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WINE TRACEABILITY AND AUTHENTICITY – A LITERATURE REVIEW

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Abstract

In the actual economic context, the agro-food economy is focused on the consumer demands regarding quality, safety and security of food and foodstuffs. Traceability of wine can be defined as a method through which anybody in the wine supply chain can be able to verify the origin and composition of each batch of wines, its conditions of storage, and all the products that were in contact with the wine after the production. Traceability in the wine industry has an important role in a quality assurance management system. It ensures the registration on specific documents of all manipulations of raw materials, ingredients and final products. They are created especially to allow a rapid identification of the product history. The wine supply chain requires traceability from grape production to processing and wine distribution. Authenticity of wine has been extensively investigated because wine is an easily adulterated product due to its chemical composition and its availability throughout the world. Responsible and continuous controls are required to maintain the quality of wine. Usually volatile compounds are used to characterize varieties, whereas minerals are used for geographical differentiation. Amino acids as well as phenolic compounds evaluation are used for both. The development of advanced techniques for wines authentication is a challenge, which currently is given a special attention. In this literature review, latest scientific papers on this subject will be assessed in order to establish the state of the art in the proposed field and to establish further research needed.

Keywords: *wine, traceability, authenticity, food safety.*

INTRODUCTION

Wine is a beverage which value is influenced by many factors amongst which the origin, vintage, grape variety and the growing condition play the major role. Wine is characterized by a wide variety of sensory characteristics. The information indicated on the wine label is connected to special consumer's expectations concerning the sensory and quality criteria. The label may indicate, therefore, significant and price-determining characteristics such as the brand, type, vintage, variety and origin of the product, which represent the wine identity. Wine control is traditionally strongly associated with proof of authenticity.

Generally, chemical falsifications to deal with are the addition of water, glycerol, alcohol, dyes, sweeteners, flavor substances, the non-authorized addition of sugars, preservatives and acidity adjustments. However, wine authentication aims to confirm all declarations of label descriptions or to detect fraudulent statements by various analytical methods (Schlesier et al., 2009).

The analysis of wine is of great importance since wine components strongly determine its stability, organoleptic or nutrition characteristics. In addition, wine analysis is also important to prevent fraud and to assess toxicological issues (Grindlay et al., 2011).

The great number of parameters affecting wine quality has initiated the development of different protocols for analysis. Wine constituents are strictly regulated by international organizations (OIV, 2014) or government agencies to avoid fraud and health risks. Luque de Castro et al. (Luque de Castro et al., 2005) have recently reviewed methods of analysis for the most commonly determined parameters in wine such as ethanol, sulphur dioxide, reducing sugars, polyphenols, organic acids, total and volatile acidity, Fe, soluble solids, pH and color (Grindlay et al., 2011).

For the wine industry and market sector, it is particularly essential that the intended value traits created via genetics (variety), origin of production (typicity), and unique inputs or processing method (vinification technology) are preserved. In other words, it must be ensured that a product's label is accurate and not misleading, since consumers distinguish peculiar commodities from a mass of other similar ones, on the belief that they bear a superior quality. However, wine is a product that can be easily adulterated, and for this reason wine authenticity is guaranteed by strict guidelines laid down by responsible national authorities, and includes sensory evaluation, chemical analyses, and examination of the records kept by wine producers (Makris et al., 2006).

The EC regulations dealing with geographical indications (GI) all include traceability provisions. These are built into the provisions dealing with certification schemes and the various requirements concerning the overall control of the producers' operations.

For example, Article 118p of EU Regulation 1234/20073 incorporated EU Regulation 479/2008 (dealing with wine) provides for annual verification of compliance with GI product specifications by relevant bodies (e.g. product certification bodies, public authorities, etc.). In all cases, producers will need to be able to show inspectors how and where products were produced using reliable traceability systems.

In the certification and control processes provided for GIs under these EU regulations, traceability is a core element. Only by recording the origin of the various components and tracking the production chain it is possible for the certification and control bodies to verify, certify, and monitor whether the final product actually has the claimed link with its geographical origin and conforms to the relevant specification and quality requirements (Sciarra and Gellman, 2012).

