A FOOD AND BEVERAGE MAP: EXPLORING FOOD-BEVERAGE PAIRING THROUGH PROJECTIVE MAPPING

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1. Introduction

1.1 Food pairing

Food pairing has been a popular topic amongst scientists, chefs, and researchers who try to find new successful food combinations and identify a pattern in how consumers pair food (Ahn et al., 2011). When studying food pairing, the “food pairing hypothesis” arises, which states that two ingredients that share chemical compounds are more likely to taste (and smell) good together (Simas et al., 2017; Kort et al., 2010; Tallab & Alrazgan, 2016). From a gastronomic approach, flavor pairing could be defined as flavors that, if paired, will produce an experience that is more appreciated than either of the two flavors alone (Møller, 2013). However, not all the flavor combinations are accepted worldwide, as they also heavily rely on culture (Arellano-Covarrubias et al., 2019).

Ahnert (2013) and Simas et al. (2017) studied the influence of culture and found that the rules that followed the food pairing are different between cultures. For example, Ahn et al. (2011) found that, in general, both Western and European Cuisine use ingredients that share similar flavor compounds, while East Asian Cuisine does the opposite. Following this last statement, Jain et al. (2015) found that different regional Indian Cuisines followed “negative” food pairing patterns: meaning that the higher the flavor sharing between two ingredients of Indian recipes, the lower the co-occurrence in that cuisine.

Besides the influence of culture in food pairing, other authors like Shepherd (2006) stated that the perception of flavor involves many sensory and motor systems. For instance, integral components of our eating experiences arise from all sub modalities of the somatosensory system: fine touch, creaminess, deep pressure (such as crunchiness), temperature, and pain (in the case of the burning sensation of chilis). In other words, an additional layer of olfactive or aromatic coincidence should be added to the act of pairing two or more food products. In this way, Eschevins et al. (2019) reported some pairing principles obtained from French sommeliers and beer experts that could be categorized in “conceptual” (geographical identity and context of consumption), “affective” (consumers’ preferences and emotions), and “perceptual” (aroma, taste, texture); so, when venturing into food pairing research, several aspects should be considered.

Traditionally, food pairing research has widely focused on studies with wine and foods, such as cheese (Galmarini, 2020; Harrington & Seo, 2015; King & Cliff, 2005;). Some research studied how certain attributes of wine were affected by different food pairings. To take an example, hollandaise sauce (Nygren et al., 2001) and blue mold cheese (Nygren et al. 2002) were found to affect the perception of wine attributes such as a decrease in sour, bitter and toasted flavors, and an increase in butter flavor, in the case of hollandaise sauce research (Nygren et al., 2001); while buttery and woolly flavors and saltiness and sour taste decreased after tasting dry white wine (Nygren et al., 2002). With similar results, Madrigal-Galan and Heymann (2006) evaluated the effect of cheese before wine consumption and found that some wine attributes such as astringency, bell pepper, and oak flavor significantly decreased when red wine was evaluated after tasting the cheese. Therefore, the consumption of certain foods has been shown to impact the perception of the beverage, and vice versa; consuming a certain beverage is able to modify the perception of certain foods.

In a recent study, Kustos et al. (2020) found that appropriate food and wine pairings are positively correlated to liking, sensory complexity, and expected price to pay, and negatively with balance as a slight wine dominance was preferred. Bastian et al. (2010) evaluated wine and cheese matches where consumers rated whether the wine dominated the pair, or the cheese, or if the combination was an “ideal match”. Authors found that wine domination of the cheese does not appear to drive the preference for wine and cheese pairs; it revealed that match perceptions were related to the overall liking for the wine alone. In this line, other studies (Donadini et al., 2012) explored the combination of several beverages with chocolate and found that the liking of a chocolate and beverage pair depended more on the liking for the beverage than for the chocolate or the level of the match of the two.

The evaluation of ideal food and beer pairings has also attracted researchers’ attention (Donadini et al. 2013). Donadini et al. (2008) found that the suitability of a food-beer pair was positively correlated to the liking of the beer. In a similar study on craft beer and soup pairings, Paulsen et al. (2015) found that there is a significant effect of the beer type tasted and liking, as well as the dominance of either one of the components can reduce liking and perceived harmony, while the dominance of soup reduced the complexity of the pairing.

Regarding the food chemical interactions, some research has focused on different food pairings such as banana with basmati rice, bacon, and extra virgin olive oil (Traynor et al., 2013). The authors suggested that synergistic and/or antagonistic interactions between the volatile compounds in the evaluated foods influenced the ratings of the food pairings. Therefore, the hypothesis of successful food pairings based on the common shared volatiles was not verified. Contrarily King and Cliff (2005), found that, in general, stronger flavorful cheese is more likely to be a good match with a flavorful wine than milder flavorful cheeses. In the same way, Cichelli et al. (2020) studied the aromatic similarity as a congruency of the same flavor. The authors suggested a flavor congruency to enhance the oil-pairing harmony between olive oil with Italian vegetables, where harmony was maximized for olive oil with green and bitter flavor paired with very bitter or pungent vegetables. These last statements followed, to some degree, the food pairing hypothesis: “The more aromatic compounds two foods have in common, the better they taste together,” which according to Klepper (2011), is particularly strong when two foods share aromas that make up their characteristic flavor.

However, restricting the food pairing to only the chemical similarity hypothesis would not necessarily lead to a successful food pairing, since all food combinations could have cultural, traditional, and physiological factors (Madrigal-Galan & Heymann, 2006), which makes the pairing more complicated than simply pairing foods that share common key compounds (Traynor et al., 2013). In addition, some of the reported findings are mainly based on professionals’ perspectives and may not reflect how consumers feel (Madrigal-Galan & Heymann, 2006).

Some limitations of the study of “ideal pairings” in rather analytical studies have been the use of scales to indicate an ideal match where neither the food nor the wine dominates (King & Cliff, 2005; Bastian et al., 2010; Donadini et al., 2008; Donadini et al., 2013). Another limitation is that only a few products have been tested in the food pairing research and in western countries. A whole set of products and different cultures need to be explored to increase our understanding of ideal food-beverage pairings. In general, food pairing research opens a window of opportunity to apply different methodologies and approaches in the sensory and consumer research field due to the need to study the whole experience of food-beverage and food-food combinations (Galmarini, 2020).

