Chapter 12

Aroma Compounds in Wine

Fengmei Zhu, Bin Du and Jun Li

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Abstract

Volatile aroma compounds are very important to grape wine quality. In order to understand the flavor of wine, a multitude of scientific investigations was carried out and a number of appropriate analytical tools for flavor study were developed in the past few decades. This chapter deals with major achievements reported in wine aroma and flavor. Firstly, we illustrate the existing knowledge on aroma compounds contributing to wine flavor, as well as the types of wine aroma compounds. Furthermore, the main factors affecting flavor quality in wine are discussed. Finally, the genomics and biotechnology of wine flavor are also summarized. This chapter broadens the discussion of wine aroma compounds to include more modern concepts of biotechnology and also provides relevant background and offers directions for future study.

Keywords: grape wine, aromatic compounds, terpenes, free volatile aroma compounds, bound volatile aroma compounds

1. Introduction

Wine aroma can be perceived by nose or in the mouth via postnasal way [1], and is a direct function of the chemical composition of the wine. Perceived flavor is the result of complex interactions between all the volatile and nonvolatile compounds present in wine [2]. The aroma of the wine consists of 1000 aroma compounds [3]. The diversity of aromatic compounds in wine is immense and ranges in concentration from several mg l^{-1} to a few ng l^{-1} [4]. Wine flavor can be divided into classes: varietal aroma, typical of grape variety; prefermentative aroma, originated during grape processing; fermentative aroma, produced by yeast and bacteria during alcoholic and malolactic fermentations (MLFs); postfermentative aroma, which is due to transformations that occurred during conservation and aging of wine [5]. This chapter will provide an overview of wine aroma and flavor starting with occurrence. The main focus of the review will describe the types of aroma compounds, as well as the main factors of wine aroma compounds in wine. More detail will be given on genomics and biotechnology. The sensory perception will also be discussed.

2. Occurrence of aroma compounds contributing to wine flavor

Knowledge of the volatile composition of a wine is of great interest, since these compounds are highly related to beverage flavor [6]. Although hundreds of chemical compounds have been identified in grapes and wines, only a few compounds actually contribute to sensory perception of wine flavor [7]. The perception of wine flavor and aroma is the result of a multitude of interactions between a large number of chemical compounds and sensory receptors [8]. Higher alcohols, acids and esters are quantitatively dominant in wine aroma and are important in the sensory properties and quality of wine [9]. Small amounts of higher alcohols contribute positively to wine quality, while excessive amounts may detract from quality [10]. Esters contribute to wine odor and relatively concentrations of fatty acids give an appreciable strong odor [11].

The main compounds responsible for the most intense aromas in Sauvignon Blanc wines have been assumed to be methoxypyrazines and varietal thiols in the Marlborough region [12].

Darici et al. [13] evaluated the aroma of a Turkey Çalkarası rosé wine by sensory evaluation analysis, gas chromatography-olfactometry (GC-O) and four quantitative methods. The volatile compounds of the wine were dominated by fresh fruit, floral and red fruit notes. An extract obtained using a dynamic headspace technique was subjected to GC-O. The aroma showed a complex profile with 28 compounds determined above their odor threshold.

3. Types of wine aroma compounds

Aroma styles are particularly important for wine exports, and preferences in aroma profiles can differ between markets in various countries [14].

3.1. Wine aroma formed by yeast during fermentation

Wine quality is closely related to microbial ecology of fermentation. Yeasts contribute to wine aroma by producing volatile metabolites with different flavor profiles. The aromatic profile of wine has been studied in relation to the amount of assimilable nitrogen available from the yeast present in the must [15]. Gil et al. [11] isolated and analyzed the aroma compounds of wines inoculated with pure and mixed cultures of apiculate and *Saccharomyces* yeasts by gas chromatography with flame ionization and mass spectrometry (MS). The findings showed that samples fermented with mixed cultures produced a higher concentration of selected compounds and higher total amounts of alcohols and acids, by comparison, wines produced with pure cultures of *Saccharomyces* spp. Apiculate yeasts are essential in the chemical composition and quality of wine.