Traceability is defined as the ability to follow a product batch and its history through the whole, or part, of a production chain from raw materials through transport, storage, processing, distribution and sales (called chain traceability) or internally in one of the steps of the chain, for example the production step (called internal traceability). Traceability of products has been introduced since the 1990s (Cimino and Marcelloni, 2012) and is still under investigation by scientific and industrial bodies (Bevilacqua et al., 2009) (Gandino et al., 2009). A number of traceability systems, technologies and standards have been developed to carry out supply chain traceability and internal traceability, with different business objectives (Bechini et al., 2008) (Bertolini et al., 2006). Nevertheless, only large enterprises, which are characterized by a tightly aligned supply chain and supported by a considerable use of information and communication technology, employ very efficient and fully automated traceability systems. On the contrary, small enterprises only rarely implement traceability and, when they do, they add the traceability management to their normal operation, decreasing the efficiency and increasing the costs. Thus, today, a considerable challenge is to develop agile and automated traceability platforms for communities of small-scale enterprises (Cimino and Marcelloni, 2012).

Figure 1 highlights the main actors of the supply chain. Each actor is responsible for specific activities which have to be traced so as to enable supply chain traceability. For each actor, the activities and the corresponding data which have to be collected are described as follows:

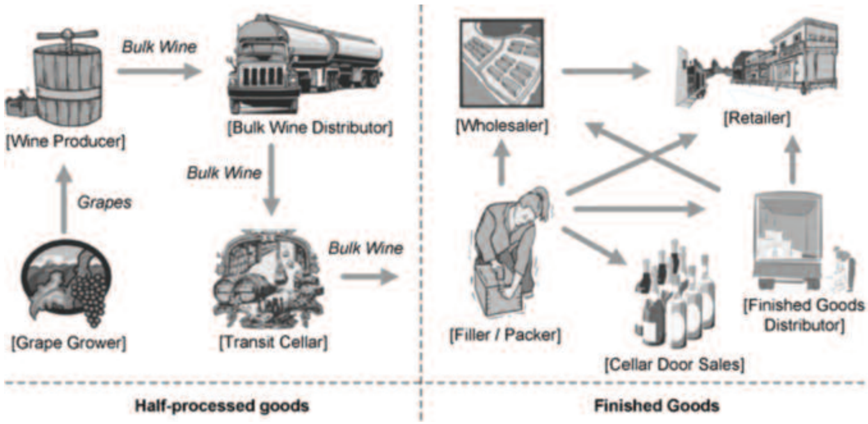

Figure 1. A representative scenario of wine supply chain. Source: (Cimino and Marcelloni, 2012)

Grape Growers are responsible for the production, harvest and delivery of grapes. Growers should record, details about the location, type of the vines, annual production record, origin and chemical content of water used for cleaning and irrigation, and the annual treatment. For each treatment product, growers should record the supplier's details, a description of the product received, as well as applicable batch numbers.

The growers supply, with each delivery, the location number of the plot from which it comes and the date of picking, so that the receiving wine producers can link the related details to the wine made from these grapes.

Wine Producers are responsible for the production, manufacture and/or blending of wine products. Wine producers should record where, in the winery, grapes or juice was stored. They must keep accurate records for the procedures and operations performed. The wine producer is responsible for identifying each production run with a batch number. For the receipt of additives, the producers should record the supplier's details, receiving date, a description of the product received, as well as applicable batch numbers.

The *Bulk Distributor* is responsible for receipt, storage, dispatch, processing, sampling and analysis of bulk wine. The bulk distributor checks the receiving documents, records all the information including the amount of received wine and takes samples for tasting and analysis. If the wine is rejected, the wine returns to the source, otherwise, two distinct processes are performed:

(i) storage and dispatch of bulk wine without any blending or any other processing;

(ii) storage, blending of different wines and dispatch of the new bulk blend. Identification is handled for the bulk distributor and the bulk wine container. To ensure forward tracking, it is essential to record references of the delivery items and to link these to the recipient.

The *Transit Cellar* is responsible for the receipt, storage, dispatch, processing, sampling and analysis of bulk wine. The transit cellar receives bulk wine from bulk distributors in different kinds of containers. Each of these containers is identified with a proper code. The transit cellar sends batches of bulk wine to the filler/packer. Each container sent is identified with a unique number, and with the associated quantity of wine (liters). In order to maintain accurate traceability throughout the chain, it is necessary that the transit cellar records the item and batch numbers, as well as the identifier of each dispatched item. To ensure forward tracking, it is necessary to record the global identifiers of the shipped items and link these to the location of the recipient.