1.2 Evaluation of food pairing

Since the study of food pairing became popular in consumer research, different methodologies have been applied to find successful food and beverage pairings as well as to understand the dynamics that explain why consumers pair certain foods with others. Regarding the hedonic side of food pairing, Donadini et al. (2013) explored the consumers' hedonic responses to cheese and beer pairings by using a natural environment of consumption. Consumers evaluate each cheese-beer pairing using a 9-point hedonic scale; additionally, a Just About Right scale was used to evaluate each pair for which flavor lingered the most (cheese or beer flavor). Likewise, Bastian et al. (2010) evaluated pairings of wine and cheese in a consumer test in a sensory lab. A Just About Right scale was used to test the “ideal match” of wine and cheese, and the liking of the pairing was rated on a 15 cm hedonic line scale. Harrington and Seo (2015) utilized a Likert-type 9-point scale to evaluate hedonic consumer' responses perceived from wine, food (dark chocolate and goat's cheese), and wine and food pairings.

A purely computational approach was taken by Ahn et al. (2011), who explored the impact of flavor compounds on combinations of ingredients by introducing a network-based approach. A bipartite network was built, which consists of two different types of nodes: ingredients used in recipes throughout the world and the flavor compounds that contribute to the flavor of each ingredient, where the natural occurrence of a compound in an ingredient was represented by a link (Ahnert, 2013). The bipartite network projection into the ingredients space represented the flavor network in which two nodes (ingredients) are connected if they share at least one flavor compound. In their study, Ahn et al. (2011) found that North American and Western European Cuisines exhibit a tendency towards recipes whose ingredients share flavor compounds, so in general, these cuisines confirmed the food pairing hypothesis in contrast to East Asian and Southern European cuisines.

Eschevins et al. (2018) tested the effect of the aromatic similarity on liking, harmony, homogeneity, complexity, and balance of food-beverage combinations by pairing a lemon soft drink with four dairy products prepared from “Fromage Blanc” (a kind of unsalted cottage cheese), aromatized with lemon, citrus + lemon, vanilla, and strawberry + lemon. In a second experiment, two beers were flavored with lemon and smoky aroma, and savory verrines were aromatized with the same aromas as those used for the beers. For each experiment, consumers tested the pairings using rating scales to evaluate liking, harmony, homogeneity, complexity, balance, and familiarity of pairings. In general, they found that pairings high in aromatic similarity showed increased ratings of harmony and homogeneity, and decreased complexity. Additionally, according to the food pairing hypothesis, the product pair with high aromatic similarity was preferred significantly over the pair the pair with low aromatic similarity.

With a different approach, Galmarini et al. (2017) evaluated the impact of wine on the perception of cheese, where the cheeses were dynamically characterized (with and without wine consumption) by using temporal dominance of sensations (TDS) coupled with a hedonic rating on a continuous scale. The researchers concluded that the wine had no impact on the liking for cheese, while the liking of wine was affected by cheese.

The reviewed literature only shows a brief compilation of the various methodologies and approaches that have been used in the research of food pairing where, except for the computational methodologies, only a few beverages and food items have been tested at once. The need for a methodology that could be repeated and standardized in the food pairing field (Galmarini, 2020) and the use of more consumer-oriented methods raise the interest in implementing new techniques that could lead to a better understanding of how consumers pair specific types of food and beverages.

1.3 Projective mapping

In the present research, projective mapping is presented as a tool for creating maps to better understand preferred food and beverage pairing amongst consumers. Projective mapping is a descriptive method that has been widely used in the sensory field as a method for fast profiling and measurement of consumers' perception (Berget et al., 2019), which provides a map that best reflects the perceived similarity of the evaluated products (Valentin et al., 2016).

The primary purpose of projective mapping is to obtain global similarity measurements between products from participants that, in general, are not trained assessors (Valentin et al., 2016). One of the main advantages of this methodology is the avoidance of panelist selection and training, which could impact the cost and time involved in maintaining well-trained panels; likewise, its relative ease of use compared with traditional descriptive models, such as quantitative descriptive analysis (QDA) (Savidan & Morris, 2015), has attracted researchers' attention. Moreover, the undirected nature of projective mapping as a projection technique, and the flexibility of the method, makes it suitable for diverse applications such as preference hedonic frame (Varela et al., 2017; Kim et al., 2019) or to study more complex sensory attributes, for example, the minerality of wines (Heymann et al., 2014).

Results from projective mapping can be analyzed with Principal Component Analysis (PCA) or Generalized Procrustes Analysis (GPA) (Gower, 1975; Tomic et al., 2015); additionally, Multiple Factor Analysis (MFA) (Brown et al., 2020) is also suitable because it considers the differences between assessors (Valentin et al., 2016). In the case of analyzing projective mapping with GPA, only two components can be extracted from the data (Tomic et al., 2015), while MFA results could provide more components (Berget et al., 2019).

According to Tomic et al. (2015), MFA and GPA typically find quite similar structures. Nestrud and Lawless (2008) previously reported that results from GPA and MFA were also very similar when the methods were applied to data from a single experiment of 13 citrus juices evaluated by experienced chefs and untrained consumers. In addition, GPA reduces individual differences between consumers' data by the processes of translation, rotation, reflection, and scaling of the configurations, and consequently, it preserves relative distances between the products in each configuration (Tomic et al., 2015). In this research, the distance and the variability of the consumers' food pairing data is essentially different; thus, adjusting and preserving the space are needed to find a consensus across all individuals. Therefore, in the case of food and beverage pairing, GPA seems to be statistically more suitable for analyzing consumers' information from projective mapping.

Traditionally, for projective mapping, the participants are asked to position products on a sheet of paper in such a way that the positions of the products reflect the products' similarity structure (Valentin, 2016). In this research, projective mapping was adapted, to where the positions of the products reflect food and beverage pairings according to consumer preferences: the shortest distance between two products represents a suitable food and beverage pairing. In contrast, the largest distance between two products represents a non-suitable food and beverage pairing.

In general, projective mapping has been used for assessing several food products. However, as Galmarini (2020) stated, food products are not usually consumed in an isolated manner; additionally, the author reported that the ingredient and food-beverage interactions are more complex than the study of shared volatiles alone, as food pairing theory states. These statements make it necessary to explore not only the aromatic compounds of food pairing but also the perception and preferences of food-food and food-beverage pairings. On these bases, the present research aims to explore young Mexican consumers' food and beverage pairing by using projective mapping as a consumer-oriented method to create maps that represent successful pairings.

2. Materials & methods

2.1 Food and beverages selection

According to a previous study (Arellano et al., 2019), beer was the most commonly explored alcoholic beverage due to it being the most consumed alcoholic beverage by Mexicans (Euromonitor International, 2014). However, since other beverages, such as wine and tequila, are also frequently consumed according to the above referenced sources, it was decided to explore not only beer but the most frequently consumed beverages among young Mexican consumers and their respective pairings from a set of frequently consumed food products.

