Assessing Wine Authenticity: Establishing Criteria Necessary for Robust Wine Authenticity Databases


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About the International Wine Technical Summit
The International Wine Technical Summit (IWTS) is a collaborative group of government and industry representatives who have an understanding of the technical issues surrounding wine production and trade.

The purpose of the IWTS is to share best practices, and exchange ideas and experiences while fostering a collaborative environment in which to discuss:

*Sound science in wine regulation and enforcement, and Trade issues of a technical or scientific nature.*

Abstract
This paper stresses the importance of utilizing databases for the assessment of wine authenticity that are demonstrably robust across a comprehensive array of criteria and highlights the finding that, following extensive literature searching, these requisite criteria are poorly defined at best and nonexistent at worst. In the absence of clearly defined criteria to ensure the robustness of authenticity databases alternative approaches, such as the implementation of properly regulated traceability systems, may need to be considered until such time as requisite criteria are adequately defined.

Introduction
The global nature of wine trade necessitates that technical barriers are minimized through a common set of principles in relation to wine regulation. One such set of principles is the *Tbilisi Statement on Analytical Methodology and Regulatory Limits* adopted in 2014 by the World Wine Trade Group (WWTG), an informal group of government and industry members from various wine producing countries. Many of these principles have subsequently been endorsed by the beverage alcohol NGO FIVS. The principles contained in the *Tbilisi Statement* provide guidance on reducing some of the technical barriers frequently encountered in the wine trade; *e.g.*, variations in
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terminology and reporting for wine analytical parameters. At the 2015 International Wine Technical Summit (previously known as the ‘International Wine Technical Forum’), participating government and industry wine technical experts established working groups to facilitate practical implementation of the *Tbilisi Statement* principles. This paper represents the first outcome of one Working Group’s efforts, focusing on Tbilisi Principle #10 which states “Where wine authentication is deemed essential to prevent counterfeit or misleading practices, governments should compare test samples against a sufficiently comprehensive database of authentic samples to avoid miscategorizing legitimate samples as fraudulent”.

The necessity and utility of such reference databases is well understood; however, what remain lacking are rigorously defined criteria essential to ensuring these databases are suitably comprehensive and robust. These criteria must need include production criteria (issues of import to winemakers, viticulturists, etc.), scientific criteria (the chemistry, biology, etc. underlying the analytical approaches appropriate to the specific database) and statistical criteria (the mathematical constraints underpinning sampling and multivariate calibration). Any truly robust database will need to appropriately address criteria from each of these categories to ensure the requisite comprehensiveness and applicability.

**Authenticity Defined and Its Importance**

Wine authenticity is a broad concept that can refer to such diverse aspects as wine age, wine geographical origin, wine varietal composition, wine production practice or wine purity. Each of these aspects has relevance to international trade; pricing, as well as consumer acceptance (and consumer safety), are often dependent upon these factors. Clearly then wine authenticity is intimately tied to product labeling, having to do with a comparison of claims presented on a bottle label to what is actually contained therein. This importance was recognized in the WWTG’s “Agreement on Requirements for Wine Labelling” (2007); the country of origin is considered common mandatory information and criteria for vintage, variety, and wine region labeling are defined in the 2013 Protocol to that Agreement.

Wine authenticity is therefore of great importance throughout the wine supply chain and market. Consumers need to have confidence that what is claimed on the label is accurate in relation to the contents of the bottle. Reputable producers’ businesses may be threatened if they are undercut in the marketplace by products that make false claims related to authenticity. Conversely, it is equally important that legitimate product not be miscategorized as fraudulent. Finally, there may be revenue implications for the administration from products that are deliberately mislabeled. It is critical, then, that steps are taken to safeguard and enhance the authenticity of wine in international trade.

**Authenticity Issues Impeding International Trade**

There have been many instances wherein legitimate wines were rejected by international trade partners based upon analytic measures that did not comply with accepted ranges in established reference
databases. This calling into question the authenticity of perfectly legitimate wines has caused significant problems in international trade; wine consignments have been detained on suspicion of non-authenticity when the actual reason for the discrepancy was that the reference database was simply not comprehensive enough.

As an example, it is generally not allowed to irrigate a vineyard in the EU from which a “quality wine” will be produced. That fact enables some determinations of the geographic origin of wines to be made based upon the characteristics of the rainwater and the groundwater that exist in the region of production. However, such methods are wholly inappropriate when applied to wines produced in countries where vine irrigation is permitted, and the water used may quite legitimately come from meltwater, river-water, rainwater, well-water, and may even be tankered some distance to the vineyard where it is used. Furthermore, wines from Argentina and Chile, although produced at similar latitudes and altitudes and irrigated from Andes snow melt, exhibit very different isotopic signatures\(^1\), stressing the need for considered application of this methodology.