The *filler/packer* is responsible for the receipt, storage, processing, sampling, analysis, filling, packing and dispatch of finished goods. The filler/packer receives containers of bulk wine from the transit cellar, and also "dry goods" in contact with wine (bottles, caps, corks, etc). Each of the containers of bulk wine and logistic units of dry goods are identified with a proper batch number. During this stage, the wine is poured into different kinds of containers, such as bottles, bags, kegs or barrels, and a lot number is allocated to them. A link between these components (bulk wine, finished product) should be maintained. The next step is the packaging into cartons and pallets and the dispatch of these cartons and pallets (identified with a lot number) to the finished goods distributor. The lot number must be linked to the batch (es) of bulk wine used to fill the bottles. To ensure forward tracking, it is necessary to record the global lot number of the shipped items and link these to the location number of the recipient.

The *finished goods distributor* is responsible for the receipt, storage, inventory management and dispatch of finished goods. The finished goods distributor receives pallets and cartons from the filler/packer and dispatches them to the retailer. These trade items are identified with lot numbers. To ensure forward tracking, it is necessary to record the global lot number of the shipped items and link these to the location number of the recipient.

The *retailer* receives pallets and cartons from the finished goods distributor and picks and dispatches goods to the retail stores. The container number of an incoming pallet is recorded and linked to the location number of the supplier. The retailers keep a record of the container number and the lot numbers of the components of the pallets and cartons they receive. The retailers sell consumer items (bottles, cartons) to the final consumer. These items are identified with a number allocated by the brand owner.

This brief description of the wine supply chain has highlighted that all the processes from the grape grower to the consumer can be traced by associating appropriate identifiers with the traceability entities managed by the single supply chain actors and, for each identifier, creating a record with all the information required about the entity. Each actor of the supply chain is therefore responsible for recording traceability data corresponding to specific entities. Further, each actor has to create the links between identifiers which identify correlated entities (Cimino and Marcelloni, 2012).

MATERIALS AND METHODS

The authenticity of wine is guaranteed by strict guidelines laid down by the responsible national authorities that include official sensory evaluation, chemical analyses and examination of the register kept by the wine producer (Rapeanu et al., 2009).

1. Authentication of geographical origin (production area)

Climatic, edaphic and orographic factors influence the process of vine growth, with direct influence on the compositional and sensory parameters of wines (Ballabio et al., 2006). Since the area of production raises the visible mark on originality and quality characteristics of products, the determination of geographical origin is a main requirement for wine authenticity. The concept of "*terroir*" has been introduced within Europe, considering the specific characteristics of a wine that are induced mainly by geographical location and characteristics of production in the concerned areas. The “denomination of origin” (DOC) regions are areas within designated traditional wines, which have great quality features.

Sensory evaluation done by specialists (tasters) was the only way to determine the geographical origin of wines. The method has a high degree of uncertainty; therefore, instrumental analysis is used to identify the compounds which are in very small quantities (Rapeanu et al., 2009).

The principal methods used for authentication of geographic origin are:

1.1. Analysis of volatile compounds profile

Based on the content in 1-hexanol and cyclohexanone, it was able to differentiate between Pinot noir wines of French and American origin (Kwan and Kowalski, 1978). Further, it was able to identify the geographic area of French red wines and Spanish white wines by use of more volatile compounds (ethyl esters, isoamyl esters, aldehydes, acetals etc.) (Rapeanu et al., 2009).

1.2. Analysis of amino acidic profile

By investigating the amino acids arginine, alanine, tyrosine, valine and leucine, which are responsible for the amino acidic profile of wines, it is possible to identify the geographical origin of wines (Flamini and De Rosso, 2006) (Chambery et al., 2009).

1.3. Mineral profile analysis

The "fingerprinting" of mineral profile of wines is the most valuable method of assessing the geographical origin. Investigation of mineral elements of wine is the main procedure to authenticate the geographical origin of wines. Since some of the macro and micronutrients have great changes during technological process, such as Na, K, Ca, Fe, Cu, Zn and others, attention has been focused on the elements which show very small changes during technological process, although they are found in small quantities or as traces (Cr, Co, Sb, Cs, Sc, Eu, Hf, Ta etc.). Lithium and rubidium are the most relevant to geographical origin authentication. They are in very small quantities, 1-200 ppm lithium and rubidium 0.5-5.0 ppm, but may be quantified in a relatively simple manner by modern methods (flame atomic emission spectrometry). Investigation of rare earth elements (lanthanides) also provides valuable information in order to detect the growing areas of the vine, by using mass spectrometry with inductively coupled plasma (ICP-MS) (Dutra et al., 2011).