The foods and beverages were selected from the information published in Arellano et al. (2019): several phrases, tweets, Instagram and Facebook posts and publications of consumers, related to both beer and food, were extracted from social media and mainstream (Corporate channels or Internet sites. e.g., general news, magazines, newspapers) data, for a one-year period, regardless of the time of day or the place the posts were published. Due to the nature of the extraction process and the privacy policies of some social media platforms, the gender and age of the users could not be registered exactly. From this study, sixty-four foods with a high frequency of being paired with beer were extracted. Analogously, from the information from Instagram and Twitter, thirty-six foods that were popular among young Mexican users were also extracted. From the information, the most frequently paired foods in social media data were selected (Supplementary material 1).

A final list of thirty foods (Table 1) and six beverages were selected: soda, white and red wine, tequila, and blond and dark beer, due to the high popularity observed in the previous research, and growing (wine) or high (soda) consumption by Mexican consumers.

Table 1

30 foods used in the projective mapping task that were extracted from social media data (Adapted from Arellano et al., 2019)

Avocado	Shrimp	Spices	Butter	Bread	Pineapple
Oats	Red meat	Hibiscus	Mango	Potato	Pizza
Salty snacks	Onion	Ginger	Apple	Cucumber	Chicken
Peanuts	Chili	Tomato	Berries	Fish	Cheese
Coffee	Chocolate	Lime	Orange	Pepper	Tortillas

2.2 Participant’s selection

One hundred Mexican participants were recruited from a Mexican University to perform this exploratory study. The recruitment process was carried out through advertisements, email messages, and personal communication. The inclusion criteria were to be above 18 years of age, and a regular alcoholic beverage consumer (at least once a month); however, consumer habits were not recorded. The gender and age of the participants were registered. Due to the recruitment process, the most expected age segment was 18-25 years old; therefore, the subsequent age categories were defined for intervals of 10 years.

2.3 Projective mapping

Several paper cards were designed for each food and beverage (Supplementary material 2) to guarantee that consumers evaluate all food and beverage items in the same way, as if they were testing real products (as usually done in face-to-face research). In addition, the use of images along with the product's name allowed the consumers' perception of the general sensory profile of foods and beverages to be investigated, and not only a specific flavor; furthermore, this approach allowed the test to be applied on different days without having variances in the food and beverages preparation. The use of images for research has been previously used for sorting tests with children (Varela & Salvador, 2014); also, Mielby et al. (2014) compared projective mapping and sorting to a generic descriptive analysis, using visually different pictures of fruit and vegetable mixes. In general, the use of visual stimuli instead of actual food products can minimize the time for sample preparation and the cost of the experiments (Mielby et al., 2014); in addition, in consumer studies, this approach has been increasing in recent years (Kildegaard et al., 2011; Mielby et al., 2012; Arce-Lopera et al., 2015, Varela & Salvador, 2014). In this research, images were used by designing several paper cards (3x4 cm) containing an image of the food/beverage and their respective names (Fig. 1).

Figure 1. Food and beverages paper cards design used in the projective mapping, examples of red wine and berries.

The projective mapping was performed in a single session. Each participant was asked to first place the beverages on a sheet of paper (60x40cm) (Valentin et al., 2016). The cards' positions reflected similarities or differences between the beverages, so that the closer the beverages were positioned to each other, the greater their similarity. Second, consumers were asked to position each food card on the same sheet of paper so that the cards' positions reflected better combinations between foods and beverages, while the closer a food was to a beverage or another food, the better the food-beverage or food-food pairing, according to their preferences. If some product seemed not to combine well with any food/beverage, the participants were asked to position it further from all the products. Participants could change the positions of the beverage and food cards as often as they needed.

To avoid errors in the measurements of the positions of the products on the sheet of paper, the participants were instructed to replicate the food and beverage maps on a computer screen, which was programmed in a similar way, and with similar measurements to those on the sheet of paper, by using the Fizz software® (Mielby et al., 2014). Any further change in the positions of the products on the computer screen was allowed in order to create a map of preferred food and beverage pairings. The duration of the task was about ten minutes. Fizz software® (version 2.51 c 02) was used to convert the positions into coordinates, guaranteeing the unit measurements' homogeneity in the dimensions. Finally, the X and Y coordinates of each product for each participant were recorded.

2.4 Data analysis

The demographic information of the consumers, such as gender and age, were determined after the recruitment. Regarding the food and beverage pairing information, all food/beverage coordinates for each product and for each consumer were extracted from Fizz® and submitted to Generalized Procrustes Analysis (GPA). A permutation test for GPA (10000 permutations; significance 5%) was performed to test that the consensus map was above chance (Wakeling et al., 1992); and for the consensus coordinates, an Agglomerative Hierarchical Clustering (AHC) was performed (Euclidian distance; Ward's criterion) to find all food items that could be combined with each beverage. The variance within and inter clusters was calculated from 2 to 10 clusters to understand the differences across clusters, and better define the final number of clusters. Finally, to test the gender effect, a GPA for each gender was performed and RV coefficient was calculated between female and male GPA' coordinates, as has been previously done for projective mapping data (Tomic et al., 2015; Orden et al., 2021; Vidal et al., 2014b). All statistical analyses were performed using XLSTAT software version 2012.5.02 (Addinsoft, 2019).

3. Results

Results from the participants' characteristics are shown in Table 2, the percentage of gender and age was calculated with the total sample of 100 participants. The study's goal was to achieve approximate balance in gender, resulting in 58% of women and 42% men. Regarding the participants' age, more participants from 18 to 25 years old responded to the test. Because individual differences were beyond the scope of this study and due to the unbalanced age segments of consumers, no further analysis was performed on the age segments.

Table 2

Participant’s demographic characteristics (N 100).

	Gender (Biological sex)	**Age** (years)				
	Percentage (%)	18-25	26-35	36-45	46-55	Unknown
Women	58	42	13	0	0	3
Men	42	30	7	3	1	1
Total	100	72	20	3	1	4

3.1 Food-beverage pairing from projective mapping

Figure 2 shows a product map from one consumer, where the proximity between beverages and foods represents the food and beverage pairings.

Figure 2. Food and beverage map from projective mapping with images. Names of the products are shown in the original language (Spanish) of the test.