Wines from Australia have faced rejection based upon acylated anthocyanin ratios or shikimic acid profiles that differed from ostensibly representative databases\(^2\); in Italy there were cases in which legitimate Brunello di Montalcino wines were blocked from export during the so-called “Brunellopoli” scandal based upon profile comparisons against non-representative analytical databases\(^3\).

Clearly then, if the database of authentic wines underpinning the method does not take account of different practices in different growing regions, and wines legitimately produced in one region where a given practice is allowed are compared with a set of samples derived only from places where that practice is prohibited, the result may be that genuinely authentic wines appear to be fraudulent.

**Authenticity Assessment**

In almost all methods for determining wine authenticity, samples are tested for certain physical or chemical characteristics (e.g., stable isotope ratios, metals content, pigment classes, aroma profiles, etc.) and these analytical results compared to those obtained from authentic samples. However, problems arise when the wines thus tested are not adequately represented in the database of authentic samples to which the results will be compared. The database may not, for instance, take into account the annual variation intrinsic to all agricultural crops, the variation due to geographical location, or the variation resulting from differing production practices. Therefore, methods designed for authentication of wine must be based upon analytical databases of considerable size and scope, derived from samples

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2 Personal communication, Winemakers’ Federation of Australia, 2016
3 Personal communication, Unione Italiani Vini, 2016
that span the underlying variability from all sources, to ensure that the test samples are compared against a truly representative array of authentic wine samples.

**Establishing Authenticity Criteria**

What is necessary to ensure confidence in such reference databases is to identify those essential criteria to which comprehensive and robust databases must comply, and, more specifically, define what “robust” and “comprehensive” mean within this context. Given the myriad analytical approaches utilized in assessing authenticity creating an exhaustive list of specific criteria is neither feasible nor advisable. Rather, the goal is to identify the key criteria to which reference databases should satisfy. The end purpose is, of course, to ensure that extant or future databases do not serve as impediments to international trade due to any intrinsic limitations in their design and construction.

It should therefore be a recognized principle in the authenticity testing of wine that the major factors that could potentially influence the result of an analytical procedure are identified and taken into account in the construction of the database of authentic wines. These factors may be subdivided into three broad categories. First, there are distinct “families” of criteria which these databases must of needs address: the production, scientific and statistical criteria referenced earlier.

Furthermore, there exist multiple analytical techniques for assessing authenticity; these include:

- Targeted analysis
  - e.g. LC-MS/MS
- Non-targeted profiling/Fingerprinting
  - e.g. HR-NMR, HR-LC-MS, Chemical, Spectroscopic
- Stable Isotopes
  - e.g. SNIF-NMR, IRMS
- Omic Technologies
  - e.g. DNA, proteomics, metabolomics

Each of these approaches has its own idiosyncratic advantages and limitations. Therefore, in addition to general overarching “scientific” criteria, key criteria unique to specific authenticity methods must also need to be identified.

Finally, authenticity may imply the fore-mentioned geographic authenticity, varietal authenticity, vintage authenticity, production authenticity (e.g., as in the case of sparkling or rosé wines) or even freedom from adulteration. The specific authenticity type will in and of itself necessitate further unique criteria.

**Outline of Approach**
In order to define these key criteria the Authenticity & Counterfeit Working Group of the IWTS proposes a series of white papers, beginning with this introductory paper. The next paper will focus on varietal authenticity, identifying criteria that a robust varietal authenticity database must need satisfy, with the understanding that these criteria will certainly be necessary but may not be sufficient. Subsequent papers will then focus on identifying requisite database criteria appropriate for geographical authenticity, vintage authenticity and standards of identity.

Criteria Defined in the Literature

As Brereton\textsuperscript{4} notes: “many samples of authentic samples are required to build a reliable database with which to challenge the suspect sample. Chemometrics are often needed to provide interpretation and demonstrate the uncertainty of the result. Such uncertainty does not sit well within the legal process. . .” How then can a database be constructed and utilized such that it can successfully stand up to legal challenge? A search through the authenticity literature reveals that, while it is thorough with regards to analytical methodologies (see Palade and Popa\textsuperscript{5} for a review) and statistical and chemometric approaches (e.g., Dordevic \textit{et al.}\textsuperscript{6}, Gad \textit{et al.}\textsuperscript{7}, Riedl \textit{et al.}\textsuperscript{8}), criteria essential to constructing robust databases are seldom referenced, much less rigorously defined. The need to better address issues of sampling, method performance and uncertainty was raised by Carcea \textit{et al.}\textsuperscript{9} As they stated, “Without knowing the above mentioned parameters it is difficult to obtain reliable analytical data to be used in legal or commercial decisions.”

The Bundesinstitut für Risikobewertung report “Wine Control Praxis in Germany”\textsuperscript{10} contains a section on “Use of Databanks.” While the author states that “authenticity and representativeness of the reference samples are crucial points that arise if any jurisdiction becomes involved,” he then notes that “the process of selecting relevant reference data. . . is not discussed in this report.” What are discussed instead are the statistical methodologies employed following establishment of the database.


