
The Science Behind Wine and Food Pairing

Giorgi Patsatsia

Department of Artificial Intelligence, Georgian Technical University Tbilisi, Georgia

Abstract

Wine and food pairing is usually associated with culinary experience, cultural traditions, and sommelier expertise. However, a successful pairing is not determined only by personal preference. It also depends on the interaction between the sensory and physicochemical characteristics of wine and food. Acidity, sweetness, tannins, alcohol level, body, fat content, saltiness, spiciness, texture, and flavor intensity can all influence whether a wine and a dish create a balanced and pleasant tasting experience.

This paper examines the scientific principles behind wine and food pairing, with particular attention to the main characteristics of wine and food and the way they interact. The discussion focuses on common pairing mechanisms such as balance, contrast, complementarity, flavor intensity matching, acidity-fat interaction, sweetness-spiciness balance, and tannin-protein interaction. The paper also considers wine-food pairing as a structured decision-making task that may support the development of AI-based recommendation systems in the wine industry. From an informatics perspective, sensory and physicochemical characteristics can be treated as input features for models that evaluate the compatibility between wines and dishes. The paper contributes a structured synthesis of expert-based pairing principles and a conceptual mapping of these principles to content-based recommendation logic, providing a foundation for future AI-supported wine recommendation research.

Keywords: wine and food pairing, sensory science, artificial intelligence, content-based recommendation, machine learning, sensory attributes

I. Introduction

Wine and food pairing is an important part of gastronomic culture and wine consumption. In restaurants, wine tourism, and everyday dining, the selection of an appropriate wine for a particular dish can strongly influence the overall sensory experience. Traditionally, such decisions have been based on culinary traditions, regional habits, and the practical knowledge of sommeliers and wine experts. However, successful pairing is not entirely subjective. It is also affected by the interaction between the sensory characteristics of wine and food (Harrington, 2007).

From a scientific perspective, wine and food pairing can be understood through the relationship between taste, aroma, texture, and physicochemical properties. Wine characteristics such as acidity, sweetness, tannins, alcohol level, body, and flavor intensity interact with food characteristics such as fat content, saltiness, sweetness, acidity, spiciness, texture, and flavor strength. These interactions may create balance, contrast, or complementarity. For example, acidic wines can reduce the heaviness of fatty dishes, sweet wines may soften the perception of spiciness, and tannic wines often pair well with protein-rich foods (Jackson, 2022).

The scientific study of wine and food pairing is also relevant from an informatics perspective. Recommender systems are widely used to provide users with suitable suggestions based on item characteristics, user preferences, or previous interaction data (Aggarwal, 2016). If wine and food characteristics can be described as structured attributes, they can be used as input features for computational models. This creates a basis for artificial intelligence-based recommendation systems that suggest suitable wine and food combinations. In this context, wine-food pairing is not only a culinary practice but also a decision-making problem that can be supported by data, expert rules, and user feedback (Ricci, Rokach, & Shapira, 2021).

The aim of this paper is to synthesize the existing scientific literature on wine and food pairing and to organize its core sensory and physicochemical principles into a structured overview. While prior work has addressed pairing from culinary (Harrington, 2007), sensory (Lawless & Heymann, 2010), or computational (Trattner & Elswailer, 2017) perspectives individually, this paper bridges these domains by showing how established pairing principles can be interpreted as decision criteria for AI-based recommendation systems. The contribution of this paper is thus twofold: it provides a consolidated reference for researchers entering this interdisciplinary field, and it proposes a conceptual mapping between expert-based sensory rules and content-based recommendation logic, illustrated in Table 1.