The food and beverage pairing data from projective mapping were analyzed with Generalized Procrustes Analysis (GPA). To explore the effect of gender, a GPA for each gender was performed and RV coefficient between female and male coordinates was calculated. The RV coefficient in the area of projective mapping has been the standard method when comparing matrices (Robert & Escoufier, 1976), and it has been used frequently for comparing data sets and consensus solutions (Tomic et al., 2015). The results of RV coefficients range from 0 to 1, with values closer to 1 indicating a greater degree of similarity between two configurations. Results of RV coefficient between women and men (0.694; *p-value<0.001*) was relatively high, showing that both women's and men's coordinates were similar, and consequently, that their representation of the food and beverage pairings were comparable. Therefore, the interpretation will be focused only on the overall consensus GPA solution.

A PANOVA table (Supplementary material 3) was computed to evaluate the contribution of each Procrustes transformation to the reduction of the total variance in the GPA consensus. Results showed that a reduction of the variance was obtained from the three transformations, so in general, the individual differences between consumers were successfully reduced. Rotation (10.9, *p-value<0.0001)* followed by translation (8.9, *p-value<0.0001)* had the greatest effect on reducing variance, while scaling (1.8, *p-value<0.0001)* had the lowest effect. According to Tomic et al. (2015), the differences in how consumers place the products could be due to two aspects. The first one depends on the differences in the perception of the products, while the second relies on the different ways of using the directions of the mapping sheet and is not related to the differences between products. In this sense, results of PANOVA showed that a large variance reduction of the non-sensory related individual differences was obtained through the Procrustes transformation.

A permutation test for GPA was performed to test whether the consensus map was real or a product of chance. The Rc statistic obtained from the permutation test represented the total variance explained by the consensus after the Procrustes transformations, with high Rc values indicating true consensus across individuals. The results showed an Rc statistic (0.153) greater than any of the Rc values from the 10

000 permutations (Mean Rc value: 0.065; Maximum Rc value: 0.07) and therefore, that the consensus configuration was not achieved by chance (100% percentile; level of significance of 5%) and the reduction of variance by Procrustes transformations was significant.

To understand the differences across clusters, the variance within and inter clusters was calculated from two to ten clusters. The results from the evolution of the clusters are shown in Table 3, as a function of the variance within-classes and inter-classes. As can be seen, from two to four clusters the decrease of the within variance is greater than those found from five to ten clusters, analogously, the inter-class variance increased more from two to four clusters than from five to ten clusters. Therefore, both variances show that 4 clusters are enough to consider as a cutting point in the AHC.

Table 3

Evolution of the within-classes and inter-classes variances. Values shown are percentages.

Number of clusters	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Within-class variance	55.5	38.5	27.2	20.1	16.2	12.6	11.5	10.5	9.0
Inter-class variance	44.5	61.5	72.8	79.9	83.8	87.4	88.5	89.5	91.0
Total	100	100	100	100	100	100	100	100	100

In general, projective mapping analyzed with GPA followed by AHC provided a suitable and easy interpretation of the food-beverage pairing from Mexican users. According to the consensus of the participants' preferences (consensus GPA map), the shortest distance between two products represents a better food and beverage pairing. To obtain data about which foods pair well with each beverage, an AHC was applied to the GPA consensus coordinates. The results clustered all food and beverages into four groups. The main finding is that each beverage could be clustered in an independent group along with different foods that people combined. The first group clustered both beers together, the second one grouped both wines, the third cluster contained Tequila and the last one contained soda. Figure 3 represents the clusters obtained, where each group included all the foods that paired well with each beverage, according to consumer preferences.

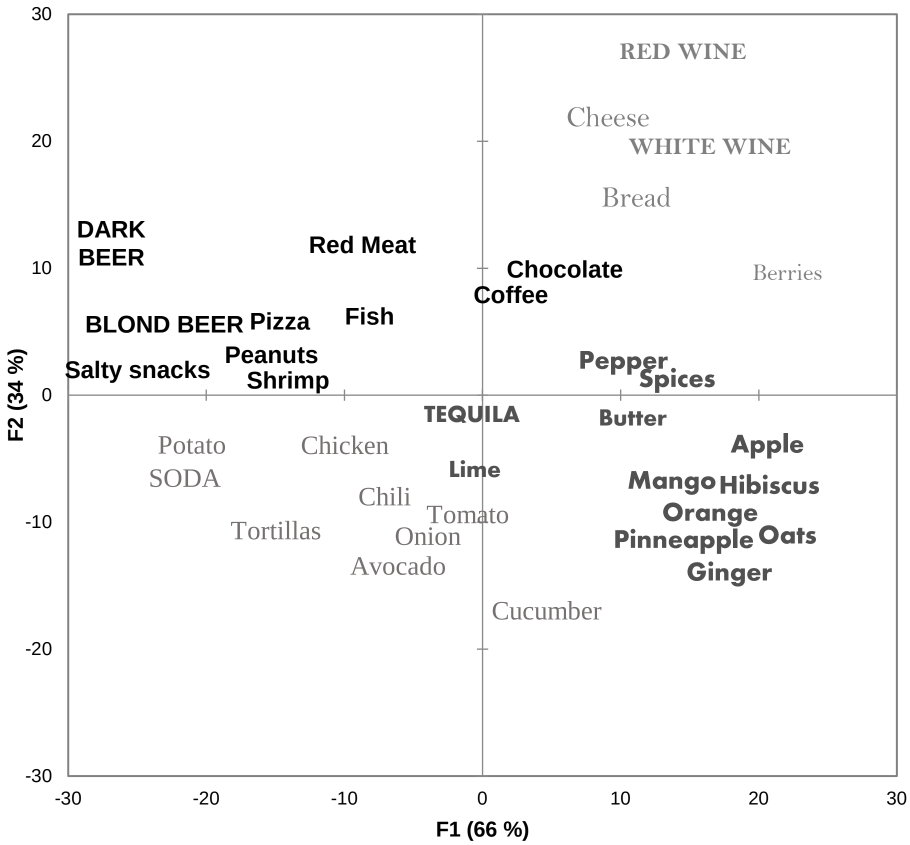

Figure 3. Food-beverage pairing map for AHC of GPA. The hierarchical clustering is represented by similar gray color and font. AHC shows that beverages, and their respective food pairings, could be clustered into 4 groups.

Concerning the beverages, some of the map patterns were that dark and blond beer were clustered in the same group, along with some products such as salty snacks, pizza, peanuts, shrimp, red meat, and fish. In the case of wine, both red and white were clustered only along with cheese, bread, and berries; regarding Tequila, it was clustered with lime, which Mexican people usually combine with this beverage, also, butter, spices, pepper, and several fruits were grouped together. Soda was grouped with chicken, chili, potato, some vegetables, and tortillas, a popular product that Mexican people combine with their regular meals.

