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The role of sensory science in the evaluation of food pairing

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The role of sensory science in the evaluation of food pairing

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Abstract (100 – 120 words)

Flavor pairing is the base of food product development. Moreover, foodstuffs are rarely consumed in an isolated manner, needing to study the sensory experience of food-beverage and food-food combinations. The field of flavor combination includes: the intrinsic arrangement of ingredients within a recipe; the combination of food products among them and with beverages; and the preparation of a whole meal. This review goes over the different definitions used to describe pairing and the sensory methods proposed in the literature.

Introduction

Cooking can be defined as the practice or skill of preparing food by combining, mixing, and heating ingredients (Oxford English Dictionary). In this way, pairing is the base of most food products, from homemade meals to those industrially developed. Moreover, foodstuffs are rarely consumed in an isolated manner, revealing the need to

study the sensory experience of food-beverage and food-food combinations. Therefore, the field of flavor combination includes: the intrinsic arrangement of ingredients within a recipe; the combination of food products among them and with beverages; and the preparation of a whole meal (e.g.: entrée, main dish, and dessert).

According to de Klepper [1] food pairing is the creative side of cooking. This is why it has been subject of many studies in the gastronomic sector, where chefs are constantly looking for rules to create original, yet successful recipes and menus. However, cooks do not test their meals with statistics or by means of a panel, as it is done in sensory science.

Sensory and consumer science includes a series of methods to evaluate perception and appreciation of foods and beverages (as well as non-edible products like cosmetics, fragrances, textiles). Whether working with qualitative or quantitative data, the experimental method and the use of appropriate statistical analysis are what differentiates it from a simple tasting. Also, information, training and cultural background are considered when preparing the experiment.

Given the vastity of the field, there are many questions to be answered: is there a rule for flavor pairing and for food-beverage combinations? Does this have a physiological base or is tradition more important? It is the aim of this review to go over the different methods used in the area of consumer and sensory science to evaluate the perception of food pairing. Papers in the field of sociology and anthropology were not included in the review.

The role of aroma: The Food Pairing Theory

The Food Pairing Theory was presented in 2002 by the Michelin-starred chef Heston Blumenthal together with the flavor expert François Benzi (working in Firmenich, Geneva). The hypothesis was quite straightforward: the more aromatic compounds two foods have in common, the better they taste together. It was based on the fact that flavor

is determined mostly by the volatile aromatic compounds rather than mouthfeel and taste [1]. According to this, regardless of basic taste (salty, sweet, bitter, sour or umami) a combination would be successful when volatiles are shared. For example, chocolate and blue cheese would be a good match because they share at least 73 flavor compounds [2]. Based on this, in 2007, the chef Martin Lersch started the blog "They Go Really Well Together" (https://blog.khymos.org/tgrwt/) where he periodically presented ingredients which could potentially be combined based on their chemical composition (e.g.: garlic, coffee and chocolate with 2-methylfuran-3-thiol in common). The readers (mainly food lovers and chefs) created recipes and uploaded them to the blog adding personal comments. These were the first "reviews" of the theory.

Computational gastronomy [3] allows the visualization of possible ingredient combinations based on volatile composition by means of flavor network graphs (see Figure 1A and Figure 2 of Ahn, Ahnert [2] or de Klepper [1] for examples of flavor networks). de Klepper [1] explains that in this graphical representation, every branch refers to a category of food e.g.: spices, herbs, nuts. The lengths of the lines between the original ingredient and the branches do not hold meaning, but the lengths of lines within the branches indicate the degree of aroma overlap: the longer the line, the fewer overlapping aromas.

Ahn et al [2] used the network-based approach to evaluate recipes from different types of traditional cuisine. They presented a bipartite network consisting of two different types of nodes: the ingredients used in recipes across the world (381), and the compounds that contribute to the flavor of each of these ingredients (1,021). In this way, they constructed flavor networks where two nodes (ingredients) were connected if they shared at least one flavor compound. One drawback of this study was that neither the concentration nor the detection threshold of the compounds were weighted. Also, they considered that all recipes were equally accepted by consumers: the sole presence of the ingredients in a formulation validated their combination (which is far from measuring consumers' acceptance). They studied 56,498 recipes from geographically distinct

cuisines: North America, Western Europe, Southern Europe, Latin American and East Asia. They found that shared compounds had a significant role in some cuisines, but not in all of them: North American and Western European dishes tended to combine ingredients that shared flavor compounds while East Asian cuisine avoided them.

