing, the must's temperature, brix, and total acidity were assessed (Table 1). The must intended for trial sample preparation had its total acidity adjusted using tartaric acid.

Table 1. Results of Must Analyses

Grape must	Brix °	Temperature, °C	Total acidity Prior adjustment	Total acidity in Trial Samples after adjustment
Rkatsiteli	24.7	18.3	5.8	6.3
Kisi	24.4	18.1	5.6	6.1
Khikhvi	23.8	17.4	6.0	6.5

The research team selected and purchased the following materials: Myzym White Fruits (enzymes), IOC Be Fruits (yeast), and Potassium Metabisulfite. The essential chemicals for winery cleaning and sanitation were purchased from Asir AL GmbH & Co. KG.

2.5. Preparation of control samples

After cleaning and sanitation, the final step involved steaming the Kvevries for 45 minutes to sterilize them. Grapes were processed, destemmed, and loaded into Kvevries. Tartaric acid adjusted the pomace's total acidity after sulfurizing it with potassium metabisulfite (10 g/hl). Myzym White Fruits was added, and during 6 hours, the pre-fermentation maceration was carried out, and then 20 g/hl of rehydrated yeast was inoculated. The pomace cap was punched down 6-9 times a day, and the temperature was measured. In order to avoid oxidation, when the third stage of fermentation began, the liquid level in the kvevries was increased. At the end of the fermentation, potassium metabisulfite was added (6 g/hl), and the Kvevris were

completely filled and covered with a glass lid, which had a hole in the central part of the circle where an airlock was attached. 4 weeks later, the leads were changed and the kvevries were sealed according to the traditional method. In accordance with the traditional method, we used a stone lid to cover them. Georgia has been manufacturing these kvevri lids for centuries, mining the stone for their production in the Caucasus Mountains. We fixed the lid with a mixture of clay and water. The experimental group decided to pre-mix 1 mg of potassium metabisulfite in 1 L of water to knead the clay. On top, we added clay soil, which we compacted well [5]. The current regulation mandates that wine matures in kvevri before December 25 of the same vintage year. The trial wines were separated from the solid parts of the grapes and decanted from the kvevri on December 26-28. We used the free-run fractions for the experiment and stored them in 250-500 L capacity stainless steel tanks.

2.6 Preparation of control wine samples

Family winery owners created control samples of wine using the same techniques they use every year. Before harvesting, kvevries were cleaned from the white lime layer with water, and in wet kvevri, according to the traditional approach, sulfur sticks were burned. Following this, the pomace was immediately loaded into the kvevri. The composition of the must was not corrected, the pomace was not sulfurized, and fermentation was carried out by wild yeasts. There was no air conditioner inside the cellar. The pomace cap was punched down 3–6 times a day. At the end of fermentation, Kvevries were completely filled and covered with a glass lid, which had a hole in the central part of the circle where an airlock was attached. 4 weeks later, the leads were changed, and kvevries were sealed with a whole glass lid that was attached with Mastic Enoplastico Special.

According to local tradition, Kvevries were opened 3 weeks before Easter, 22-27 March. For the experiment, the free-run fractions were stored in 250-500 L capacity stainless steel tanks.

2.7 Method of Laboratory Analyses

OenoFoss[2] performed the must and wine analyses during grape processing, fermentation, before final closing, and after the decantation from kvevries. Accredited Wine Laboratory LTD, prior to bottling, conducted final laboratory analyses in May of the year following the harvest. Analyzes were performed according to the Compendium of International Methods of Wine and Must Analysis (Table 2) [10]. From each grape variety, control and research samples were made in triplicate. Laboratory research was conducted separately on the wine poured from each kvevri.

Table 2. Methods of Analyses

Ethanol content, volume (%)	OIV-MA-AS312-01A. Anton Par, Densitometer, Refractometer
Sugars	OIV- MA-AS313-01, SHOTT, Tirolian Alfa, Automatic Titrator
Total acids	OIV-AS311-01A, Loofah method
Volatile acids	OIV- MA-AS313-01, SHOTT, Titrolina Alfa, Automatic Titrator
Gas Chromatography	OIV-MA-E-AS312-03-METHAN. Equipment: GCMS Agilent Technologies, Gas Chromatograph, Mass Spectrometer.
Free SO_2	OIV.MA.AS313-02
Total SO_2	OIV.MA.AS323-04B

