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The Monitoring of Wine Faults in Georgian Wines

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ABSTRACT

In this study, the results from two different wine tastings were compared. The first one contains the results of wine evaluations provided by the tasting commission of the National Wine Agency of Georgia for the exportation of commercial wines in 2019. These wines are mainly produced by large wineries according to conventional winemaking methods (sulphiting, different types of filtration, conservation and stabilization by additives, etc.); 7039 samples were tasted. The second one contains the results of wine evaluations performed by the tasting commission of the Tbilisi New Wine Festival for small family producers, held in 2019. The wines are mainly produced according to methods of non-conventional or traditional winemaking; a total of 575 samples were tasted.

One of the main goals was to review the whole picture of the Georgian wine market in terms of wine faults. Tastings and evaluation of wines produced by family and big commercial wineries were not carried out simultaneously. The data collected were processed by statistical means.

The tasting commission of the National Wine Agency of Georgia rejected 7% of the presented wines, because of oxidation, lack of typicity, and reductive wine faults. In the case of the festival wines, the rejection rate was 30%. The main reasons were mice flavor, oxidation, and elevated volatile acidity.

The hypothesis for a correlation between individual wine faults and a specific wine category has been confirmed, e.g., atypical ageing (ATA) had the most considerable rate in white wines. Also, bacterial faults have been shown in the segment of wines of small producers that use fewer preservatives for wine production.

The research showed that in contrast to the general opinion, for both - the industrial and the family wine segment, "mice flavour" dominated in white wines rather than in red ones.

Interestingly, wines produced in qvevri vessels had less microbial faults than those made in other vessels. It has also been proven that some defects are correlated with wine colour regardless of the production method; other faults are correlated with the production method regardless of wine colour.

Key words: Georgian wine, qvevri, wine faults.

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Introduction

Georgia is considered to be one of the oldest places in the world where viticulture and winemaking originated. According to archaeological research, pottery and some century-old tools were found and examined nearby the capital of Georgia at Shulaveri and Gadachrili Gora sites – the cluster of the agricultural settlement of the Shulaveri-Shomutepe culture. Excavated egg-shaped clay vessels, called *qvevri* in Georgia, provided chemical and archaeobotanical evidence of grapes dating back to the Neolithic period – 6000-5800 BC. [1]. According to proto-historical and archaeological findings, wild grape domestication took place in the Neolithic Age around 6000 BC., supposedly on the territory of South Caucasus, Northern Mesopotamia, Oriental Anatolia and Syria. Later it has been spreading to neighbouring regions and other parts of Eurasia [2, 3].

Most of the grape varieties cultivated on the territory of Georgia are indigenous. There are no confirmed data about the exact amount of autochthonous varieties. Still, according to the Ampelography of Georgia, there are 525 indigenous varieties [4], of which 414 described in the Ampelography of the Soviet Union (1947-1970) and only 248 remaining in old collections until 2003 [5]. Nowadays, more than 30 indigenous grape varieties are used for wine production. Among the most popular varieties are Saperavi (red) and Rkatsiteli (white), which are also cultivated outside Georgia.

According to the tradition, wine in Georgia has been made for centuries in amphora style clay vessels called *qvevri*, similar to the ones found at Shulaveri site. Other archaeological excavations also confirm that producing wine in *qvevri* has been popular during centuries from the Neolithic period until today. The *qvevri* vessel was mainly used for wine fermentation and storage. Even today this tradition is still practiced all around Georgia and getting more and more popular in other winemaking countries. The volume of *qvevri* vessels in Georgia varied from 20 L to 10,000 L, whilst today the most commonly ones used are of 500 – 2,000 L. Usually, the vessels are stored underground and covered with earth up to the very neck, thus ensuring stable temperature for wine maturation. Traditionally grapes (whites and reds) go to the vessel directly after crushing including grape skins, pips, and sometimes stalks. During alcoholic fermentation, the wine is enriched with phenolic compounds extracted from the solids (skin, pipes, stalks). This makes the difference between the Georgian classical method of winemaking and modern methods used worldwide where grape juice (usually whites and rosé) is drained from the solids and clarified before fermentation. After alcoholic fermentation *qvevries* are topped, sealed and covered with specific earth, and the wines are usually stored for approximately six months with all the solids and sediments but without sunlight exposure. During the ageing process, the phenolic compounds are partially oxidized and may turn the white wine colour from light golden to dark amber, sometimes associated with orange colour. For that reason, the name of this type of wines usually referred to as *Orange wines* worldwide, may confuse customers, mistakenly thinking that the wine is made from oranges or should be precisely orange in colour. There are plenty of people making wine at home in Georgia, mainly in villages where they pick the grapes from their vineyards or purchase them from growers. Sulphur dioxide and commercial yeast strains are not widespread and rarely used. Sometimes fumigation with sulphur dioxide is used to disinfect empty *qvevries* before filling them with crushed grapes. Today different types of wines are made in *qvevri*, some of them may contain just a part of grape solids during fermentation, and some others may exclude them totally [6]. As a proof of its cultural significance "The ancient Georgian tradition of qvevri winemaking" was assigned by UNESCO as National Monument of Intangible Cultural Heritage [7].