Later, Jain et al. [4], evaluated regional cuisines of India finding similar results. Each one followed a negative food pairing pattern: the higher flavor sharing between two ingredients, the smaller their co-occurrence. Individual spices contributed to negative food pairing, while dairy products tended to positive food pairing. This did not help validating the theory because, even though shared flavors resulted in positive combinations, the opposite - ingredients which do not share volatiles - also gave successful results. Probably because an important factor was overlooked: cultural background. Tradition is usually a consequence of exposure to and availability of certain ingredients. The phrase "What grows together goes together," is a common idiom in the world of wine-food pairing, explaining that products that share terroir usually are consumed together, and this is done despite their chemical composition [5].

What was missing in the results presented so far was direct consumers' opinions on combinations with and without volatiles in common. Kort et al [6] asked a panel of 50 students to evaluate the taste of seven ingredients (pear, tomato, potato, chocolate, beef, cauliflower and anise) as such and combined in pairs of two (all combinations were tested in the form of a puree). The database 'Volatile Compounds in Food' [7] was used to evaluate the volatiles in common. When the score for the combined ingredients was higher than the average score for them separately, the combination was considered successful. Based on their results, they [6] suggested the rejection of the food pairing theory because the combinations with the highest proportion of volatiles in common were not the ones with the higher liking scores. As drawbacks of their experiment, authors stated that the way in which products were served (mixed cold purees) were not the same as how they were usually consumed and that their assumption of what would be a

successful combination could be debated. From a methodological point, using a simple combination of two ingredients rather than a whole recipe was an interesting approach to reduce variables. However, more applicable results could be obtained by studying products closer to their normal way of consumption.

In a more recent study, Eschevins et al [8] tested the impact of aromatic similarity in food-beverage pairs working with a group of consumers (n=53). Instead of using ingredients with volatile compounds in common, similarity was manipulated by aromatizing the drink and the food in the pair, controlling the concentration and level of perception of the similar/ dissimilar aroma. Two levels of aromatic similarity were contrasted; high aromatic similarity, when the same aroma was added vs. low aromatic similarity, when different aromas were used. The tested pairs consisted of beer combined with an amuse-bouche served in a transparent verrine. Consumers were first presented one beer and four verrines. They were instructed to imagine they were organizing a party where they would serve beer with an amuse-bouche, the beer was already chosen but they had to select the companion among four provided choices. This was intended to increase participants' involvement. They took a sip of beer, then tasted the four verrines presented in a random order and selected the one that best matched the beer. The same was done until obtaining a ranking of pairing choices (best to worst match). The task was repeated with the second beer. Weak to no preferential choice was observed for the verrine with aromatic similarity with the beer. The verrine-beer ranking was very similar to the verrines ranking tested alone, revealing that individual liking of the products was more important than aromatic similarity.

Stablishing a rule based on one variable, such as shared volatiles, could be tempting; however, the present evidence shows that ingredient and food-beverage interactions are more complex than that. And so are preferences. Tradition, taste, texture and individual liking of the ingredients are also important and need to be explored.

How to define a good combination? Some concepts around pairing

The terms match [9-11], ideal pair [12, 13], harmony [14] and balance [8, 15] are usually used to define what is a good combination. They refer to the fact that the flavor intensity of the components of the combination should be such that neither dominates perception. In some cases, this is achieved by complementary characteristics [13]. Several ways of measuring this can be found in the literature.

Harrington and Hammond [9] studied the level of perceived cheese and wine match. They described a nonmatch as an interaction where the wine and cheese created a negative impact on the senses when tasted together, and a synergistic match as a superior and ideal gastronomic effect. But, what is a negative impact or an ideal gastronomic effect? A negative impact could be something that causes dislike. Yet, they measured this with a trained panel and no hedonic rating. King and Cliff [12] studied the appropriateness of several wine and cheese combinations looking for an "ideal pair", where neither the wine nor the cheese dominated and the pair was better than products individually. Again, a panel of trained judges evaluated the pairs, and in this case using the "just right scale". This work had two red flags for working with a trained panel: the use of an hedonic term in the definition (better) and a scale which was designed to evaluate hedonic responses [16]. The average standard deviation found for each cheese across all wines was higher than expected for a trained descriptive panel, indicating that the judges were not in agreement. This confirmed that an ideal pair could not be measured in an objective manner with these tools. In fact, authors concluded that, although judges were experienced in food and wine pairing, their results as a group were not consistent.