II. Methodology

This paper is based on a narrative literature review conducted across three academic databases: Google Scholar, Scopus, and Web of Science. A narrative review approach was selected because the aim of this paper is to synthesize knowledge across multiple disciplines - sensory science, food chemistry, and informatics - rather than to conduct a quantitative analysis of a

homogeneous body of research. No publication date restriction was applied, as the topic draws on foundational works in sensory science and wine evaluation, as well as more recent studies related to computational food pairing and recommendation systems. The search combined keywords related to three thematic areas: sensory and physicochemical properties of wine and food, including “wine food pairing,” “sensory evaluation,” and “tannin protein interaction”; scientific pairing principles, including “acidity fat interaction” and “flavor intensity matching”; and computational approaches, including “food recommendation system,” “content-based filtering,” and “AI wine recommendation.”

Sources were selected according to their relevance to the research topic, publication in peer-reviewed outlets or by established academic publishers, and contribution to the sensory, scientific, or computational understanding of wine and food pairing. The reviewed sources included peer-reviewed journal articles, academic books, and conference papers. Sources were excluded if they were not written in English, lacked a clear empirical or theoretical basis, or were not directly related to the sensory, scientific, or computational dimensions of wine and food pairing.

The final selection comprised 17 sources, which informed the thematic structure of this review. The reviewed literature was organized into three thematic areas corresponding to the main sections of this paper: the sensory characteristics of wine and food, the scientific principles governing their interaction, and the computational approaches that may support AI-based pairing recommendations.

III. Sensory Characteristics of Wine and Food

Wine and food pairing depends on the sensory characteristics of both components. These characteristics determine how wine and food are perceived during consumption and how they influence each other when consumed together. In this context, sensory characteristics include taste, aroma, texture, mouthfeel, body, and flavor intensity. Some of these characteristics are directly perceived by the consumer, while others are related to physicochemical properties that shape sensory perception (Lawless & Heymann, 2010).

Wine Characteristics. Wine contains several sensory and physicochemical characteristics that affect its compatibility with food. One of the most important is acidity, which contributes to freshness and sharpness. Wines with higher acidity are often perceived as more refreshing and can balance rich or fatty dishes. Sweetness is another important attribute, mainly associated with the level of residual sugar in wine. Sweet wines may reduce the perception of spiciness and can also complement desserts or slightly sweet dishes.

Tannins are especially relevant in red wines. They create a sensation of bitterness and astringency and interact strongly with protein-rich and fatty foods. Alcohol level also affects the sensory profile of wine by contributing to warmth, body, and flavor perception. In addition, the body of wine refers to its overall weight and fullness in the mouth, ranging from light-bodied to

full-bodied. Flavor intensity, including aroma strength and persistence, is also important because wines with weak flavor intensity may be dominated by strongly flavored dishes, while very intense wines may overpower delicate foods (Kustos, Heymann, Jeffery, & Goodman, 2020).

Food Characteristics. Food also has sensory characteristics that influence pairing decisions. Fat content is one of the key factors, because fatty foods often require wines with sufficient acidity or tannins to create balance. Saltiness can change the perception of wine by reducing bitterness and making some wines taste smoother. Sweetness in food is important because dishes that are sweeter than the wine may make the wine taste flat, sour, or overly dry.

Acidity in food, such as that found in citrus, vinegar, or fermented ingredients, should be considered carefully because it can strongly affect the perception of wine acidity. Spiciness is another important factor, especially in dishes containing chili or strong spices. Spicy foods may increase the perception of alcohol and bitterness in wine, which is why they are often paired with wines that have moderate alcohol, good acidity, and some residual sweetness. Texture also plays an important role, since creamy, crispy, tender, or oily foods create different mouthfeel effects. Finally, flavor intensity determines how strong the dish tastes overall and should be considered together with the intensity of the wine (Lawless & Heymann, 2010).

Interaction Between Wine and Food Characteristics. Wine and food characteristics should not be evaluated separately. A successful pairing depends on the interaction between them. Some combinations create balance, such as acidic wine with fatty food, while others create contrast, such as sweet wine with spicy food. In other cases, wine and food may be paired through similarity, for example, a full-bodied wine with a heavy dish or an aromatic wine with a strongly flavored meal.