Aside from the famous 8000 years old beginnings, there are many other historical facts referred to by ancient authors: The famous Greek philosopher Xenophon (IV-V centuries BC) noted that Georgians drank wine undiluted and showed great love for dancing and singing. Another Greek philosopher Strabo, on the verge of a new and an old era, described Iberia (Eastern Georgia) and mentioned that the vineyards were so abundant that the population couldn't make use of the whole harvest. In the 6th century, the Byzantine historian Procopius of Caesarea noted that Georgians were making plenty of wine and were taking wine to other countries [8]. In the 4th century, with the spread of Christianity, the role of grapevine and wine increased and became more sacred, whilst Georgians combined their identity to grapevine and Christianity. In the 19th century, Georgia adopted the European style of winemaking, whilst also retaining its traditional method. Later under the influence of the Soviet system, Georgian winemaking turned towards mass production, falling in quality, and losing traditional values of *qvevri* winemaking, including loss of some of the indigenous grape varieties. With acquiring independence in the early 1990s, Georgian winemaking met a new reality and new requirements. Georgia adopted a system of Protected Designations of Origin and developed the Law of Georgia on Vine and Wine (1998) [9], quality control systems and technical regulations (2014) [10]. Beginning from the 2000s with great difficulties, the Georgian wine industry got out of stagnation, thus attracting the European market. The total area of vineyards is about 45,000 hectares, with more than 80% located in the eastern part of the country. According to Georgian legislation there are 25 wines with Protected Designation of Origin.

Today *qvevri* wines are of great interest in the world. The production of *qvevri* vessels as well as *qvevri* wines is increasing. Despite the high demand, some problems may influence sales and pose some risks for Georgian wine producers. In Georgia, family wineries are involved in the production of *qvevri* wines. Still, not all of them have high standards for proper maintenance of *qvevri* vessels and knowledge of modern techniques, resulting in wine faults such as microbial wine spoilage or physico-chemical disorders: mice flavour, volatile acidity, oxidation, *Brettanomyces*, malodorous volatile sulfur compounds, and others.

One of the goals of this study was the monitoring of Georgian *qvevri* wines for faults and off-flavours as commercialized in Georgia, including exported wines, to gain knowledge of the problems, thus creating the basis for future research towards improvement of *qvevri* wine quality and food safety.

Literature Review

Most of the wine faults have only sensory importance and can't cause serious problems for human health. Nevertheless, it's essential to differentiate original tastes and aromas from off-flavours caused by microorganisms or physico-chemical mechanisms. Today there is an extraordinary amount of high-quality wines in the world that makes the competition for sales stricter, thus developing quality control systems, researching tastes, aromas, and their constituting compounds. Significant influence on wine aroma has oxygen. Depending on the rate of exposure, oxygen may differentiate wines in both high and low quality wines, having great importance for consumer acceptance and preference. Too little or too much oxygen can influence the appearance of serious faults during vinification and ageing with the formation of excessive concentrations of compounds responsible for oxidative or reductive off-flavours. Usually, the oxidation of wine takes place through a cascade of reactions in which oxygen, in combination with oxidation catalysts such as iron and copper, leads to the formation of free oxygen radicals (highly reactive chemical compounds) and peroxides, which can, in turn, react with other wine compounds [11]. When phenolic compounds are oxidised, wine may turn amber or brown, changing aroma as well. The oxidation of ethanol, resulting in acetaldehyde, is usually associated with the odour of bruised apples or sherry. Some of the aerobic film-forming yeasts such as *Candida sp., Pichia sp*., *Hansenula sp., and S. ludwigii,* in the presence of air, can convert excessive amounts of wine ethanol into acetaldehyde, through a reaction catalyzed by the enzyme ethanol-dehydrogenase. Acetic acid bacteria can also produce acetaldehyde by the decarboxylation of pyruvate. According to some of the researches, the sensory threshold for acetaldehyde is about 100–125 mg/L [12]. However, according to Schneider [13] only the free form of acetaldehyde (not bound to sulphur dioxide), is sensorially active. Schneider shows that as little as 1 mg/L of free acetaldehyde which only occurs in the absence of free sulphur dioxide, can be perceived as faulty by smell. Free acetaldehyde and free sulphur dioxide exclude one another.

Along with spoilage yeasts, acetic acid bacteria may change wine quality dramatically resulting in increased levels of acetic acid, commonly referred to as volatile acidity (VA) with an odour reminiscent of vinegar. The film-forming yeasts and acetic acid bacteria normally require oxygen for growth. For that reason, oxidation and VA increase in wines are usually associated with a lack of hygiene and untopped vessels providing headspace oxygen – ideal conditions for germ development. In the case of acetic acid bacteria development, the enzyme alcohol dehydrogenase oxidizes ethanol to acetaldehyde that is further oxidized to acetic acid by the enzyme aldehyde dehydrogenase. According to Du Toit and Pretorius [14], acetic acid bacteria occur as four genera: *Acetobacter*, *Acidomonas*, *Gluconobacter*, and *Gluconoacetobacter*. *Acetobacter* is mainly found in fermented substrates, such as wine, beer, whilst *Gluconobacter*is is mainly associated with sugar-rich environments like grapes and other fruit. The legally acceptable upper limit for volatile acidity in most wines is 1.2 g/L of acetic acid [15], the aroma threshold depends on the wine style. VA concentration of 0.90 g/L can produce a slightly bitter, scratchy and sour aftertaste in wine, still without a strong odour [16], although concentrations as low as 0.6 g/L may be perceived as faulty in many wines. Commonly the "acetic nose" is due to ethyl acetate that is one of the metabolites of acetic acid bacteria. However, less ethyl acetate is produced under low oxygen conditions [17]. Yeast strains of the species: *P. anomala, Kloeckera apiculata, Hanseniaspora uvarum, Metschnikowia pulcherrima* and others along with acetic acid bacteria can form an ester taint in wines with glue-like aroma at the initial stages of alcoholic fermentation [18], especially if it is present in concentrations above 100–200 mg/L