From the dendrogram obtained from AHC, additional information could be extracted. For instance, for each cluster, the food items closer to the beverages represented a better pairing than the food items further from the beverages. Figure 4 shows the dendrogram obtained from the AHC.

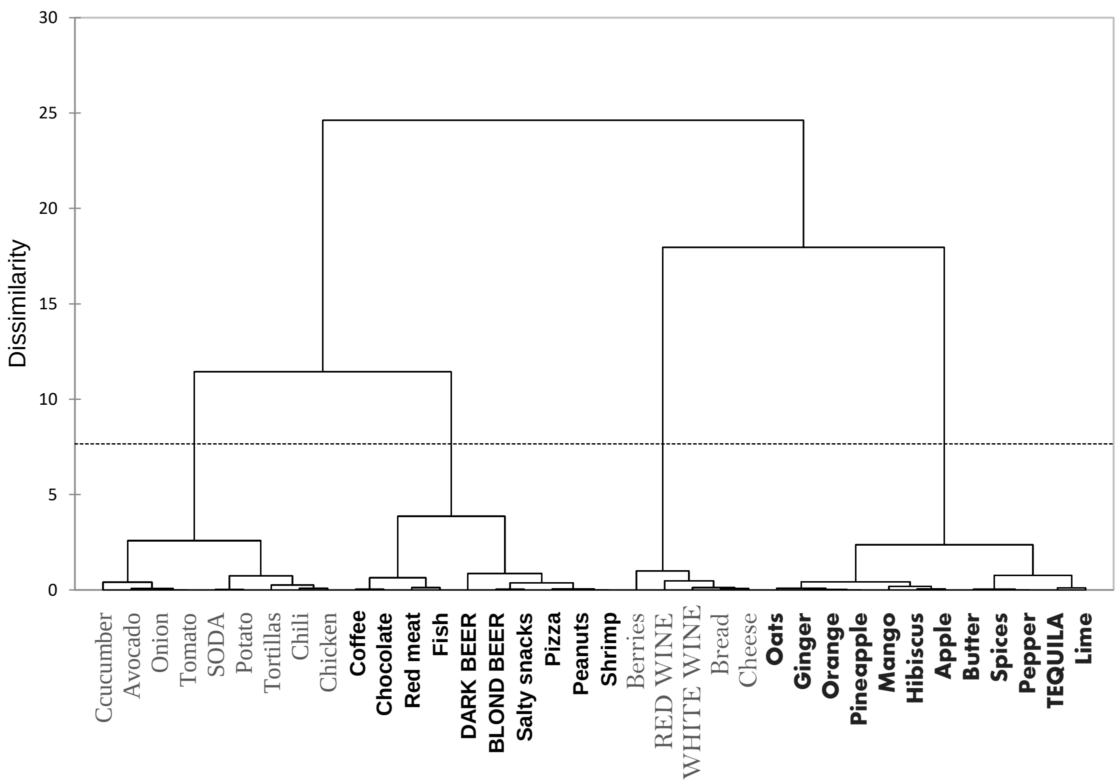

Figure 4. Dendrogram from AHC of the GPA. The hierarchical clustering is represented by similar gray color and font.

Some of the most consensual pairings could be identified from Figure 4. Potato, tortillas, chili, and chicken were closer to soda than cucumber, avocado or onion, representing a better food and beverage pairing in the cluster. In the case of beers, both dark and blond were closer to salty snacks, pizza, peanuts, and shrimp than fish and red meat. Regarding wine, both red and white were close to bread and cheese. Finally, Tequila was close to lime, and further from pepper and spices, which represented a better food and beverage pairing according to the consensus of consumer preferences.

4. Discussion

The present study aimed to explore Mexican consumers' food and beverage pairing using projective mapping as an innovative technique, analyzed by Generalized Procrustes Analysis (GPA). The analysis of projective mapping provided maps in which the proximity between products represents suitable food and beverage pairing according to the consumers' preferences.

The results from the PANOVA of the GPA showed that, in general, the individual differences between consumers were successfully reduced, and therefore, only the perception of the food and beverage products was assessed and not the individual differences across configurations. In other words, the reduction of the variance was lower when shrinking or stretching the individual map configurations until they were as similar as possible (scaling) to each other. On the other hand, when the configurations were rotated/reflected to agree with another map (rotation) or were moved to the middle of the mapping sheet (translation) (Tomic, et al., 2015), a higher reduction of the variance was obtained. These results suggest that consumers used different ways to position the products in terms of distances to represent the similarities and dissimilarities across the products and their pairings. This difference on the use of the distances across participants is better analyzed with the GPA, compared to other methods such as MFA (Berget et al., 2019).

The result of the Rc statistic from the permutation test was 0.153, showing that the consensus was highly significant at 5% level. Tomic et al. (2015), in their research comparing simulated and real data sets from mapping experiments, reported that relatively high values (of 0.5 and 0.7) of R_c are obtained when the assessed products are "simpler," such as apple juices, while low values are reported for more complex products, such as coffee or wine. In the research published by Tomic et al. (2015), only one type of product was evaluated in each study, in contrast with this research, in which several complex products (wine, coffee, beer, and food items) were tested at once, which could have impacted the results of the R_c value.

In order to find which foods paired well with each beverage, an AHC was performed to the GPA consensus coordinates. As shown in Table 3, the inter-class variance had a higher increase until 4-5 clusters, while the within-class variance decreased by the same number of clusters and, therefore, provided enough evidence of differences between clusters, and similarities between the products in each cluster. As one of our objectives was to pair all foods with each beverage, 4 clusters were selected; otherwise, with 5 clusters, a set of food products would remain with no beverage to be paired with. The results split up all beverages into different clusters, reflecting that consumers generally considered the beverages as different.

Regarding the food pairings, several food items were clustered along with the beverages; for example, both beers (dark and blond) were clustered with salty snacks. In this sense, previous research has also reported that beer is regularly consumed with snack foods in Western Cultures (Pettigrew & Charters, 2006) and associated with purchasing fattier food items (Johansen et al., 2006). With similar findings, Donadini et al. (2008) found that pizza is a good pairing consumed with this beverage, which agrees with the AHC of the GPA, where pizza, shrimp, and peanuts, were also clustered along with beer in our study. In the case of wine, both red and white wines were clustered along with cheese and bread, which are widely reported as good combinations (King & Cliff, 2005; Bastian, 2010; Harrington, 2015).