2.8. Statistical Analysis

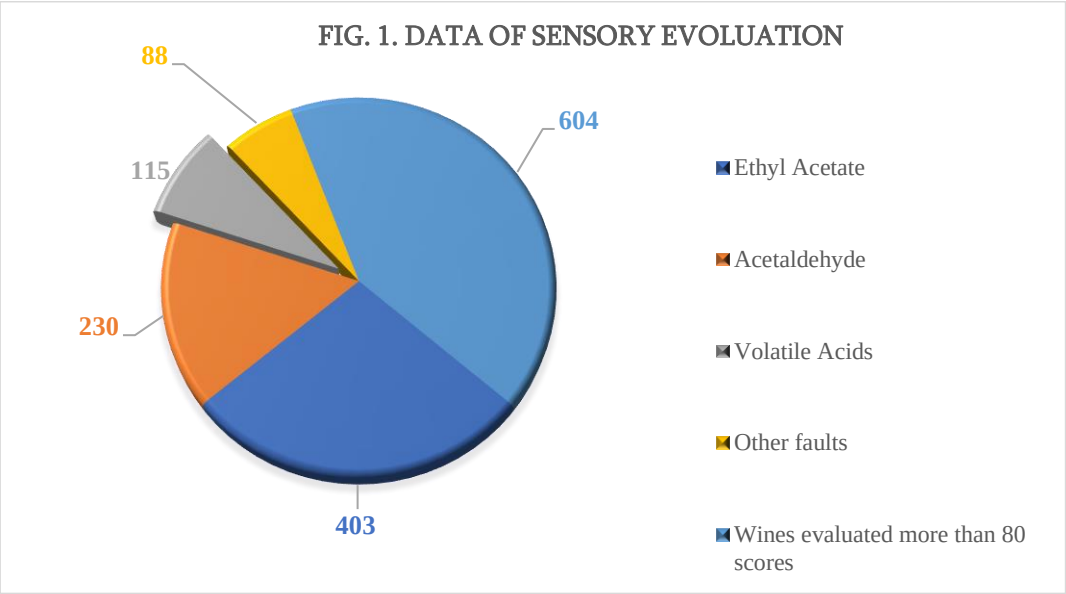
The mean ± standard deviation (SD) of three replicates was applied to convey the results of chemical analyses. The mean values were compared using Fisher LSD, and a one-way analysis of variance (ANOVA) was performed. Both were conducted with a significance level of $p < 0.05$. The mean values were compared using Fisher LSD at a 0.05 significance level, and repeated

measures ANOVA was carried out for sensory analysis. XLSTAT version 2022.4.1 (Addinsoft®, Paris, France) was employed to conduct all statistical analyses.

3. RESULTS AND DISCUSSION

3.1. Preliminary study, sensory evaluation

The conducted tasting sessions revealed I (Figure 1) that the majority of faulty wines were characterized by descriptors: brownish color, smell of vinegar, over ripened and spoiled apples, roasted nuts, metallic taste, pungent aroma of vinegar, caused by high content of ethyl acetate, acetaldehyde, and volatile acids.



The results of field research and a case study indicate that certain traditional methods have a negative impact on the quality of wine. Currently, these traditional methods of making wine, which are widely used among the rural population and in some cellars, lead to the development of wine defects. Regrettably, the proprietors of the wineries employing these flawed methods assert that they have been in operation for over half a century.