[19]. Wine spoilage may also be related to other types of yeasts such as *Dekkera/Brettanomyces* that is frequently found in wineries. When it contaminates wines, it may result in undesirable metabolites referred to as volatile phenols, in particular 4-ethylphenol (4-EP), 4-ethylguaiacol (4-EG) and 4-ethylcatechol (4-EC). The odours of these compounds in wines are described as: "clove," "spicy," "smoky," "leather," "cedar", "medicinal," "band-aid," "horsy," "wet wool," "barnyard," sometimes even "sewage" [20,21]. These volatile compounds are the decarboxylation products of phenolic acids (trans-ferulic and trans-*p*-coumaric acid) [22]. *Brettanomyces* is not the dominant yeast during alcoholic fermentation; however, it can be found after 6–10 months of storage [23]. During wine ageing in oak barrels with some dissolved oxygen, low levels of sulphur dioxide and relatively high temperature provide good conditions for *Brettanomyces* successfully growing, resulting in sensory wine defects. It is supposed that this yeast may develop in the period between the end of alcoholic and the beginning of malolactic fermentation [24], though its development can also occur after several months of additional storage, in particular in wooden barrels. Furthermore, it is thought that "Brett character" may occur even after bottling in minimally filtered wines [25]. *Brettanomyces* develops especially in red wines due to the high level of phenolic acids that are derived from grape skins during alcoholic fermentation. Its perception threshold may vary. According to Loureiro and Malfeito-Ferreira [26], 4-EP over 620 μg/L may be found unacceptable by some consumers. If the concentration does not exceed 400 μg/L, this compound sometimes may be described as "spice," "leather," "smoke," or "game." According to Licker et al. [27], "high Brett level" wines contained 3,000μg/L of 4-EP. Fugelsang and Zoecklein [28] reported that the relative amounts of volatile phenols might differ according to *Brettanomyces* strains involved. 440 μg/L of 4-EP and 120 μg/L of 4-EG were produced by one strain, whilst another strain accumulated just <10 μg/L. Besides "Brett character", *Dekkera/Brettanomyces* yeast may develop an offensive odour reminiscent of rodent cage or rabbit hutch litter, the so-called "mousy" taint. It is supposed to appear in wine due to the metabolism of amino acids such as lysine and ornithine, resulting in the formation of heterocyclic nitrogen compounds: 2-acetyltetrahydropyridine (ACTPY), 2-ethyltetrahydropyridine (ETPY), and 2-acetyl-1-pyrroline (ACPY) responsible for the offensive odour [29]. Apart from *Brettanomyces*, the growth of some strains of lactic acid bacteria (*L. brevis*, *L. hilgardii*, and *L. cellobiosus*) may also cause the production of "mousy" odours in wines [30,31]. Interestingly, it is almost impossible to smell the "mice" off-flavour. Only after swallowing the wine, the alkaline nature of saliva neutralizes wine acidity, thus releasing ACTPY and related compounds [32] recognized in the pharynx (retro-nasal area) as a persistent unpleasant aftertaste [33]. According to Sponholz [34], it is possible to identify "mice flavour" after rubbing a few drops of the infected wine between palms and smelling them fast afterwards. This fault develops mainly in wines rather than in musts because ethanol is required for the synthesis of these compounds [30]. The perception threshold of the "mousy" compounds, according to Riesen [35], is extremely low (1.6 μg/L). Therefore, very little activity of the bacteria may influence the wine spoilage. Mousiness is not a prevalent problem. It could be related more to some low-acidity wines with lack of sulphur dioxide [34]. According to Lay [36] different *Brettanomyces* cultures may form "mice flavour" in wine in the presence of the corresponding amino acids.

The importance of lactic acid bacteria [LAB] in winemaking is very high. Malolactic fermentation [MLF] induced by several species of lactic acid bacteria may provide a natural deacidification of wines. The total acidity decreases due to degradation of the dicarboxylic L-malic acid into monocarboxylic L-lactic, developing some secondary products. MLF can influence wines' microbial stability [37,38], but improper management of the process may decrease wine quality resulting in different wine faults [39]. Usually, MLF takes place at the end or after alcoholic fermentation when a low concentration of hexoses and pentoses may still exist in the wine. According to a heterofermentative or homofermentative pathway, the LAB of the genera *Lactobacillus, Oenococcus* and *Pediococcus* may assimilate sugars resulting in undesirable metabolites. The obligatory heterofermenters (*Oenococcus oeni, Lactobacillus brevis, Lactobacillus hilgardii*) degrade sugars into lactic acid, ethanol and acetic acid, the latter resulting in a VA increase, sometimes to unacceptable levels. Some of the homofermentative *Pediococcus* species transform nearly all of the hexoses into lactic acid according to the Emden-Meyerhof pathway [40,41]. Assimilating sugars through the homofermentative and heterofermentative pathway, LAB may produce a mix of undesirable end products.