There is more information with regards to the authenticity databases employed for stable isotope ratio analysis; even so the criteria are only vaguely defined. Christoph et al. (2003) discuss the importance to validate analytical data comprising a database, with regards to which the authors note the necessity for “building of appropriate data banks which contain analytical data of representative reference samples of different winegrowing regions.” However, here thoroughness of coverage is tacitly achieved by increasing the number of samples constituting the database, with the samples collected for the EU Wine Data Bank representing microvinified 15 kg lots of grapes. As Médina cautions, “It is well known to experimenters that the quality and the characteristics of wine produced in the wineries and chateaux is never reached with a microvinification.” Christoph et al. (2003) further note that for Germany, “200 samples each year represent the statistical distribution of isotope ratios in wines of the 13 German winegrowing regions” but don’t elaborate on the statistical basis for that claim, nor how it is corroborated. These samples also ostensibly “represent the different dates of vintage, grape cultivars, geographical, and meteorological differences.”

The establishment of analytical cut-off values, beyond which measures fall outside of observed authentic ranges, is discussed in Christoph et al. (2004). These are initially estimated based upon observed long-term minima and maxima and subsequently refined as the number of samples in the database increases. A legitimate sample, however, could be miscategorized by such an empirical approach. In a later paper (Wachter et al.) the authors state that the “key question to be answered. . .is whether the data pattern of the test object fits in with those of the reference group or not;” however, what is necessary to properly construct said reference set is not addressed.

Heras-Roger et al. note that studies of varietal authenticity all too often “are based on exclusively one technology or use a limited number of samples.” The authors based their own study on 250 wines although the basis for the number is not clear. Humpfer et al. are more conservative, noting that “hundreds if not thousands of authentic samples covering all relevant aspects of a particular food control application is the key requirement. . .” with regards to their non-targeted approach using NMR. Again, how adequate comprehensiveness is assessed is not addressed. The difficulties in constructing

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and validating such databases are outlined by Fernández-Ibáñez et al.\textsuperscript{17,18} in their work with near infrared spectral microscopy authentication of animal feeds.

Proper sampling design and implementation is a major factor influencing the construction of robust databases; the literature is replete with approaches based either upon Gy’s Theory of Sampling (\textit{e.g.}, Esbensen et al.\textsuperscript{19}) or other approaches (\textit{e.g.}, Sammán et al.\textsuperscript{20}). However, the authenticity literature reviewed does not explicate how sampling was designed to ensure population representativeness.

Finally, the literature makes scant mention of challenge studies performed against existing databases; internal validation procedures for assessing robustness of classification models are not as powerful as external procedures which more appropriately assess the error of prediction for classification. Certainly there will be uncertainties associated with any classification model, again highlighting Brereton’s cautionary comments (\textit{vide supra}).

**Traceability Systems**

As this review has shown, criteria necessary for the construction of robust authenticity databases are poorly explicated in the literature, if they are addressed at all. Such criteria may indeed have actually been defined in specific instances (\textit{e.g.}, for the EU Wine Databank) but, if so, they have not been disseminated to a broader audience and hence cannot be critically evaluated.

Given the regulatory ramifications associated with authenticity measures which may be subject to legal challenge, alternative approaches may need to be considered until such time as rigorous criteria are defined for ensuring database robustness. One such established and defined approach is that of traceability systems.

Traceability has been defined both by international standards (\textit{e.g.}, \textit{Codex Alimentarius} defines traceability as “the ability to follow the movement of a food through specified stage(s) of production, processing and distribution”\textsuperscript{21}) as well as by legislation (\textit{e.g.}, the European Union’s General Food Law defines traceability as “the ability to trace and follow a food, feed, food-producing animal or substance


intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution’."

The EU legislation mandated, beginning in January of 2005, the maintenance of traceability data for all food producers exporting to any member EU country. In order to ensure compliance various frameworks have been proposed23,24 and specific systems designed, one such example being GS1’s Wine Supply Chain Traceability.25,26,27 These systems establish methods allowing verification of origin and composition of wine from vineyard to consumer, utilizing documentation, information technology, analyses or some combination of the above.23,24,25,28

Conclusions and Next Steps

Reliable assessment of wine authenticity is clearly an issue of serious concern to the international wine trade. Reliable assessment, however, requires methods that will accurately identify non-authentic wines with a reasonable degree of certainty without misclassifying truly authentic wines as fraudulent. As these methods are based upon comparisons to databases comprised of data derived from authentic wines, the end goal of this project is to compose a series of white papers specific to different authenticity measures and compile lists of criteria pertinent to those measures which are necessary (but may not be sufficient) to the construction of robust and unbiased authenticity databases. It is understood that satisfying these criteria cannot absolutely guarantee correct categorization (i.e., black swan events31 can always occur); however, so doing will serve to increase the robustness of such approaches thereby reducing instances of miscategorization.