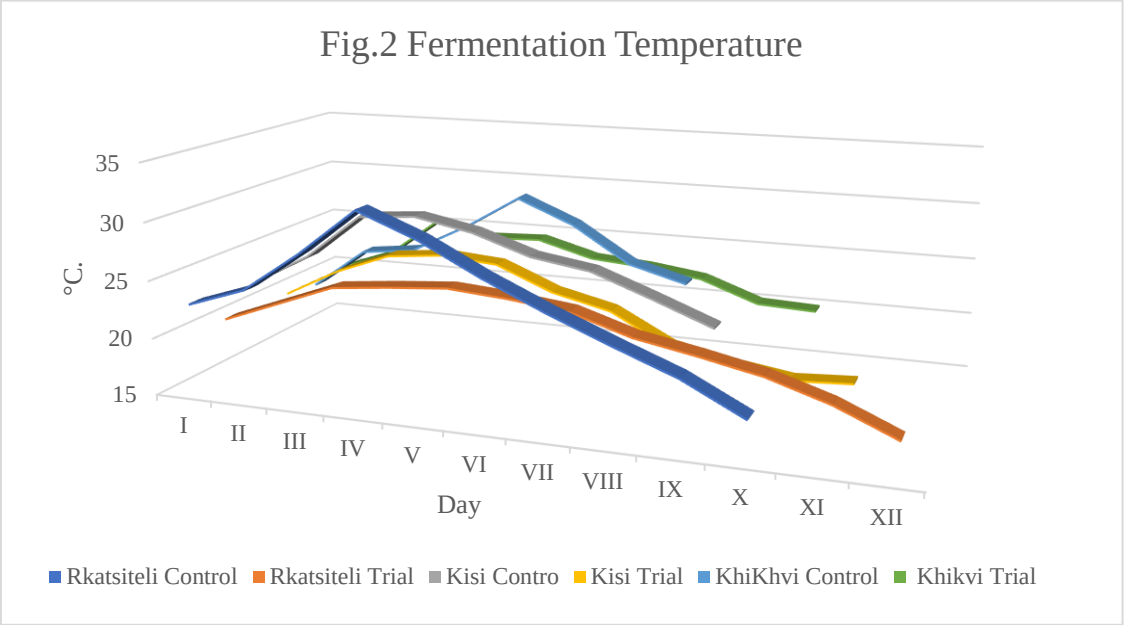
3.2. Filed research data

The experiment team identified the below-mentioned factors that lead to the development of wine faults and flaws, or the loss of varietal aroma:

1. The winemakers placed the kvevries in the cellars with minimal distance between them—only 0.5–1 meter apart. The producers did not regulate the fermentation temperature, and the average temperature during the alcoholic fermentation was higher than 27 °C.
2. Six wineries had humidity levels above 75% and lacked adequate air ventilation, which contributed to Kvevri mold growth.
3. In 11 out of 18 wineries, winemakers washed and sanitized their pitchers incorrectly. They adhere to traditional practices and use lime or ash to clean their kvevris. They sanitize the kvevri by burning a sulfur stick in the wet kvevri before loading the pomace, but they don't follow this practice by washing them with water. Burning a sulfur stick in a wet kvevri produces sulfurous acid due to the reaction of sulfur gas with water, which can lead to an unpleasant taste in the wine. They last waxed the kvevri 4-6 years ago. The space between the wax and kvevri walls is the best place for bacteria to hide.
4. Six family wineries prefer to ferment amber wine with grape stems. It is part of traditional Kakhetian technology. They are harvesting grapes with high sugar content and low organic acid content. They do not correct the acidity; the wine's pH is high, which is a favorable environment for bacterial growth [9].
5. The winery's eight representatives have a negative attitude toward sulfurizing must and wine. They prefer to ferment wine with wild yeast and do not consider using potassium metabisulfite or inert gas. Six winemakers failed to manage sulfur dioxide content properly.
6. All wineries where the research team conducted field research opened and decanted wines from Kvevries too late, usually 2–3 weeks before the Ester. During the long post-fermentation maceration, the wine is on the lees, which leads to the development of faults caused by the content of sulfur-containing compounds.

3.3. The effect of the kvevri placement method on the fermentation temperature

The grapes were not pre-cooled, nor was the pomace chilled, to assess the impact of the distance between the kvevries and their installation technique on fermentation temperature. The fermentation temperature of both the control and research samples was measured four times daily at consistent intervals: 9 a.m., 1 p.m., 5 p.m., and 9 p.m. Figure 2 presents the results of the daily average temperature recorded in three kvevries. The phase at which the residual sugar content of the wine fell below 3 g/l was deemed the conclusion of fermentation. The control samples underwent fermentation more rapidly than the trials.



Compared to the control samples, trial wines underwent fermentation at lower temperatures The control sample of the Rkatsiteli grape variety exhibited the highest daily average fermentation temperature at 32 °C. The daily average fermentation temperature in trial samples remained below 25 °C. Data obtained indicate that the organization of the winery and the placement method of kvevries, particularly the distance between them, significantly affect the fermentation temperature of wine. Fermentation conditions and temperature significantly affect the presence of specific compounds in wine. Higher fermentation temperatures typically accelerate the fermentation process, which can lead to an increased production of esters, including ethyl acetate [11]. Moreover, temperature has a significant impact on yeast growth and the production of volatile compounds; it has been observed that elevated temperatures can enhance the formation of ethyl acetate while also influencing the overall fermentation dynamics. Therefore, managing fermentation conditions carefully is essential for controlling the levels of these volatile compounds [12].