One of the most important off-flavour compounds produced by LAB is diacetyl or 2,3 butandione with a distinct buttery odour [42,43]. The LAB species: *O. oeni, L. plantarum*, *L. mesenteroides,* and *L. casei* can efficiently metabolise citric acid producing diacetyl. Its perception threshold may vary according to the wine type [44]. According to Rankine et al. [45], low concentrations of diacetyl may be desirable in some types of wines, as the amount 1-3 mg/L of diacetyl results in "nutty" or pleasant "buttery" aroma, whilst a concentration above 5-7 mg/L gives an unpleasant spoiled "buttery" odour. Along with citric acid degradation, diacetyl can also be produced by homolactic or heterolactic pathways of sugar metabolism [46]. Many factors influence the concentration of diacetyl in wine. One of them is the strain factor: *Ooenococcus oeni* may produce relatively lower concentrations than *Lactobacillus and Pediococcus* [47,48]. Another factor is the reduction of diacetyl to odourless butanediol by suspended post-fermentation yeast cells.

Some species of LAB can produce off-flavour compounds from preservatives such as sorbic acid that is sometimes used in wine to prevent residual sugar from refermentation after bottling. Sorbic acid (2,4-hexadienoic acid) is reduced to sorbitol through hydrogenation; then it is isomerised to alcohol 3,5-hexadiene-2-ol reacting with ethyl alcohol forming 2-ethoxyhexa-3,5-diene, the compound that has an offensive crushed geranium leaves odour [49] with a sensory threshold of about 100 ng/l [35]. With the development of sterile filtration and sterilization equipment, it became possible to prevent bottled wines with residual sugar from refermentation without addition of sorbic acid, thus avoiding risks for geranium taint production.

LAB can contribute to reductive off-flavour by breaking wine amino acids into volatile sulphur compounds. The *Oenococcus oeni* species may convert the amino acid cysteine into hydrogen sulfide and 2-sulfanyl ethanol, and methionine into dimethyl disulfide and other products [41]. Dimethyl disulfide gives cabbage, onion-like odours, whilst hydrogen sulfide has an odour reminiscent of rotten eggs, burnt match. It may also occur during nitrogen deficiency [50] in the process of alcoholic fermentation and act as a precursor for mercaptans [51].

Among other off-flavours, great attention is paid to "mouldy", "earthy", mushroom-like odours that occur in wine during different mould species multiplication. *Penicillium expansum* can synthesise geosmin, an earthy-muddy smelling compound with a sensory threshold of 30 to 50 ng/L. [52]. *Trichotecium roseum*, *Aspergillus* section *nigri*, and several species of *Penicillium* may influence the production of 1-octen- 3-one, a compound with a fresh mushroom flavour [53].

One of the most common wine faults that occurs explicitly in white wines is the "atypical ageing off-flavour" (ATA), sometimes referred to as UTA ("Untypische Alterungsnote") according to German terminology. The naturally occurring phytohormone indole-3-acetic acid is chemically degraded leading to the formation of 2-aminoacetophenone with an odour reminiscent of naphthalene, wet wool, floor polish, fusel alcohol, acacia blossom. This odour mainly occurs within a few days or several months after alcoholic fermentation and the addition of sulphur dioxide, the latter triggering the reaction [54]. This happens due to stress factors in the vineyard, such as insufficient water or nitrogen supply, as well as high yield and premature harvest [55].

Other problems of non-microbiological character may be mentioned. High levels of sulphur dioxide may interfere wine quality, eliciting a pungent smell and a harsh, metallic aftertaste.

The literature contains data from studies conducted at different times, which show that the wine industry of other countries faces more or less common problems.

Wines rejected by the Austrian State Tasting Commission during 2013 are presented in the following percentage ratio: reductive faults (mercaptans, hydrogen sulphide) - 32.2 % , moldy and earthy faults (including cork taint) - 30.3%, oxidation - 22.4%, lack of body - 9.2%, *Brettanomyces* - 5.3%, bitterness, sharpness - 4,6%; diacetyl - 4,6% [56].

As a result of the 2008 International Wine Challenge, 6% of the wines from about 10,000 samples were rated as faulty; the most common problems were cork taint or mouldy odour with 31%, reductive faults – 29%, oxidation – 19%, *Brettanomyces* – 16% [57].

Materials and Methods

The industrial wineries presented at the National Wine Agency tastings work according to the Law of Georgia on Vine and Wine [9] relying on the standards and regulations of the International

Organisation of Vine and Wine [58]. The sensorial evaluation of the wines is a part of the standard procedure for providing export authorization with the aim of controlling and maintaining quality standards. The sensorial evaluation is provided for the wines to be exported except for the wines produced by small family wineries (definition given in the Law of Georgia on Vine and Wine).

According to the amendments to the Law of Georgia on Vine and Wine (#2-82 from19.02.2018), wine sensorial evaluation has become mandatory for all wines to be exported since January 1, 2018.

The Wine Tasting Commission was created in 2007 with the cooperation of GIZ (German Cooperation for International Cooperation GmbH) within the frames of the program promoting the development of Georgian wine quality.