These interactions show that wine and food pairing can be analyzed as a structured process based on identifiable sensory attributes. More generally, food pairing can be studied through systematic relationships between flavor compounds and ingredient combinations, which supports the idea that pairing is not only intuitive but can also be analyzed computationally (Ahn, Ahnert, Bagrow, & Barabási, 2011). For informatics-oriented applications, structured wine and food descriptors may also be represented computationally and used in graph-based or recommendation-oriented pairing models (Simas, Ficek, Diaz-Guilera, & Obrador, 2017; Gawrysiak, 2024).

IV. Scientific Principles of Wine and Food Pairing

Wine and food pairing is based on the interaction of sensory characteristics that may either support or weaken each other during consumption. Although pairing is often associated with personal taste and culinary tradition, several general principles can explain why certain combinations are perceived as more balanced than others (Spence, 2020). These principles

include balance, contrast, complementarity, flavor intensity matching, acidity and fat interaction, sweetness and spiciness balance, and tannin and protein interaction (Galmarini, 2020).

One of the most important principles is balance. In a successful pairing, neither the wine nor the food should dominate the overall sensory experience. For example, a delicate dish is usually better paired with a light-bodied wine, while a rich and heavy dish often requires a fuller-bodied wine. Similarly, the flavor intensity of wine and food should be comparable. If the wine is too light for a strongly flavored dish, it may be overwhelmed. If it is too intense for a delicate dish, it may dominate the food.

Another important principle is contrast. Some pairings work because the wine and food provide different but complementary sensory effects. A common example is the combination of acidic wine with fatty food. Acidity can create freshness and reduce the perception of heaviness in rich dishes. Sweetness can also function as a contrasting element, especially in pairings with spicy food, where a slightly sweet wine may reduce the burning sensation and create a smoother overall impression (Keast & Breslin, 2003).

Complementarity is also central to wine and food pairing. In this case, the wine and food share similar sensory characteristics or reinforce each other. For example, an aromatic wine may pair well with a dish that contains herbs or expressive spices, while a full-bodied red wine may complement a rich meat dish. Tannins are particularly important in this context because they interact with proteins and fats, especially in meat-based dishes. This interaction can reduce the perception of astringency in the wine and create a more balanced mouthfeel (Bajec & Pickering, 2008).

Several expert-based pairing principles have been formulated in the literature to describe these relationships more systematically. Harrington's work is useful in this context because it presents wine and food pairing as a sensory process based on the interaction of wine and food characteristics such as sweetness, acidity, tannins, fatness, body, flavor intensity, and persistence (Harrington, 2007). Table 1 summarizes these principles and shows how they can also be interpreted from the perspective of recommendation systems.

Flavor intensity matching is another important principle in pairing decisions. When the overall flavor strength of a wine and a dish are similar, neither component overshadows the other, resulting in a more harmonious sensory experience. A strongly flavored dish requires a wine with sufficient intensity, while delicate dishes suit wines with more restrained profiles. Flavor persistence is equally relevant, as wines and dishes sharing a similar length of finish tend to create more cohesive pairings (Harrington, 2007; Spence, 2020).

Table 1: Expert-Based Wine and Food Pairing Principles (Harrington, 2007)