The microflora, and especially the yeast, is related with fermentation, conduces to wine aroma by mechanisms: firstly by utilizing grape juice constituents and biotransforming them into aroma- or flavor-impacting components; secondly by bringing enzymes that transform neutral grape compounds into flavor-active compounds and lastly by the de novo synthesis of many flavor-active primary and secondary metabolites [8]. Joseph et al. [16] undertook a survey of 95 Brettanomyces strains and identified whether strains consistently give positive aroma characteristics using a solid phase microextraction with gas chromatography (SPME GC-MS) analysis coupled with olfactory analysis. None of the strains yielded universally positive aromas for the evaluators. The results showed that 22 compounds were identified as having an impact on aroma, including the well-known ethylphenols and vinylphenols, as well as several fatty acids, alcohols, esters, terpenes and an aldehyde.

3.2. Wine aroma formed during alcoholic fermentation

Spontaneous wine fermentations are often unpredictable, resulting in undesirable traits that occasionally lead to spoilage [17]. Zhang et al. [18] studies the effects of three commercial maceration enzymes on aroma compounds of Cabernet Sauvignon wine during alcohol fermentation. The results showed that maceration enzymes could have a significant effect on the formation of aroma compounds. Moreover, the presence of non-*Saccharomyces* species at the onset of alcoholic fermentation may have a greater potential to contribute to the liberation of some aglycons (mainly terpenes) from the flavorless precursor glycoside during fermentation [19].

3.3. Wine aroma formed during amino acid metabolism

The most important flavor and aroma compounds formed from amino acids are higher alcohols and their associated esters and volatile acids. These odd-related products are produced from valine, leucine and isoleucine. It has been shown that the varietal aroma character of certain cultivars could be partially explained by the amino acid composition of the grape must [20]. Although yeast strains differ greatly in their ability to use nitrogen and amino acids, various studies have shown that nitrogen supplementation in the form of assimilable nitrogen and amino acids influences the volatile aroma profile of the wine [8].

There are different ways that amino acids can be metabolized into aroma compounds. The first way is Ehrlich reaction. In this process, amino acids are catabolized into higher alcohols. The Ehrlich reaction also impacts directly or indirectly on the synthesis of other aroma compounds [21]. Secondly, the sulfur-containing amino acids can have a positive impact on the aroma of wine. For example, 3-mercaptohexanol can impart fruity flavors to a wine. Another way is called Maillard reaction. Cysteine can form various odor-impacting compounds through this reaction, in which a chemical reaction between amino and carbonyl groups takes place to form new compounds [22].

3.4. Wine aroma formed during malolactic fermentation

The secondary malolactic fermentation (MLF) is principally a deacidification step, which is used to manicure the acidity of certain wine types and confer added microbial stability to the product [19]. This process is normally carried out by lactic acid bacteria isolated from wine, including *Oenococcus oeni*, *Lactobacillus* spp., *Leuconostoc* spp. and *Pediococcus* spp. [23]. It has been shown that lactic acid bacteria can influence the aroma by producing volatile metabolites and modifying aroma compounds derived from grapes and yeasts during MLF. Moreover, MLF can enhance the fruity aroma and buttery note but reduce vegetative, green/grassy aroma of wine. In recent studies, lactic acid bacteria can also influence wine aroma by producing additional oak-derived compounds [24]. In addition, MLF is important in wines from warmer region because it changes the composition of the wine and improves its organoleptic quality.

4. Main factors affecting flavor quality in wine

Wine aroma is generated through an immensely complex interaction of various classes of aroma compounds and various environmental and biological factors.

4.1. Effect of weather on wine aroma compounds

There are many factors that can influence flavor profile or wine style.

Mendez-Costabel et al. [25] evaluated the impact of winter rainfall on the main compounds responsible for green aromas in grapes and wines during the 2009 and 2010 seasons in California. Fruit and wine components were dramatically effected by the absence of rainfall in both years. Wine descriptive analysis showed that the lack of rainfall produced wines perceived as less green and of more intense fruit attributes in the first season. Due to the reduction in vine growth, however, the same treatment produced wines less intense in fruit aromas and of bad tannin quality in the following season. These results showed that if the rainfall level is below normal, the positive effect on fruit and wine composition achieved.