The evaluation system was developed based on the experience of the German DLG system. The members of the tasting commission have undergone extensive training and passed the final qualification examination. Each taste panel was composed of 5 members of the tasting commission (based on the principle of rotation) with the head of the tasting commission monitoring each tasting.

The German DLG system can be described as follows: Wine is rated on a 5-point scale that was introduced according to ISO- Norms [59]. ISO- Norms (https://www.iso.org/) regulate the vocabulary to use in sensory science (ISO 5492:2008) [60] as well as about designing a sensory test (ISO 6658:2017) [61] and the equipment being used (ISO 3591:1977 e.g. for wine testing) [62]. Sensory science distinguishes between tests where untrained people can give their opinion (e.g. preference tests; ISO 11136:2014 / AMD 1:2020) [63] and more objective tests run by trained panelists (ISO 8586:2012; ISO/CD 8586; ISO 11132:2012) [64,65,66]. The regulations incorporate how to design the specific tests as well as who to perform the statistics (e.g. ISO 29842:2011 /AMD 1: 2015) [67].

The wine testing according to DLG was established following German testing guidelines in order to describe German wines by trained panelists (DIN-Norm 10952) [68,69]. They have to score "blind" wine samples (not naming them) on a 5-point-scale and shortly describe the characteristics of the wines. A score of less than 1.5 points means rejection of the wine, in this case at least one fault or a general lack of minimum quality must be indicated. The following list indicates the reasons for possible rejection on the basis of faults: oxidation, volatile acidity (VA), reductive odours (H_2S, mercaptans), *Brettanomyces*, diacetyl, mice flavour, earthy/mouldy smell, geranium odour, excessively high free sulphur dioxide level, atypical ageing (ATA), lack of typicity.

If the wine has any unlisted fault or cannot be accurately categorised, then the rejected wine will be related to the category –"other". The tasting is carried out on weekdays on a daily basis or depending on the number of samples with a maximum of 54 samples to be tasted during the session.

Tbilisi New Wine Festival has been held since 2010. This is the largest and most popular event in Georgia for wine lovers. The festival presents mainly small enterprises and family wineries, all of them have to pass the tasting control to be allowed to the festival. Qualified wine tasters from the National Wine Agency of Georgia are invited to evaluate the wines according to the methods used in the National Wine Agency with the same possible reasons for wine rejection. The rejected wines are marked with one or more wine faults and recorded.

Chi-Square Test of Independence was carried out for statistical processing of the data to check whether the respective categories are related to each other. The *P* - value is presented in the end of each comparison of the categories.

Results

The NWA tasting data include records from 183 evaluation meetings provided during the first 9 months of 2019. In this context, 510 wine samples were rejected from evaluated 7039 wines. The presented wines are divided into the following categories: white dry, white with residual sugar (semi-sweet, semi-dry), white AOC (controlled designation of origin) wines, red dry, red with residual sugar, red AOC, red AOC with residual sugar, "amber" wines (fermented with skin contact including *qvevri* wines). In Table 2, the main 11 wine faults are specified, whilst all other faults are grouped in the category "other" due to a statistically insignificant amount.

The tasting commission of the 2019 Tbilisi Wine Festival provided a preliminary wine evaluation resulting in 575 tasting protocols with 175 wines rejected with one or several faults. In Table 4 seven main wine faults are displayed, whilst all other faults are assigned to the category "other" due to their lack of identification.

Discussion

The presented tables show the results of the wine tastings performed with two different goals. The Tables 1 and 2 contain the results of tastings of the wines from big industrial wineries intended for exportation as provided by the tasting commission of the National Wine Agency of Georgia (NWA). The Tables 3 and 4 present data for the wines trying to qualify for the festival where mainly family wineries, i.e. small enterprises are presented. Along with the main goals of the tastings and according to the results, it is possible to distinguish two different segments of wine production: (i) industrial wine production, working mostly conventionally, and (ii) small, family winemaking, primarily working according to the methods of so-called "natural winemaking" where industrial methods (sulphiting, different types of filtration, conservation and stabilization by additives, etc.) for wine treatment are totally excluded or minimized.

The number of wines evaluated at the NWA is 7039, the number of those submitted for the festival – 575.

In total, 7% of the samples submitted to the NWA tasting and 30% of the festival wine samples were rejected. This ratio may be considered logical because the NWA wines were produced by professional winemakers and controlled according to internal and international standards including tastings prior to bottling.

The largest number of rejected wines from the NWA tastings is caused by oxidation with 41% of the total of rejected wines, followed by lack of typicity – 19%, reductive taint (hydrogen sulfide, mercaptans) – 12%, VA (volatile acidity) - 10%.

Among the rejected wines from the festival, mice flavor has 34%, VA - 31%, oxidation – 22%, diacetyl – 15%, musty/mouldy taint – 11%.