1.4. Analysis of stable isotopes and organic compounds of lead

Determination of stable isotopes and isotopic reports and subsequent interpretation of experimental data using chemometric methods: principal component analysis (PCA), linear discriminate analysis (LDA), is another way to authenticate the geographical origin of wines.

Since the contents of stable isotopes of water and alcohol of wine, and their isotopic ratios (D/H, 18O/16O, 13C/12C) had variations caused mainly by climatic factors they may be used to locate areas of growing, especially depending on their climate (cold and dry, cold and wet, hot and humid, hot and dry).

There was a decrease in content of oxygen isotopes (18O) and of deuterium (2H) of wine water, when they move from warmer areas to areas with a temperate climate and from West to East. The isotopic ratio value of 13C/12C is depending of the weather conditions, particularly the temperatures at which are grapes ripening.

Recorded values of the ratio generate reliable information for elucidation of the area production of a wine (country, continent). Moreover, because the values of isotopic ratios D/H and H2 18O/H2 16O are dependent on soil water isotopic composition (and climatic conditions, especially precipitation), investigation of these ratios provide relevant information's to authenticate the geographic origin of wines (Rapeanu et al., 2009).

2. Authentication of grape variety

Biotic factor has a major contribution to the formation of qualitative characteristics of wine, so the compositional and sensory parameters are largely dependent on a variety of vines.

2.1. Sensory Analysis

Sensory is limited by the influence of several factors (ecological, agro and technological) that modify significantly the primary characteristics of the variety.

Although sensory analysis is still influenced by human subjectivity, statistical interpretation of results and using equipment such as "electronic nose" and "electronic tongue" improved the performance of sensory evaluation (Biernacka and Wardencki, 2012).

2.2 Mineral profile analysis

As the vine varieties selectively accumulate various metals, their identification can be achieved by the content of certain elements of the wine like: lithium, nickel, calcium, rubidium etc (Rapeanu et al., 2009) (Dutra et al., 2011).

2.3. Amino acid and protein profile analysis

While soil, agro-technical and technological factors causes the large variations, the content and nature of amino acids may contribute to recognition of the vine variety. Recent research has shown that molecular weights of proteins recorded small variations in wines by variety. Proteins are stable in must and can be found in wine and even those subject to stabilization. Protein quantification is relatively simple and can be done by conventional methods (electrophoresis) or by modern methods (mass spectroscopy etc.) (Rapeanu et al., 2009).

2.4. Analysis of polyphenolic profile

Their evaluation is useful to authenticate individual wines by botanical origin. Investigation of phenolic compounds by multidimensional nuclear magnetic resonance allows the differentiation of wines by variety, and even the clones of the same variety. The most representative phenolic compounds of red wines are the anthocyanins. They are in the free form, anthocyanins /anthocyanidins (malvidol, delfinidol, cyanidol, peonidol and petunidol), as well as acyl and coumaryl compounds. Cabernet Sauvignon is characterized by a higher content in malvidol and coumaryl anthocyanins while Merlot is highlighted by a higher content in peonidol and coumaryl anthocyanins (González-Neves et al., 2004).

Because during the grapes processing and wine preservation acyl and coumaryl anthocyanins are more stable, it was proposed that anthocyanins fingerprinting of red wines to express the amount of acyl anthocyanins + coumaryl anthocyanins and ratio of acyl anthocyanins/coumaryl anthocyanins (von Baer et al., 2008).

Since the authentication variety by using the fingerprint anthocyanins is operational only in red wines, white wines, roses and even the red is investigating by the content of shikimic acid (Mardones et al., 2005). Shikimic acid is found in small amounts in various fruits, including grapes. In wine is found in concentration of 10-150 mg/L. The content of shikimic acid is especially recommended for white wines authentication and as the additional indicator for red wines authentication (Makris et al., 2006).

2.5. Analysis of volatile compounds profile

Quantifying the odorant substances of wines, compounds that usually are found in extremely small quantities, is achieved by their extraction with various solvents and determination with modern methods such as gas chromatography coupled with spectrometry mass (GC-MS, LC/ESI-MS, MALDI-TOF-MS) (Nasi et al., 2008).

2.6. Residual DNA analysis of grapes

Since it was found that wines have small amounts of DNA from grapes, their analysis is done in order to identify the variety of the vine (Baleiras-Couto and Eiras-Dias, 2006).