4.2. Effect of soil type on wine aroma compounds

Soil type, though closely related to soil water status, has an independent effect on grape aroma quality [26]. Falcao et al. [27] assessed soil characteristics of the different four sites in Santa Catarina State, Brazil. The results indicated that vineyard location had a strong influence on the volatile wine fraction. The varietal volatile compounds were a key factor in differentiating wines according to the sites. In addition, Ribereau-Gayon et al. [28] reported that soil has a decisive influence on methoxypyrazine concentrations due to its effect on vegetative growth in Merlot, Cabernet Franc and Cabernet Sauvignon wines of the Bordeaux region. The results showed that grapes grown on well-drained gravelly soils have lower concentrations than those grown on limestone or clay-silt soils.

4.3. Effect of vineyard management practices on wine aroma compounds

4.3.1. Effect of water on wine aroma compounds

Bonada et al. [29] assessed the sensory and compositional characteristics of grapes and wines from a field trial where water deficit factor was directly manipulated. The results indicated that the effect of water deficit leading to colorful and flavorsome wines rich in phenolic substances may not be held under high temperature.

4.3.2. Effect of copper on wine aroma compounds

Martins et al. [30] investigated the effect of the application of Bordeaux mixture in the vineyard on the copper concentration in the must, and the consequences for the volatile composition of wine. The results showed that the concentration of copper decreased from 31.4 to 12.6 mg/L during fermentation, as measured by atomic absorption spectrometry. Promoted copper concentration caused a significant decrease in the concentration of higher alcohols, including isoamyl alcohol, and of esters of organic acids, including ethyl lactate, as analyzed by liquid–liquid microextraction gas chromatography (GC)-flame ionization detection and solid phase extraction GC-ion trap-mass spectrometry (MS) analysis. By contrast, the ethyl acetate and linalool concentration rose dramatically.

4.3.3. Effect of nitrogen fertilization on wine aroma compounds

For example, Mendez-Costabel et al. [31] investigated the effect of two irrigation levels and a higher than standard nitrogen fertilization on the concentration of both 3-isobutyl-2-methoxypyrazine (IBMP) and six C6 compounds during fruit development. The results showed that deficit irrigation increased fruit color, quercetin glycosides and phenol-free glucose glycosides (i.e., aroma precursors), decreased vine yield and increased concentration of IBMP during fruit maturation.

4.4. Effect of aging and maturation on wine aroma compounds

The release of aroma precursors can occur during wine aging, under mild acidic conditions [32]. Higher alcohols are important as precursors for ester formation during aging. The flavor-active metabolites that have an impact on wine perception are derived from the grapes and from microorganisms during fermentation, as well as from chemical processes during production and maturation [2]. The final aroma and flavor profile is furthermore strongly dependent on all aspects of postfermentation treatments such as filtration and maturation strategies, including aging in wooden containers [8].

5. Free and bound volatile aroma compound

Aroma compounds in wine are typically found both as "free" and "bound" to a sugar moiety. In wine, a large proportion of aroma compounds are found in the bound form [33]. Potentially volatile terpenes (PVTs) are more responsive to viticultural and oenological practices than free volatile terpenes (FVTs). Many lactic acid bacteria possess catalytic enzymes capable of liberating grape-derived aroma compounds from their natural nonaromatic glycosylated state [34]. The classes of enzymes (β-glucosidase, proteases, esterases, citrate lyases and phenolic acid decarboxylases) can possibly hydrolyze flavor precursors and so influence wine aroma [35–37]. The hydrolysis steps are shown in **Figure 1**.