Rule No.	Pairing Dimension	Pairing Principle	Interpretation for Recommendation Systems
1	Sweetness balance	The sweetness level of food should be less than or equal to the sweetness level of wine.	Avoid recommending dry wines for dishes with high sweetness.
2	Acidity balance	The acidity level of food should be less than or equal to the acidity level of wine.	Prefer wines with sufficient acidity for acidic dishes.
3	Saltiness and effervescence	Highly salty foods pair better with wines that have high effervescence.	Increase the compatibility score of sparkling wines for salty foods.
4	Bitterness reduction	The negative effect of bitter food may be reduced by wines with moderate to high effervescence.	Treat effervescence as a balancing attribute for bitter foods.
5	Tannin-fat interaction	Wine tannin level should correspond to the fattiness of animal-based foods.	Recommend tannic wines for fatty meat-based dishes.
6	Acidity-fat interaction	Wine acidity should correspond to the fattiness of vegetable-based foods.	Recommend acidic wines for fatty vegetable-based dishes.
7	Body matching	The overall body of wine and food should be similar.	Match light dishes with lighter wines and heavier dishes with fuller-bodied wines.
8	Spiciness matching	Food spiciness and wine spiciness should be balanced.	Consider the spice intensity of both wine and food.
9	Spicy food pairing	Spicy food is often suitable with off-dry, acidic white wines.	Give higher scores to off-dry acidic white wines for spicy dishes.
10	Flavor type matching	Wine and food flavors can be matched through similarity or contrast.	Use either complementary or contrasting flavor profiles.
11	Flavor intensity matching	Wine and food flavor intensity should be similar.	Pair strongly flavored dishes with wines of sufficient flavor intensity.
12	Flavor persistence matching	Wine and food flavor persistence should be similar.	Pair long-lasting food flavors with wines that also have persistent flavor.

The principles summarized in Table 1 show that wine and food pairing can be viewed as a structured evaluation process. Although these rules come from culinary knowledge and sensory observation, they can also be converted into practical decision criteria. This is relevant for informatics-oriented research because wine and food characteristics can be used as features in recommendation models. In this way, expert-based pairing principles provide a useful foundation

for AI-supported wine recommendation systems. It should be noted that the fourth column of Table 1, which interprets each pairing principle from the perspective of recommendation systems, represents a conceptual mapping proposed in this paper based on the original rules described in the wine and food pairing literature (Harrington, 2007). This mapping illustrates how domain knowledge from sensory science can be translated into computational logic applicable in AI-based pairing tools.

V. Wine and Food Pairing as a Structured Decision-Making Problem

Wine and food pairing can be considered a structured decision-making problem because it requires the evaluation of several characteristics at the same time. A suitable pairing is not determined by one attribute alone, but by the combined effect of acidity, sweetness, tannins, body, fat content, saltiness, spiciness, texture, and flavor intensity. Therefore, the selection of a wine for a particular dish can be understood as a process of comparing wine attributes with food attributes and estimating their compatibility.

From an informatics perspective, these characteristics can be represented as input features. For example, a wine may be described by acidity, sweetness, tannin level, alcohol content, body, and flavor intensity, while a dish may be described by fat content, saltiness, sweetness, acidity, spiciness, texture, and flavor strength. This approach is close to content-based recommendation, where suggestions are generated by using item descriptions and user preferences (Pazzani & Billsus, 2007). Such feature-based representation makes it possible to analyze pairing decisions in a more systematic way.

The expert-based principles discussed in the previous section may serve as decision rules for a recommendation system. For instance, if a dish has high fat content, the system may give higher priority to wines with higher acidity or tannins. If a dish is spicy, the system may recommend wines with moderate alcohol, good acidity, and some sweetness. This logic is consistent with knowledge-based recommendation, where domain knowledge and explicit constraints are used to guide recommendation decisions (Burke, 2000).

This approach is also relevant for artificial intelligence-based recommendation systems. In a simple model, expert rules may be used to generate initial recommendations. Later, user ratings and feedback can be collected to improve the quality of suggestions. Such a structure is close to hybrid recommendation, where different recommendation strategies are combined to improve performance and overcome the limitations of a single method (Burke, 2002).