The food and beverage pairings found in this research were not based on a flavor similarity approach but on consumer acceptance and perception which could generally rely on consumption habits in Mexico. For example, lime was clustered with Tequila, which is a highly accepted combination for younger Mexican consumers. Chili was clustered along with soda and several foods such as tortilla, chicken, tomato, and onion, which could reflect the Mexican behavior of adding chili to almost all food products in regular meals; as Rozin and Schiller (1980) stated since 1980, chili is a ubiquitous feature in the Mexican gastronomy, in other words, the chili pairing in Mexican consumers is more a matter of culture than flavor similarity.

In this study, popular foods and beverages among young Mexican consumers were tested; however, it is widely reported that cultural context influences consumer preferences and that beverage consumption with specific foods is a significant factor in distinguishing cuisines (Harrington et al., 2008). Therefore, since consumer culture is also a key component in food pairing and that little cross-cultural research can be found regarding food and flavor pairing (Galmarini, 2020), it could be interesting to assess the same set of products, as well as different popular foods, in other cultures, to evaluate the differences/similarities of acceptable pairings between consumer preferences. For example, with French consumers, who are known to have an extensive wine culture, the food and beverage pairings could have been different from those found in this research; analogously, the inclusion of other traditional beverages for Mexican consumers, such as Mezcal or Pulque, could have also yielded different results.

Regarding the data analysis, the RV coefficient was used to test the similarities between women's and men's GPA coordinates. Vidal et al. (2014a) reported that this analysis is a good predictor of similarity. Results of RV coefficient between women and men was high, representing similar configurations, and therefore, the perception of suitable food and beverage pairings was also similar between male and female consumers.

Previous research has reported that gender influences the habits and preferences of alcoholic consumption, e.g., Jimborean et al. (2021) found that Romanian male students drink alcoholic beverages to relax or socialize and, in general, preferred beer, while females consume alcohol for the beverage's taste or flavor and their favorite beverage was wine. In this sense, gender differences between young adults could play a role in the preferred alcoholic beverages (Martínez et al. 2017) and could impact the food and beverage pairing preferences of consumers. In an article on stereotypes and alcohol consumption, Rodrigues et al. (2020) talk about the gender differences across Mexican consumers, in terms of biological (sex) differences, and cultural gender differences. However, in this study, and as both beer and wine were tested, gender had no effect on food pairing.

This research showed the use of projective mapping for exploring food and beverage pairings, which produces maps that visually represent the consumers' preferences for pairing specific food products. With the aim of exploring food-pairing preferences of younger Mexican consumers, neither the share volatile compounds, from food-pairing theory, nor the concentration or detection threshold of the products were considered, only the consumer's perceptions of food and beverage combinations.

Some advantages can be highlighted in projective mapping as a methodological approach. In this research, no hedonic or rating scales were applied to evaluate consumer acceptance; the distance between food-food and food-beverages was used as a unit measurement for preferred food-pairing instead. Although the distance and the variability of the consumers' food and beverage pairing data could be essentially different, the adjustment and preservation of the space to find a consensus across all individuals was reached using GPA. The projective mapping approach allowed the evaluation and visualization of consumer preferences for a whole set of products simultaneously, in which a closer position between foods and beverages reflected a better combination of the items.

With the purpose of exploring consumers' preferences according to food consumption habits or traditional manner of consumption, the paper cards were designed only as a guide of isolated products. However, consumers were free to create a whole map of how they usually combined their foods and not how a product should be served. Also, consumers did not receive a description of what a "good combination" is, no definitions of an ideal match, balance, or harmony; nor were complementary or similarity matching in the products defined, which helped avoid biasing consumer perception of certain combinations. Additionally, by allowing consumers to position a "non-combinable" item further from all products, the methodology could explore if some food items were not suitable to be combined; however, this tendency was not observed in the maps obtained.

Although projective mapping was an effective and practical approach for exploring food-food and food-beverage pairings, the study had some limitations. Traditionally, a pairing usually starts with the food, and it is the beverage which accompanies the food.

Here, however, we inverted the task as our research interest was exploring which foods would pair well with specific beverages. Additionally, in the projective mapping task, it was more manageable for consumers to start with visualizing the six beverages instead of the thirty food items. In further analysis, this aspect should be considered; however, it will depend on the study's objectives.

Some other factors, such as age, gender, and other demographic variables, should be considered in food pairing evaluation (Galmarini, 2020); however, in this research, no differences in food and beverage pairing could be found between female and male consumers. However, it could be a matter of the relatively low sample size, or that the stimuli used were too similar for the consumers, and therefore culture has a bigger effect than gender. In the case of the age of participants, it has been reported that it could impact consumers' habits and preferences, e.g., Garcia et al. (2013) reported that wine is the most frequently consumed drink among Spanish people over the age of 35, while consumers under 35 frequently consumed other drinks, such as beer. In this study, consumers were recruited only from a university in Mexico City from a narrow age range (18 to 25 years). Further research should include older consumers over 25 years old to test a potential age effect.

Another limitation to consider is the use of images instead of real food products. While several studies have used real food products to test food pairing, in this study, due to the high number of food and beverages tested, images were used only as a guide for consumers' perception homogeneity. So, this research provides an overview of what consumers perceived to be a suitable food and beverage pairing, based on their previous experiences. Further research must explore if the found pairings with images agree with real food products. In general, several aspects should be considered to follow this food pairing approach. Demographic variables, the use of real food instead of images, the evaluation of different food products, and the comparison of different cultures, could greatly interest the food pairing field.

In general, it was possible to relate a whole set of food items to a specific beverage or group of beverages. In some cases, such as wine, the pairings were previously reported for other cultures, while other pairings were specific to Mexican culture.

Additionally, some food items were found to pair better than others. Overall, and according to the results, the exploration of food and beverage pairing through projective mapping, and analyzed through GPA, seems to be a suitable tool for exploring food and beverage pairing, and from which it was possible to obtain a complete food and beverage map that represented the better food combinations for consumers. However, the various aspects discussed above should be considered for further research exploring the proposed methodological approach.

Conclusions

This research showed that projective mapping was an effective technique to explore food-beverage pairings by producing maps representing how consumers combine specific foods and beverages. From these maps, it was possible to identify some patterns according to consumers' preferences, in which gender had no effect, meaning that consumers' culture was more important than gender. In general, GPA was a valuable tool to analyze and visualize consumers' food and beverage pairing data.

Some of the limitations that arise when analyzing the results are the relatively small sample size, the fact that all participants were young Mexican consumers, and that they come from a specific region in the center of Mexico. As previously suggested, culture could have a bigger impact than gender; the fact that consumers come from different cultures or from different age groups, can bring changes to flavor pairing, and has yet to be explored.