As expected, some faults were detected only in the wines produced according to the conventional methods, e.g., geranium odour - the sensory problem caused by microbial degradation of the preservative potassium sorbate. The category "lack of typicity" is relevant only for AOC (controlled designation of origin) wines and the ones produced according to the established technological standards, its rejection has a fairly high rate. In contrast, the festival wines have no preliminary definition of typicity, therefore the category "lack of typicity" is not used during the evaluation of the festival wines. Theoretically, wines from non-conventional wineries could be rejected due to "atypical ageing" (ATA), although there was no sample with this problem detected at the festival qualifying tasting in 2019. The low rate of rejected *amber* (skin contact, whether from *qvevri* or another vessel) wines in the industrial segment is significant: *amber* – 2%, other – 7% (P=0.001), whilst almost no significant difference is observed within the festival wines: *qvevri* - 28%, non-*qvevri* – 32% (P=0.19). *Qvevri* wine for industrial wineries is less commercial and carries more prestigious character undergoing special care and treatment. For family wineries, *qvevri* wine sometimes is a standard product.

Along with the above-mentioned problems exclusively encountered in industrial wines, the comparison of different wine faults exhibits other essential distinctions between industrial and family wines. According to Figure 1, oxidation (acetaldehyde) in faulty NWA wines is almost twice as much (41%) as in faulty festival wines (22%), (P<0.001). There is no objective precondition for this due to technological differences, as both groups of wines have a comparable risk of oxidation or comparable protection against oxidation. Traditionally, e.g., *qvevri* wines hold a big part of small (family) enterprises production, in which the methods usually comprise longer contact with lees and the abundance of phenolic compounds resulting from fermentation on grape solids - skins, seeds, and sometimes stems. Consequently, they may show antioxidant properties even with less SO_2. On the other hand, the largest part of industrial wines is presented as non-*qvevri* wines, with less antioxidant properties but protected more by the addition of higher amounts of SO_2 post-fermentation. In both situations the level of antioxidant stability relies on the skills and preferences of winemakers that may finally influence the quality of both categories to the same extent. In this case this fact may be explained by more tolerance towards oxidised wines produced by family/small enterprises during the wine evaluation. The problem here is more tolerated than in conventional - NWA wines that are mainly exported. If one compares the technological facilities of industrial and small wineries, the results should not diverge in this way. It is difficult to say that one production method is much safer than another. However, if the tasting reports included the analytical data of free SO_2, which is not the case, more conclusions could be drawn.

The amount of reductive faults in faulty NWA wines is not significant - 12% compared to 8% of festival samples (*P* = 0.11).

All other faults of microbiological origin occur in festival wines to a greater extent with significant difference and are discussed further below:

Wine spoilage due to aerobic bacteria, resulting in high volatile acidity, was observed in 31% of all rejected festival wines, whilst the same problem was observed in only 10% of all rejected NWA wines (*P*<0.001). The reason may partially be related to the fact that industrial wines undergo two stages of control before NWA evaluation: inner and external laboratory check for chemical composition. In contrast, in the case of festival wines (small enterprises), only sensory assessment is performed.

Wine spoilage due to lactic acid bacteria (LAB) resulting in malodorous diacetyl levels was observed in 15% of all rejected festival wines, whilst for NWA wines it was 2% (*P* <0.001).

Mice flavour caused by LAB was 34% of all rejected festival wines and 5% for NWA wines (*P*<0.001).

Sensory problems usually related to *qvevri* maintenance and hygiene resulting in a musty/mouldy fault were identified in 11% of all rejected festival wines, but for NWA wines they were only 6% (*P* =0.046).

Analysing the difference between the categories of the industrial wines, it becomes evident that the highest rate of rejected samples is 15% in the AOC wines with residual sugar. This is much higher than the average of 7% (*P* <0.001), even though in this type of wines the risk of bacterial spoilage is much lower than in dry wines having undergone malolactic fermentation. Indeed, there is only 5% of all microbiological faults in the rejected AOC wines with residual sugar in contrast with 34% of all other rejected wines (*P* <0.001). A high rate of rejected AOC wines with residual sugar can be explained by the “lack of typicity” that is exceptionally high - 36%, whilst in other wines this problem is less than 10% (*P* <0.001). “Lack of typicity” is related to the lack of varietal and fruity aromas that should be typical for a certain wine.

There could be found a tremendous difference in other wines as well. For example, white AOC wines were rejected due to ATA in 28% of all rejected samples, whilst the rate of this fault in other white wines was around 2% (*P* <0.001). This can be explained by the fact that other white wines may contain more phenolic compounds due to the use of higher amounts of press fractions or due to a more prolonged skin contact period. Indeed, phenolics are supposed to mitigate the appearance of ATA [54]. Conversely, AOC wines contain less phenolic compounds due to the limited usage of press fractions or less skin contact. In the case of oxidation, the ratio is 52% for AOC white wines to 27% of other white wines (*P*=0.014). This fact may be related to the poor stability of free SO_2 and its decrease by oxygen uptake during bottling and bottle storage.

As it is usually described in the literature, *Brettanomyces* is mainly a problem of red wines, in NWA wines it shows as follows: red dry – 16%, red dry AOC – 13%, red with residual sugar – 9%, whites - not detected. In the case of mice flavour, the results show that this fault is mainly associated with white wines, as this fault was observed in 14% of all rejected white wines, whilst in reds the number was 3% (*P*<0.001). This may be a coincidence, as there is no plausible reason for it.

The evaluation of wines presented for the wine festival showed that the faults are not associated with a specific category of wine, but there was a clear relationship between the wine fault and paired categories. The pairings are based on the colour and the wine production method.