Several machine learning models are relevant to the wine and food pairing recommendation task. Decision tree models offer a natural fit for rule-based pairing logic, as they partition the feature space according to attribute thresholds and produce interpretable outputs that mirror the expert rules summarized in Table 1. Support vector machines (SVMs) can be applied to binary compatibility classification tasks, where a pairing is labelled as suitable or unsuitable based on wine and food feature vectors (Ahn, Ahnert, Bagrow, & Barabási, 2011). Neural network models

offer greater flexibility by learning non-linear relationships between attributes, but require larger datasets and produce less interpretable outputs. Graph-based models represent another promising direction, where wines, dishes, and shared flavor compounds are represented as nodes and edges in a network, allowing compatibility to be estimated through structural proximity (Gawrysiak, 2024; Simas, Ficek, Diaz-Guilera, & Obrador, 2017). Each approach has different strengths depending on data availability, interpretability requirements, and task complexity.

Overall, the structured nature of wine and food pairing makes it a well-suited domain for AI-based recommendation research. The availability of sensory descriptors, the existence of expert-based pairing rules, and the potential for user feedback collection create a foundation for developing recommendation systems that are both scientifically grounded and practically useful.

VI. Discussion

The analysis presented in this paper shows that wine and food pairing can be understood as more than a matter of personal taste or culinary tradition. Although individual preference remains important, many pairing decisions are influenced by recognizable sensory and physicochemical relationships. Acidity, sweetness, tannins, body, fat content, saltiness, spiciness, texture, and flavor intensity all contribute to the way wine and food are perceived together.

The expert-based principles discussed in the previous section demonstrate that pairing knowledge can be organized into structured rules. These rules explain why certain combinations are commonly recommended, such as acidic wines with fatty dishes, sweet wines with spicy foods, or tannic wines with protein-rich meals. Such principles do not eliminate subjectivity, but they provide a practical basis for making pairing decisions more consistent and explainable.

From an informatics perspective, this structured approach is especially useful. If wine and food characteristics are represented as attributes, they can be used in recommendation systems to estimate compatibility between wines and dishes. A rule-based model may apply expert knowledge directly, while a more advanced AI-based model may combine these rules with user ratings and feedback. This creates the possibility of developing recommendation systems that are both explainable and adaptable to individual preferences.

At the same time, wine and food pairing remains a complex problem. Sensory perception can vary between individuals, cultures, and contexts. The same pairing may be evaluated differently depending on personal taste, previous experience, serving temperature, cooking method, portion composition, and regional food habits. Therefore, AI-supported pairing systems should not be viewed as replacing human expertise, but rather as tools that can support decision-making and improve the accessibility of wine knowledge.

Overall, the scientific and computational interpretation of wine and food pairing can be useful for the wine industry. It may support restaurants, wineries, wine tourism platforms, online wine shops, and digital recommendation services. For research in informatics, wine and food pairing provides a relevant example of how sensory knowledge, expert rules, and user feedback can be combined in intelligent decision-support systems.

VII. Conclusion

This paper examined the scientific principles behind wine and food pairing and showed that pairing decisions can be explained through the interaction of sensory and physicochemical characteristics. Although wine and food pairing is often associated with tradition, personal preference, and sommelier experience, many pairing patterns are based on identifiable relationships between wine and food attributes. Acidity, sweetness, tannins, body, fat content, saltiness, spiciness, texture, and flavor intensity all contribute to the overall compatibility of a wine and a dish.

The discussion showed that successful pairings are commonly based on principles such as balance, contrast, complementarity, flavor intensity matching, acidity and fat interaction, sweetness and spiciness balance, and tannin and protein interaction. These principles make it possible to interpret wine and food pairing as a structured evaluation process rather than as a purely subjective practice.

From an informatics perspective, the same principles can support the development of AI-based recommendation systems in the wine industry. Wine and food characteristics can be represented as input features, while expert-based pairing principles can be used as decision rules. In more advanced systems, these rules may be combined with user ratings and feedback to improve recommendation quality over time. Therefore, wine and food pairing represents a useful example of how sensory science, expert knowledge, and artificial intelligence can be integrated in practical decision-support applications.

Future research may focus on creating datasets of wine and food attributes, testing compatibility models with real users, and developing personalized recommendation systems that consider both sensory principles and individual preferences.

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