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Authors' Contributions

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Araceli Arellano-Covarrubias: Methodology, Formal Analysis, Investigation, and Writing-Original draft preparation

References

Addinsoft (2019). XLSTAT statistical and data analysis solution. Long Island, NY, USA. https://www.xlstat.com.q

Ahn, Y.-Y., Ahnert, S. E., Bagrow, J. P., & Barabási, A.-L. (2011). Flavor network and the principles of food pairing. *Scientific Reports,* 1, 196. https://doi.org/10.1038/srep00196.

Ahnert, S. E. (2013). Network analysis and data mining in food science: the emergence of computational gastronomy. *Flavour,* 2,4. https://doi.org/10.1186/2044-7248-2-4.

Arce-Lopera, C., Masuda, T., Kimura, A., Wada, Y. & Okajima, K. (2015). Model of vegetable freshness perception using luminance cues. *Food Quality and Preference.* 40, 279-286. http://dx.doi.org/10.1016/j.foodqual.2014.06.010.

Arellano-Covarrubias, A., Gómez-Corona, C., Varela, P., & Escalona-Buendía, H.B. (2019). Connecting flavors in social media: A cross cultural study with beer pairing. *Food Research International,* 115, 303-310. https://doi.org/10.1016/j.foodres.2018.12.004.

Bastian, S. E. P., Collins, C., & Jhonson, T. E. (2010). Understanding consumer preferences for Shiraz wine and Cheddar cheese pairings. *Food Quality and Preference,* 21, 668-678. https://doi.org/10.1016/j.foodqual.2010.02.002.

Berget, I., Varela, P., & Næs, T. (2019). Segmentation in projective mapping. *Food Quality and Preference,* 71, 8-20. https://doi.org/10.1016/j.foodqual.2018.05.007.

Brown, A. L., Bakke, A. J., & Hopfer, H. (2020). Understanding American premium chocolate consumer perception of craft chocolate ad desirable product attributes using focus groups and projective mapping. *PLoS ONE,* 15:11. https://doi.org/10.1371/journal.pone.0240177.

Cichelli, A., Cerretani, L., Lecce, G. D. & Piochi, M. (2020). Exploring harmony in extra virgin olive oils and vegetables pairings. *Grasas y Aceites.* 71:2, 1-10. https://doi.org/10.3989/gya.0117191

Donadini, G., Fumi, M. D. & Lambri, M. (2012). The hedonic response to chocolate and beverage pairing: A preliminary study. *Food Research International*. 48:2, 703-711. https://doi.org/10.1016/j.foodres.2012.06.009.

Donadini, G., Fumi, M. D. & Lambri, M. (2013). A preliminary study investigating consumer preference for cheese and beer pairings. *Food Quality and Preference,* 30, 217-228. https://doi.org/10.1016/j.foodqual.2013.05.012

Donadini, G., Spigno, G., Fumi, M. D., Pastori, R. (2008). Evaluation of ideal everyday Italian food and beer pairings with regular consumers and food and beverages experts. *Journal of Institute of Brewing.* 114:4, 329-342. https://doi.org/10.1002/j.2050-0416.2008.tb00777.x.

Eschevins, A., Giboreau, A., Allard, T., Dacremont, C. (2018). The role of aromatic similarity in food and beverage pairing*. Food Quality and Preference, 65, 18-27.* https://doi.org/10.1016/j.foodqual.2017.12.005.

Eschevins, A., Giboreau, A., Julien, P., Dacremont, C. (2019). From expert knowledge and sensory science to a general model of food and beverage pairing with wine and beer. *International Journal of Gastronomy and Food Science,* 17 https://doi.org/10.1016/j.ijgfs.2019.100144.

Euromonitor International. (2014). *Beer in Mexico.* London: Euromonitor International. Retrieved from Euromonitor Passport database.

Galmarini, M. V. (2020). The role of sensory science in the evaluation of food pairing. *Current opinion in Food Science,* 33, 149-155. https://doi.org/10.1016/j.cofs.2020.05.003.

Galmarini, M. V., Loiseau, A-L., Debreyer, D., Visalli, M., & Schlich, P. (2017). Use of multi-intake Temporal Dominance of Sensations (TDS) to evaluate the influence of wine on cheese perception. *Journal of Food Science,* 82:11, 2669-2678. https://doi.org/10.1111/1750-3841.13500.

Garcia, T., Barrena, R. & Grande Ildefonso. (2013). The wine Consumption preferences of young people: a Spanish case study. *International Journal of Wine Business Research,* 25:2, 94-107. https://doi.org/10.1108/IJWBR-2012-0007.

Gower, J. (1975). Generalized Procrustes analysis. *Psychometrika, 40:1, 33-51.*

Harrington, R. J., Miszczak, D. C., & Ottenbacher, M. C. (2008). The impact of beer type, pizza spiciness and gender on match perceptions. PASOS. *Revista de Turismo y Patrimonio Cultural,* 6:2, 173-188. https://doi.org/10.25145/j.pasos.2008.06.014.

Harrington, R.J. & Seo, H-S (2015). The impact of liking of wine and food items on perceptions of wine-food pairing. *Journal of Foodservice Business Research,* 18,5, 489-501. https://doi.org/10.1080/15378020.2015.1093455.

Heymann, H., Hopfer, H., & Bershaw, D. (2014). An exploration of the perception of minerality in white wines by projective mapping and descriptive analysis. *Journal of Sensory Studies,* 29:1, 1-13. https://doi.org/10.1111/joss.12076.

Jain, A., N. K., R. & Bagler, G. (2015). Analysis of food pairing in regional cuisines of India. *PLoS ONE,* 10,10. https://doi.org/10.1371/journal.pone.0139539.

Jimborean, M.A.; Salanță, L.C.; Trusek, A.; Pop, C.R.; Tofană, M.; Mudura, E.; Coldea, T.E.; Farcaș, A.; Ilieș, M.; Pașca, S.; Uifălean (2021). A. Drinking Behavior, Taste Preferences and Special Beer Perception among Romanian University Students: A Qualitative Assessment Research. *International Journal of Environmental Research and Public Health*, 18:6 3307. https://doi.org/10.3390/ijerph18063307

Johansen, D., Friis, K., Skovenborg, E., & Grønbæk, M. (2006). Food buying habits of people who buy wine or beer: Cross sectional study. *BMJ: British Medical Journal*, 332 (7540), 519 -521. https://doi.org/10.1136/bmj.38694.568981.80

Kildegaard, H., Olsen, A., Gabrielsen, G., Møller, P. & Thybo, A. K. (2011). A method to measure the effect of food appearance factors on children's visual preferences. *Food Quality and Preference,* 22, 763-771. https://doi.org/10.1016/j.foodqual.2011.06.009.