The difficulties like - low content of DNA in wine, contamination (DNA from yeast, bacteria), changes during processing and inhibitors for the PCR reaction - were solved by using appropriate methods of DNA extraction and improving performance analysis using microsatellite PCR amplification.

3. Authentication of wine age

During time, the wines suffer a number of beneficial changes such as physical-chemical and even biochemical changes. They cause the development of refined sensorial qualities, thus, old wines are more valuable.

Moreover, the crop year, which benefited from favorable weather conditions, also give great features to the wines, therefore, being appreciated by consumers.

The analytical method that is frequently used is to determine the radioactivity of the 14C isotope of the ethanol molecule in wine. The method is relatively simple and consists in determination of the 14C isotope radioactivity of the concentrated solution (minimum 95%) of alcohol obtained by wine distillation or other alcoholic beverages. For red wines, to increase certainty, it is recommended to combine this results with those obtained from analysis of polyphenolic compounds and color indices. Determination of radioactivity by measuring the activity of wine sediment isotopes such as 210Pb, 210Po, 239Pu, 240Pu, 13 Cs, etc. is another way of knowing the wine age. The validity of the method was verified by appropriate dating of wine during 1850-1968, for every 6 years.

Age rating wines and other alcoholic beverages by determining radioactivity of isotopes have a high degree of reliability only for products with a considerable age (Dutra et al., 2011).

4. Authentication technology for production

There are a variety of techniques and processes of winemaking, authorized or used fraudulently altering appreciably the compositional and sensorial wine parameters.

This aspect of authenticity has a particular relevance to special wines like the sparkling wine, the oxidative wines etc.

4.1. Authentication of sparkling wines

Sparkling wines, which included class sparkling wines (sparkling), semi-sparkling, sparkling, pearl etc., are elite alcoholic beverages, much appreciated by consumers. There are a wide range, determined both by the diversity and quality of raw materials (wine based) but also technology development. Besides the general aspects of wines authentication, sparkling wines should represent be a clear distinction between products which contain endogenous origin CO_2 (sparkling wine) and those with totally or partially exogenous CO_2 (Martinelli et al., 2003). The most information is provided by the component amino acid analysis certainty being higher when is associated with the study of other compounds like: odorant substances, polyphenols content, carbohydrates etc.

Isotopic analysis is generating the most rigorous investigation results by determining the amount of isotope ratio 13C/12C. In this way, is precisely the origin of carbon dioxide in the product, if whether it comes from plants with C3 metabolism (the vine) or C4 (sugar beet etc.) or from other sources (industrial, synthesis etc.) (Calderone et al., 2007).

4.2. Authentication of oxidative type wines

Oxidative type wines, with the main representatives of Port wine, Madeira, Jerez etc. are characterized by sensorial properties, generated mainly by biochemical or physical-chemical oxidative processes.

Authentication aims to detect the original products of imitation. In addition to sensory evaluation, content analysis of metals (Rb, Li, Mn, Fe and Al), phenolic compounds, the carbohydrates (including the ratio of glucose and fructose), presence and content of amino acids etc. generate information that is useful to identify the original products (Câmara et al., 2006).

4.3. Authentication of rose wines

Rose wines are at the border between white and red wines, having specific chemical compounds, so it is difficult to license their origin. Authentication of rose wines has two major objectives. The first step is to identify the source of raw material in the sense that comes from red grapes or a blend of white grapes and red or white and red wines, and secondly to assess the authenticity of color, to detect possible fraud color of white wines by oenocyanin addition. Analysis of compounds and parameters such as polyphenols, sugars, volatile acidity, extract and especially the color indices etc. and comparing the results with reference values provide a high degree of certainty.

The recommended method for defining the color is the spectrophotometric method, the reference method, which monitors the three color indices: bright, chromaticity and purity (Rapeanu et al., 2009).

CONCLUSIONS

The ability to trace and authenticate a food product is of major concern to the food industry.

Wine authenticity is very important, especially in the case of quality control and consumer information.

Since wine quality is dependent on the consumer demands, compliance with traceability provisions satisfies the associated economic needs.

It is necessary that a traceability information system exists on the wine supply chain, in order to provide a better management of all representative events which may arise on this chain, from grape production to wine selling.

Traceability documents allow the detection of certain deviation from the usual process, that may render the final product unsafe or of a lower quality than the one expected.

Therefore, identifying the safety and quality issues during the process, by means of authentication and traceability, assures the compliance, within the framework of international regulations, with consumers' request for the certification of quality attributes.

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