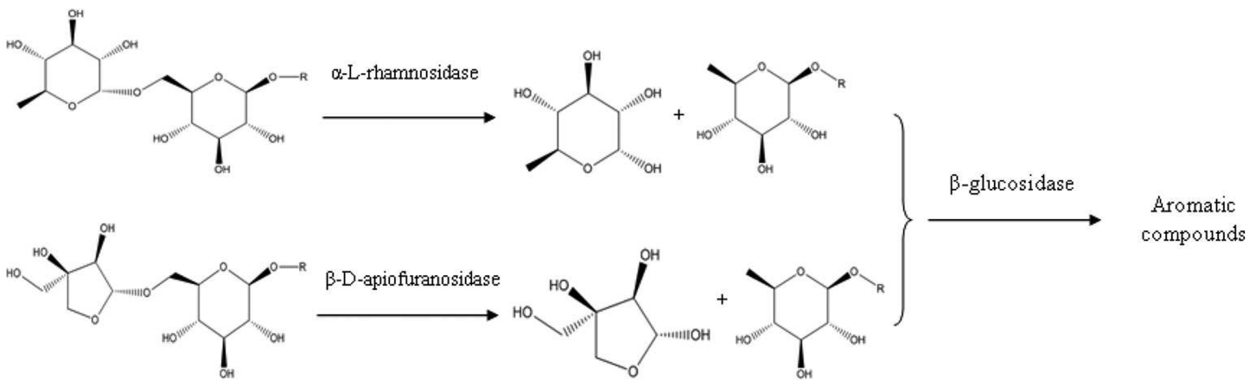

Figure 1. The hydrolysis scheme of glycosidic aroma precursors.

6. Genomics and biotechnology of wine flavor

In wine-making industry, some biotechnological techniques have been of fundamental importance [38]. Colagre et al. [38] illustrated the importance of the characteristics of wine yeast and of a genetic improvement program for the wine industry, as well as the complexity of the genetic modifications of commercial wine yeast strains. Moreover, commercial preparations of glycosidases, usually sourced from *Aspergillus* sp., can be used to liberate more flavor aglycons into the wine, but may not function well under key wine conditions of low pH, ethanol content or residual sugar content [39]. An alternative approach to preparing a crude or pure extract of glycosidases for addition to wine is to express the appropriate enzyme gene in *S. cerevisiae*. For example, the rbaA gene (α-L-rhamnosidase) from *Aspergillus aculeatus* has been successfully expressed in conjunction with the Candida molischiana β-D-glucosidase in an industrial wine yeast strain to increase the pool of linalool, nerol and α-terpineol in Muscat wine [40].

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7. Aroma compounds and sensory perception

Aroma compounds play an important role in the quality of wine because those compounds produce an effect on sensory senses [5].

The aroma of wines is the result of the contribution of some hundreds of volatile compounds and it is an important factor to consider in their sensorial quality [6]. Once the wine has been made, the appreciation of wine requires various senses: firstly to observe the color and appearance, secondly to judge the wine bouquet, thirdly to taste the wine itself and fourthly to enjoy the mouthfeel and aftertaste [7].

Quantitative descriptive analysis is one of the most comprehensive and informative tools used in sensory analysis. Tomasino et al. [41] identified aroma compounds of major sensory significance in New Zealand Pinot Noir wines using canonical correlation analysis and addition/omission tests. There are some similar researches in Merlot and Cabernet Sauvignon wine. The effect of benzaldehyde, ethyl octanoate and 2-phenyl ethanol on the aroma of Pinot Noir wine was investigated. The results showed that the contribution of these compounds is similar in a range of red wines. Both ethyl decanoate and ethyl octanoate played an important role acting as aroma enhancer compounds. Moreover, Welke et al. [42] reported the quantitative determination of volatile compounds of Chardonnay wines using HS-SPME-GC × GC/TOFMS along with the determination of odor activity value (OAV) and relative odor contribution (ROC) of volatiles.

On the other hand, sensory analysis involves the detection and description of qualitative and quantitative sensory compounds of a product by a trained panel of judges [43]. Wine tasting and perception is therefore largely a subjective experience, and simple factors such as the absence or presence of saliva greatly influence the release of aroma compounds from both red and white wines [44].

8. Conclusions and future prospectives

This review summarizes the aroma compounds contributing to wine flavor and the types of these aroma compounds. The specific compounds in wine are not clear. It is important to study the chemical and biochemical changes during fermentation and storage. Nevertheless, further research into the sensory impact of wine aroma compounds both alone and in mixtures will be focused.

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Author details

Fengmei Zhu[1], Bin Du[2] and Jun Li[1*]

*Address all correspondence to: trueyeoman@163.com

1 College of Food Science and Technology, Hebei Normal University of Science and Technology, Qinhuangdao, P.R. China

2 Analysis and Testing Center, Hebei Normal University of Science and Technology, Qinhuangdao, P.R. China

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