Cerretani et al [14] studied the harmony between extra virgin olive oils and different foods (food-food pairing). They designed specific scorecards for the evaluation, tasting both products at the same time. Pairing attributes (fruity taste, pungency, bitterness, sweetness, greenness, ripeness and fruity smell) were rated from 0 to 10: a

5 corresponded to a perfect harmonic pair, lower values were given to pairings with olive oils that were too “light” compared to the food, and higher ratings were given when the olive oil was too intense. Authors proposed a “disharmonic index” calculated as the sum of the absolute distances (from 5) of the median panel values for the seven attributes, reaffirming that *harmony* is when the taste of one product is not more intense than another. The use of perceived intensities of different attributes was adequate for working with a trained panel, but the impact on liking remained unknown.

Paulsen et al [15] mention that complexity is a characteristic of a successful combination as the distinction of the mixture’s components. In their work they state that liking and complexity would be related by an inverted u-shaped function. An optimum level of perceived complexity leads to the highest appreciation level, if the perceived complexity is lower or higher than this optimum, the combination is less liked (see [17] for a review on complexity). However, it should be noted that complexity is a collative property that depends both on the complexity of the product(s) and the level of complexity acceptance of the perceiver [17, 18]. The way of measuring it can vary and it has not been thoroughly explored in food-food or food-beverage combinations. Medel et al [19] developed a questionnaire to investigate sensory complexity of wines where the following underlying dimensions were also taken into account: familiarity, homogeneity, harmony, balance, the number of perceived aromas, the ability to identify sensations and the strength and persistence of flavor perception.

All the above-mentioned concepts would be better explored with consumers than with trained panels, given their closeness (by definition) to subjective preferences. Bastian, Payne [20], Bastian, Collins [21], Donadini, Fumi [22], Koone, Harrington [23], Paulsen, Rognså [15], and Eschevins, Giboreau [8], among others, tried to establish what made up a good combination based on preferences. They all found interesting results for particular cases (cheese and wine, chocolate and beverages, beer and food), yet no general rules were determined. Due to the way variables increase when working

with combinations, large tasting populations are required and this is complicated to achieve under controlled circumstances. Rather than being discouraging, this enhances the need to work on the food pairing field with a consumer-oriented approach, to better understand what makes a good combination.

Tasting methodology in food-food and food-drink evaluation

The tasting experiments to evaluate the sensory effect of pairing between different products have been, originally, mostly focused on wine and food [9-11, 20, 21, 23-29]. Wine labels were the first to give menu suggestions, reflecting the interest of consumers around wine-food matches. The first experimental methods on sensory science were used to evaluate this famous pair, and then expanded to other alcoholic beverages such as beer [13, 30, 31] and food-food combinations [32, 33]. Some experiments can also be found on non-alcoholic food and drink combinations as cookies and juice [34] or chocolate and beverages [22].

Sequential Tasting consists on trying one product after the other to evaluate their mutual impact on perceived flavor. This was the first method, developed by Nygren et al who used it to evaluate chardonnay wine and Hollandaise sauce [24] and white wine and blue mold cheese [25, 27]. In Nygren et al. [25] a trained panel first assed the wine (rating several aroma and taste attributes), then tried a sample of cheese and afterwards evaluated a second sip of wine. Unfortunately, some of the habits of a professional wine tasting panel were kept to the detriment of the method. All samples (wines and cheeses) were expectorated instead of swallowed. Expectorating is used in wine tasting due to the alcohol content; however, it is well known that it changes the sensory experience, especially when assessing the impact of one product on the taste of another. Moreover, between wine and cheese intakes, panelists rinsed their mouth with water. This is a classic *good practice* in tasting, but it is not appropriate when assessing combinations because it does not allow the products to interact. The same authors afterwards

proposed the Mixed Tasting method [26]. In this case, the trained assessors had wine and cheese in their mouth at the same time and evaluated the perceived intensity of several attributes. The mixture of wine and cheese was also expectorated, this interfered with the tasting and was considered unpleasant by the panelists. Results showed that perception of wine attributes decreased more when using the Mixed Tasting technique but tasting and sipping in sequence was considered as a normal way of consuming wine and food. In conclusion, Sequential tasting was more appropriate for evaluating combinations.

The Sequential Method was then used by Madrigal-Galan and Heymann [35] to study the impact of cheese on red wine. Trained assessors performed the descriptive analysis of wines and wine-cheese combinations. Samples were also expectorated but they rinsed their palate only between combinations. In agreement with previous authors, it was found that cheese significantly decreased the perceived intensity of several wine attributes. Aaslyng and Frost were the first to use the Sequential Method for food-food interactions. In a first work they evaluated the effect of basic taste solutions and vegetable accompaniments on the sensory properties of pork [32]. In a second work they studied the effect of the combination of salty, bitter and sour accompaniment on the flavor and juiciness of pork patties [33]. The experiments demonstrated food–food sensory interactions between the meal components, but the effect was reduced in more complex meal combinations (more different vegetables, [33]) compared with a simpler set-up with only one vegetable [32]. The fried meat flavor, the piggy flavor, and, to some extent, the metallic and liver flavors were reduced, especially with a sour accompaniment.