The 4 categories indicated in the festival wines are:

White non-*qvevri* wine

White *qvevri* wine

Red non-*qvevri* wine

Red *qvevri* wine

These categories were paired as follows:

All white wines vs. all red wines;

Qvevri wine of both colours vs. non-*qvevri* wine of both colours.

In Figure 2, as a reference, there is an average indication for all wines.

The grouping of the four categories of wines from the Tbilisi Wine Festival tastings gives an excellent opportunity to compare wines according to colour and production method. Categories resulting from the Tables 3 and 4, after grouping show the following:

Reductive notes are noticeably higher in non-*qvevri* wines - 12% than in *qvevri* wines - 4% (*P* <0.049). This might be related to the lower oxygen uptake in non-qvevri wines, which are frequently stored under anoxic conditions in stainless steel vessels. Colour has no influence: non-*qvevri* - 7% to *qvevri* - 10% (P <0.45).

As expected, *Brettanomyces* is more common in red wines (17%) than in whites (1%) (P <0.001), whilst the production method has no influence – *qvevri* - 6% to non-*qvevri* - 9% (P <0.56).

Mice flavour is more common in white wines – 41% than in reds – 24% (P=0.017). Similar results were shown by the NWA tasting commission. There is an assumption that *qvevri* wines are more infected by mice flavour than non-*qvevri* wines, although the difference here is not significant. Moreover, mice flavour was found in 31% of *qvevri* wines, non-*qvveri* - 38% (P =0.30).

In the case of diacetyl, no correlation was found between colours (P=0.52) or production methods (P = 0.65). All results were close to average.

A musty or mouldy fault is related to the *qvevri* technology -19%, non-*qvevri* - 1% (P <0.001) with no relationship to the wine colour: red – 13% to white - 8% (P = 0.18). This phenomenon might be related to the difficulty of properly sanitizing *qvevri* vessels.

Volatile Acidity (VA) for wines not fermented in *qvevri* was 38%; for wines fermented in *qvevri* – 26% (P = 0.07). Colour has no influence as well: red - 30%; white - 34% (P = 0.57).

Oxidation for white wines – 25%; for reds – 18% (P = 0.29).

Vessels type has no influence as well: *qvevri* - 24%, non-*qvevri* - 20% (P = 0.45).

Table 1. *Georgian National Wine Agency – results of the 2019 wine tasting as a percentage of faulty wines according to wine category.*

Type of Wine	White			Red				Amber	Total
	Dry	R.S. [1.]	AOC [2.]	Dry	R.S.[1.]	AOC[2.]	AOC R.S.		
Number of tested samples	458	1036	559	1281	1654	544	1286	221	7039
Number of faulty wines	33	52	29	90	91	24	187	4	510
% of faulty samples	7	5	5	7	6	4	15	2	7

1. R.S. – Wines with residual sugar; 2. AOC – wines with controlled designation of origin.

Table 2. *Georgian National Wine Agency – breakdown of wine faults found in the 2019 tasting.*

№	Type of wine	White						Red								Amber	
		Dry		R.S.		AOC		Dry		R.S.		AOC		AOC R.S.			
	Number of faulty wines	33		52		29		90		91		24		187		4	
	Wine faults[3.]	№	%[4.]	№	%	№	%	№	%	№	%	№	%	№	%	№	%
1	**Volatile acidity, ethyl acetate**	1	3	4	8	1	3	24	27	14	15	2	8	1	1	3	75
2	**Oxidation, acetaldehyde**	11	33	12	23	15	52	40	44	42	46	11	46	75	40	2	50

3	**H_2S, mercaptans**	8	24	13	25	2	7	10	11	13	14	2	8	15	8	0	0
4	**Brettanomyces**	0	0	0	0	0	0	14	16	8	9	3	13	3	2	0	0
5	**Diacetyl**	0	0	3	6	0	0	5	6	1	1	1	4	1	1	0	0
6	**Mice flavor**	5	15	8	15	3	10	2	2	6	7	1	4	2	1	0	0
7	**Mouldy odour**	4	12	2	4	1	3	7	8	6	7	2	8	9	5	1	25
8	**Atypical ageing**	1	3	1	2	8	28	0	0	0	0	0	0	0	0	0	0
9	**Lack of typicity**	3	9	2	4	8	28	9	10	4	4	3	13	68	36	0	0
10	**Extra SO_2**	0	0	1	2	0	0	1	1	1	1	0	0	0	0	0	0
11	**Geranium odour**	0	0	0	0	0	0	0	0	1	1	0	0	2	1	0	0
12	**Other or unidentified off-flavours**	7	21	11	21	2	7	13	14	17	19	0	0	16	9	1	25

3. Wines can show one or more faults; 4. Percent of samples

Table 3. *Tbilisi Wine Festival – results of the 2019 wine tasting as a percentage of faulty wines according to wine category.*

Type of Wine	**White**		**Red**		**Total**
	Non qvevri	Qvevri	Non qvevri	Qvevri	
Number of tested samples	117	218	126	114	575
Number of faulty wines	44	60	37	34	175
% of faulty samples	38	28	29	30	30

Table 4. *Tbilisi Wine Festival – breakdown of the wine faults found in the 2019 tasting.*