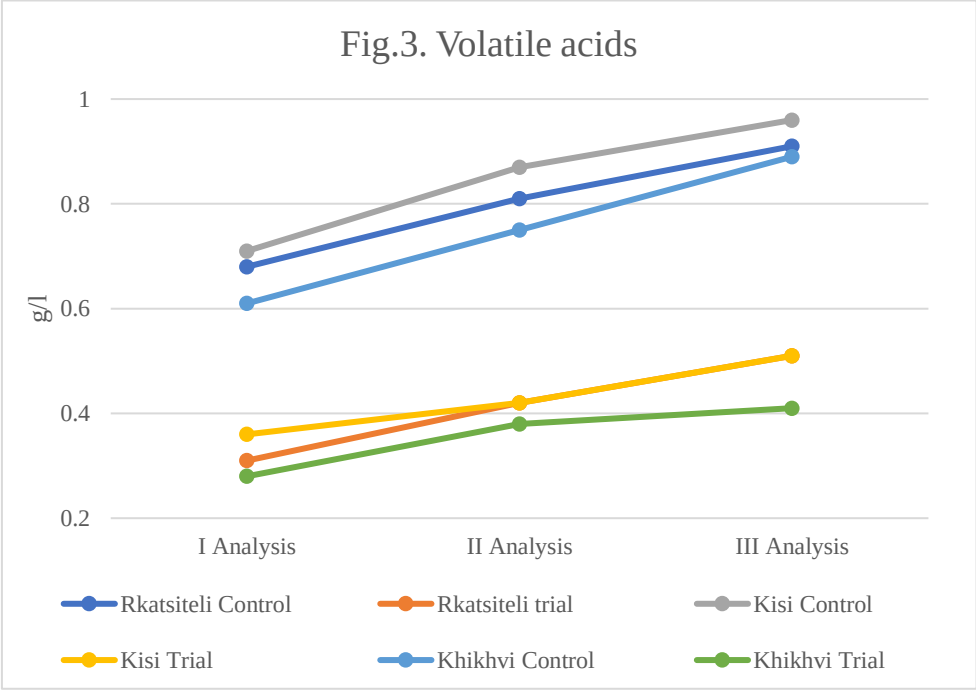
3.3. Study of wine oxidation markers in trial and control samples

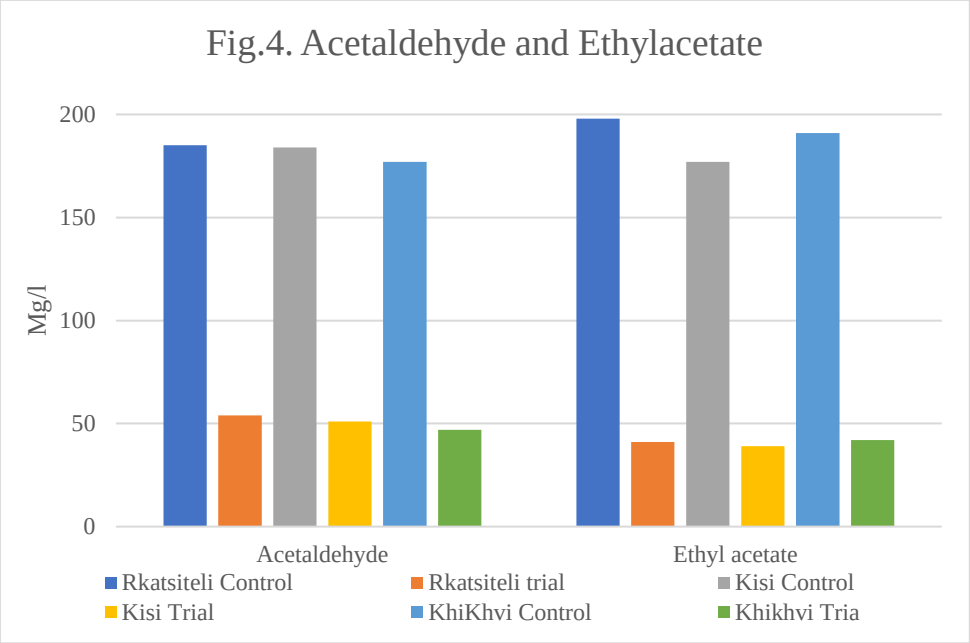
Family producers of Kvevri wine now emphasize the production of wine devoid of additives. The cellar owner consistently prepares control samples utilizing a uniform method and firmly rejects the incorporation of sulfating pomace or wine in his production process. Wild microflora fermented the control wine samples. The type of yeast strains employed in fermentation markedly affects the production of volatile acids, ethyl acetate, and acetaldehyde due to microbial activity [13]. Various yeast strains demonstrate differing capacities to synthesize these compounds, with certain strains producing significantly reduced amounts of acetic acid and acetaldehyde [14, 15]. In the preparation of control samples, the local winemaker confirmed the absence of inert gas usage during wine decantation, resulting in unprotected wines susceptible to oxidation. The researchers thought it was important to check the amounts of volatile acids, ethyl acetate, and acetaldehyde in both the test and control samples (Figures 2 and 3). They also did the usual wine tests, which included checking the amounts of ethanol, sugar, and sulfur dioxide (Table 3). Chemical parameters were assessed at various stages of the winemaking process. Measurements were conducted at three stages: (I) at the conclusion of fermentation, (II) before the initial decantation, and (III) prior to bottling.