All these research works helped advance the methods to study perception of product-product interactions: evaluations closer to real life consumption, but that still control the most variables to obtain repeatable results. They all worked with trained panels, considered as the best option for describing product perception. However, in recent years, sensory science has shifted towards consumer-oriented descriptive

methods [36], faster and more efficient. Also, new dynamic methods giving descriptive [37] and hedonic data have been developed [38], evaluating even complete portions [39].

Galmarini and collaborators used something similar to the Sequential Method to study the impact of wine on cheese [40] and vice-versa [41]. But, in both cases, they used a panel of consumers who described their perception and appreciation with the multidimensional and dynamic method, Temporal Dominance of Sensations (TDS). TDS consists in presenting to the assessors a list of descriptors from which they can choose the one they consider dominant (the most "striking" perception at a given time, not necessarily the most intense) at every moment of consumption [42]. A succession of the most important sensations is obtained, without attribute quantification.

In a first experiment [40], consumers described by TDS three consecutive sips of wine, ingesting a bite of cheese between sips. Also, after doing the dynamic description, consumers rated their liking. Description and liking scores were obtained for the wine alone (first sip) and for the same wine after cheese intake (sips two and three). All samples were ingested controlling alcohol consumption per session. Cheese intake in-between sips changed the dynamic characterization of wines and the opposite (wine effect on cheese) was also found in a second study [43]. However, the liking of cheese was not affected by wine while the liking of wine was affected by cheese. This impact on preference was never negative: none of the cheeses decreased the liking of wine.

In a later work, Galmarini and collaborators [44] presented another method, evaluating the combination as a whole, as if it was one only product, using TDS and simultaneous liking [45]. Consumers were presented a complete portion of wine and cheese, which they ate in a free manner indicating the dominant sensation at each moment of the tasting and giving their level of liking all along the evaluation. Consumers could mix the products in their mouth as it is normally done while eating. According to Tuorila et al. [34], who tested the pleasantness of eating cookies with juice, interactions occur more strongly if the products are physically combined. The protocol proposed by Galmarini et al. [44] gave consumers the possibility to eat a complete portion in a

somewhat traditional manner. Also, hedonic responses allowed to obtain positive and negative temporal drivers of liking (TDL) (see Thomas et al [46] for a deeper interpretation on the subject). It was found that perception of a combination of products is not the result of an additive or subtracting effect which can be predicted based on their individual perception: they are complex associations. This is one of the reasons why establishing a rule of thumb is still difficult and sometimes even contradictory.

Moreover, it is known that factors such as age, gender, familiarity and other demographic variables, are important when explaining preference and should also be taken into consideration in food paring evaluation and conceptual understanding. Even though these variables have been widely explored in preference, there is still little work involving them in food association since we are still developing methods to better evaluate the sum and pairing of variables. Therefore, before giving a further step in the complexity of the analysis (e.g. evaluating food pairing by gender, etc) we need to have a methodology which could be repeatable and standardized, as we already have in sensory analysis when evaluating one product at a time.

The challenge of sample selection

According to Tuorila [34], when studying combinations, samples portray some of the problems that are faced when moving from solutions of taste substances towards ”real foods”. The difficulty of choosing samples and combinations that would allow at least some generalization; and the fact that real foods are complex entities with many sensory attributes that interact still needs to be tackled.

Nestrud et al [47] (see also [48] for complementary information) explored the field of graph theory as an alternative approach to reduce the number of possible combinations. Consumers (n=105) were asked to provide appropriateness [49] responses for pairwise combinations of 25 salad ingredients. This compatibility was analyzed with graph theory techniques to build larger combinations. This allowed reducing a vast number of combinations of food items, which could then be evaluated by

consumer scientists. One limitation was that items were tested at the conceptual level. This is what allows to test so many combinations, but obviously does not state that any version of a successful combination would be so in the marketplace [48].

Cross-cultural studies in food paring

Tradition is also a key component in food pairing. And, even though cross-cultural studies make up for a big chapter in sensory science, few papers can be found regarding food and flavor pairing.