#	**Wine Faults**	**White**				**Red**			
		Non-qvevri		**Qvevri**		**Non-qvevri**		**Qvevri**	
	Number of faulty wines	44		60		37		34	
	Wine faults	№	%	№	%	№	%	№	%
1	**Volatile acidity, ethyl acetate**	16	36	15	25	15	41	9	26
2	**Oxidation, acetaldehyde**	10	23	16	27	6	16	7	21
3	**H_2S, mercaptans**	5	11	2	3	5	14	2	6
4	**Brettanomyces**	0	0	1	2	7	19	5	15
5	**Diacetyl**	5	11	9	15	6	16	6	18
6	**Mice flavor**	19	43	24	40	12	32	5	15
7	**Mouldy odour**	1	2	13	22	0	0	5	15
8	**Other or unidetified faulty off-flavours**	7	16	11	18	9	24	11	32

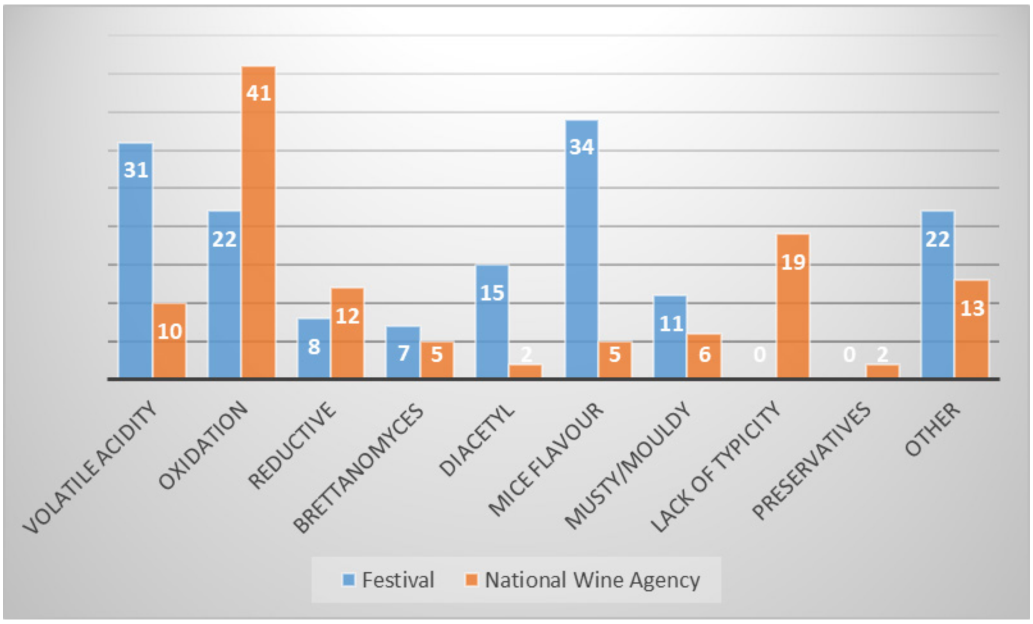

Figure 1. Comparison (in %) of wine faults identified by the Festival and the National Wine Agency.

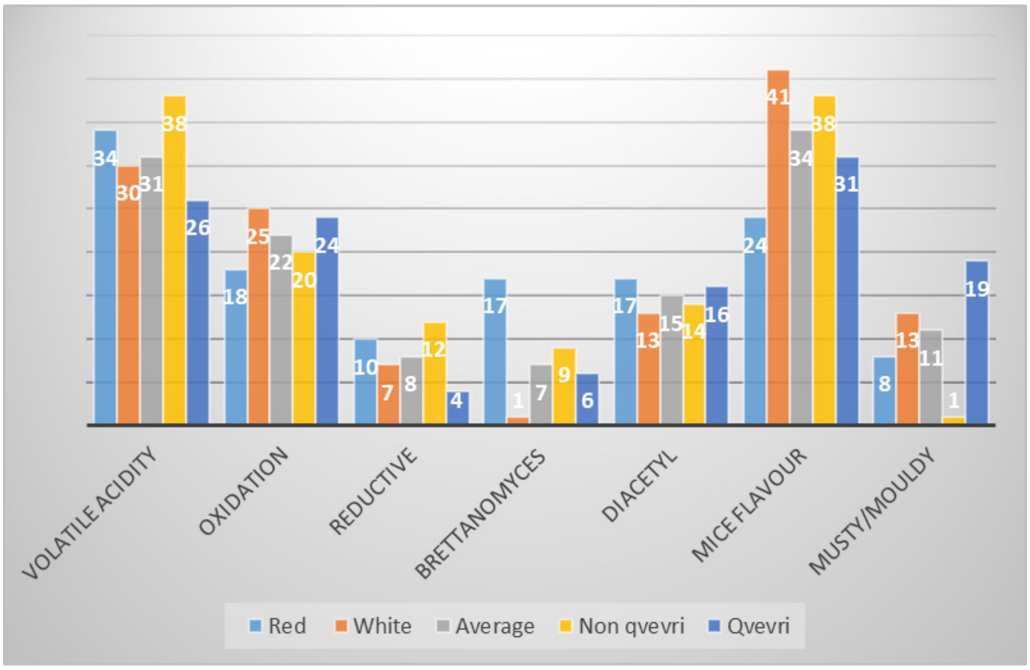

Figure 2. Tbilisi Wine Festival wines: Breakdown (in %) of the wine faults identified in the 2019 tasting. comparison according to categories (%)

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