Table 3. Chemical parameters of wines

Wine	Analysis	Ethanol by vol. %	Sugars, g/l	Free / Total SO_2, mg/l	Total Acids, g/l

		Control	Trial	Control	Trial	Control	Trial	Control	Trial
Rkatsiteli	I	12.68	12.88	2.6	2.8	11/27	19/75	5.0	6.3
	II	12.51	12.67	2.16	2.66	8/24	25/87	4.8	5.9
	III	12.3	12.52	2.1	2.64	6/21	26/124	4.6	5.5
Kisi	I	13.1	13.46	2.76	2.3	18/34	21/67	5.2	5.7
	II	12.6	13.38	2.61	2.41	14/32	25/87	4.4	5.4
	III	12.2	12.9	2.89	2.41	11/29.7	26/131	4.1	5.2
Khikhvi	I	12.8	13.3	1.8	1.4	19/38	21/83	5.7	5.8
	II	12.56	13.0	1.76	2.39	17/34	23/97	5.1	5.4
	III	12.4	12.7	1.71	2.39	8/31	26/141	4.9	5.4





The study found that the control wines have three times more ethyl acetate and acetaldehyde and two times more volatile acids than the trial wines. According to the research results, the Kvevri wine production method developed and implemented by the experimental group enables the production of high-quality, traditional Kvevri wine.

CONCLUSION

This study illustrates that combining traditional Kvevri winemaking techniques with contemporary oenological practices can enhance the quality of Georgian Amber wines significantly. It was possible to make wines with much lower levels of ethyl acetate, acetaldehyde, and volatile acids using the experimental method, which involved carefully placing the Kvevri, controlling the temperature, and adding certain yeasts and enzymes. The distance between Kvevries and their installation method significantly affects fermentation temperature, with increased spacing resulting in more favorable fermentation conditions. Effective sanitation, management of sulfur dioxide, and regulation of fermentation parameters are essential for the production of high-quality Kvevri wines. The application of specific yeasts and additional solutions, coupled with meticulous fermentation monitoring, can mitigate the likelihood of wine faults. Avoiding the use of sulfur dioxide in traditional practices may result in a heightened risk of oxidation and microbial spoilage. The timing of decanting wine from Kvevries is crucial, as earlier decanting may decrease the likelihood of fault development.

AUTHORSHIP CONTRIBUTION STATEMENT

Mariam Khomasuridze, Nazi Kutsiava, and Ani Chutlashvili: Investigation, Methodology, and Writing—original draft. Nino Tektumanashvili and Sofio Tamazashvili were responsible for the planning and organization of the study.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ACKNOWLEDGMENTS

The authors thank the local wine producers association Georgian Wine Guild for funding this research, the wineries participating in this study for their contribution, and LTD Wine Laboratory for supporting the research by conducting laboratory analyses and certification of the wines.

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