Kim et al [50] evaluated cross-cultural acceptance levels and drivers of (dis)liking of hot sauces applied to five food items (pizza, cream soup**,** grilled chicken wings, rice noodle soup) in South Korea, the US, and Denmark. They also identified well-paired food items in each country allowing consumers to use the different sauces in home use test environment. The large number of consumers and the fact that the tasting was done in in-home conditions are highlights of this work. Authors found that consumer's perception showed that culinary exposure, usage and reasons for liking the sauces and the combinations varied widely among different cultures. Traditional cuisine, and familiarity were important factors for Koreans for liking a hot and spicy flavor, while social interactions, eating out, and ethnic food trends were important for Danish and US consumers. Particular sauces showed better pairings with specific food items (e.g. rice noodle with Sriracha sauce for Koreans), and these pairings were culture-dependent. Authors found that the matching between sauces and food items depended on the flavor characteristics, but was also affected by the cultural context.

Using a completely different methodology, Arellano et al [51] studied flavor pairing of beer using social media to extract data in four different countries (Argentina, Colombia, Peru and Mexico). According to the authors, the main advantage of social media is that it provides instant access to a vast amount of information in a specific time and avoids the bias or limitation of asking people questions. They used the co-occurrence of paired flavors in social media to build a similarity matrix that was analyzed using

multidimensional scaling (MDS) in order to find a pattern of pairing per country. They obtained a map which could help understand the cultural differences in flavor paring per country. However, it should be noted that this is closer to a word association technique [52] and results should be carefully interpreted. For example, it was found that beer and wine had a high co-occurrence. But this probably does not mean that wine and beer go well together, but that people associate these two alcoholic drinks.

Conclusions

There are different reasons that lead to ingredient and food combinations. Even though it could be tempting to try to reduce this to chemical composition, it has been shown that volatile compatibility is not the only answer when it comes to good pairing.

In the literature, several terms are used to describe what makes up a good pair (harmony, balance, ideal). However, it is important to escape tautologies when defining a good combination and use appropriate terminology: hedonic terms should not be included when working with trained panels.

The use of trained judges should not be discarded, since they could give an important descriptive insight to understand changes in perception; however, consumers determine acceptance. Therefore, the use of more consumer-oriented methods is important. This includes panels of consumers giving hedonic and/or descriptive responses, and tasting methodology which reenacts traditional ways of consumption. This is the big challenge of sensory tasting, especially when it comes to food-food or food-beverage combinations: evaluating the products in the more natural possible way, while controlling the most variables to obtain reproducible and representative data. Dynamic methods are an interesting way to approach consumption. Sample selection is also a key step which could be based on surveys and mathematical methods or traditional cuisines.

Cultural background, tradition and eating habits are also important pieces of the puzzle which should be taken into consideration. Sociology and anthropology are good partners of the sensory science which could complement the methods used. Understanding our eating behaviors, and particularly flavor pairing, requires a multidisciplinary approach.

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Buenos Aires, 7th February 2020

Editorial office Current Opinions in Food Science

Dear Editor;

I am here enclosing the manuscript entitled: *"The role of sensory science in the evaluation of food pairing",* to which I am the only author. As such, I declare to have no conflicts of interest.

Best regards,

Mara V. Galmarini, PhD

Response to reviewers

Answers are addressed below each comment. In addition to the revisions resulting from these comments, after re-reading the manuscript several other minor changes have been made. All of them are highlighted in yellow in the revised version.

Reviewer 1: This work aims to compile different sensory approaches used to study food pairing. The manuscript is well written, concise, and easy to read, so I only have few comments.

1. On page 2, the author questioned if tradition or cultural background are more important than physiological aspects when evaluating food pairing. In order to increase the scientific contribution, the author could deepen in the cultural aspect and how it influences the food pairing.

*A new section entitled "**Cross-cultural studies in food paring**" has been added in the revised manuscript. Moreover, a comment on the importance of culture was added in the section: **"The role of aroma: The Food Pairing Theory"***

2. Several researches that are described in the draft used both panel and consumers with different ages (e.g.,students) and gender characteristics. It has been reported that the perception of some flavors or basic tastes is lost (or diminish) with ageing. How could this impact the results of "ideal pairings" or the concept of balance?. Age or even socioeconomic status could have an impact on the results of the pairings?. What could the author discuss?

The reviewer has an interesting point. The main issue with this is that even though these variables have been widely explored in preference, there is still little work involving them in food association since methods to better evaluate the sum and pairing of variables are still being developed. Therefore, before giving a further step in the complexity of the analysis (e.g. evaluating food pairing by gender, etc) we need to have a methodology which could be repeatable and standardized, as we already have in sensory analysis when evaluating one product at a time. This has been added in the revised version.

3. On page 9, the author describes Aaslyng and Frost's research using the sequential method for food-food interactions; however, their results section is not clear. It could be rewritten.
The mentioned section has been rewritten in the revised version.

Credit Author Statement

As the sole author of this review I, Mara Galmarini, am responsible for conceptualization, original writing, research, review and editing.