King, M. & Cliff, M. (2005). Evaluation of ideal wine and cheese pairs using a deviation-from-ideal scale with food and wine experts. *Journal of Food Quality,* 28, 245-256. https://doi.org/10.1111/j.1745-4557.2005.00033.x.

Kim, M-R., Kim, K-P., & Chung, S-J. (2019). Utilizing hedonic frame for projective mapping: A case study with Korean fermented soybean paste soup. *Food Quality and Preference,* 71, 279-285. https://doi.org/10.1016/j.foodqual.2018.07.014.

Klepper, M. (2011). Food pairing theory: A European fad. *Gastronomica*, 11(4), 55–58. https://doi.org/10.1525/gfc.2012.11.4.55

Kort, M., Nijssen, B., van Ingen-Visscher, K., & Donders, J. (2010). Food pairing from the perspective of the "Volatile compounds in food" database. *Expression of Multidisciplinary Flavour Science: Proceedings of the 12th Weurman Symposium, Interlaken, Switzerland, 589-592.*

Kustos, M., Heymann, H., Jeffery, D.W., Goodman, S. & Bastian, S. E. P. (2020). Intertwined: What makes food and wine pairings appropriate?. *Food Research International.* 136, 109463. https://doi.org/10.1016/j.foodres.2020.109463

Madrigal-Galán, B. & Heymann, H. (2006). Sensory effects of consuming cheese prior to evaluating red wine flavor. *American Journal of Enology and Viticulture,* 57:1, 12-22.

Martínez, D. C., Hammond, R.K., Harrington, R.J. & Wiersma-Mosley, J. D. (2017). Young adult’s and industry expert’s subjective and objective knowledge of beer and food pairings. *Journal of Culinary Science & Technology,* 15,4, 285-305. https://doi.org/10.1080/15428052.2016.1256243.

Mielby, L. H., Hopfer, H., Jensen, S., Thybo, A.K., & Heymann, H. (2014). Comparison of descriptive analysis, projective mapping and sorting performed on pictures of fruit and vegetable mixes. *Food Quality and Preference,* 35, 86-94. http://dx.doi.org/10.1016/j.foodqual.2014.02.006.

Mielby, L. H., Kildegaard, H., Gabrielsen, G., Edelenbos, M. & Thybo, A. K. (2012). Adolescent and adult visual preferences for pictures of fruit and vegetable mixes- Effect of complexity. *Food Quality and Preference,* 26, 188-195. http://dx.doi.org/10.1016/j.foodqual.2012.04.014.

Møller, P. (2013). Gastrophysics in the brain and body. *Flavour,* 2:8. https://doi.org/10.1186/2044-7248-2-8.

Nestrud, M., & Lawless, H. T. (2008). Perceptual mapping of citrus juices using projective mapping and profiling data from culinary professionals and consumers. *Food Quality and Preference,* 19:4, 431-438. https://doi.org/10.1016/j.foodqual.2008.01.001.

Nygren, I. T., Gustafsson, I-B., Haglund, Å., Johansson, L. & Noble, A.C. (2001). Flavor changes produced by wine and food interactions: Chardonnay wine and hollandaise sauce. *Journal of Sensory Studies,* 16:5, 461-470. https://doi.org/10.1111/j.1745-459X.2001.tb00313.x

Nygren, I. T., Gustafsson, I-B. & Johansson, L. (2002). Perceived flavour changes in white wine after tasting blue mould cheese. *Food Service Technology,* 2:4, 163-171. https://doi.org/10.1046/j.1471-5740.2002.00048.x

Orden, D., Fernández-Fernández, E., Tejedor-Romero, M., & Martínez-Moraian, A. (2021). Geometric and statistical techniques for projective mapping of chocolate chip cookies with a large number of consumers. *Food Quality and Preference*, 87, 104068.

Paulsen, M. T., Rognsa, G. H. & Hersleth, M. (2015). Consumer perception of food-beverage pairings: The influence of unity in variety and balance. *International Journal of Gastronomy and Food Science.* 2:2, 83-92. http://dx.doi.org/10.1016/j.ijgfs.2014.12.003

Pettigrew, S., & Charters, S. (2006). Consumers' expectations of food and alcohol pairing. *British Food Journal,* 108:3, 169-180. https://doi.org/10.1108/00070700610650990.

Robert, P. & Escoufier, Y. (1976). A unifying tool for linear multivariate statistical methods: The RV-coefficient. *Applied Statistics*, 25, 257–265. http://www.jstor.org/stable/2347233.

Rodrigues, H., Goméz-Corona, C., & Valentin, D. (2020). Femininities & masculinities: sex, gender, and stereotypes in food studies. *Current Opinion in Food Science*, 33, 156-164.

Rozin, P., & Schiller, D. (1980). The nature and acquisition of a preference for chili pepper by humans. *Motivation and Emotion*, 4, 77–101. https://doi.org/10.1007/BF00995932.

Savidan, C. H. & Morris, C. (2015). Panelists' performance and strategies in paper-based and computer-based projective mapping. *Journal of Sensory Studies.* 30:2, 145-155. https://doi.org/10.1111/joss.12146.

Shepherd, G. M. (2006). Smell images and the flavour system in the human brain. *Nature,* 444, 316-321.

Simas, T., Ficek, M., Diaz-Guilera, A., Obrador, P., & Rodriguez, P. R. (2017). Food bridging: a new network construction to unveil the principles of cooking. *Frontiers in ICT,* 4,14. https://doi.org/10.3389/fict.2017.00014.

Tallab, S. T. & Alrazgan, M. S. (2016). Exploring the food pairing hypothesis in Arab cuisine: A study in computational gastronomy. *Procedia Computer Science,* 82,135-137. https://doi.org/10.1016/j.procs.2016.04.020

Tomic, O., Berget, T., & Næs, T. (2015). A comparison of generalised Procrustes analysis and multiple factor analysis for projective mapping. *Food Quality and Preference,* 43, 34-46. https://dx.doi.org/10.1016/j.foodqual.2015.02.004.

Traynor, M. P., Burke, R., O'Sullivan, M. G., Hannon, J. A. & Barry-Ryan, C. (2013). Sensory and chemical interactions of food pairings (basmati rice, bacon and extra virgin olive oil) with banana. *Food Research International, 54, 569-577. https://doi.org/10.1016/j.foodres.2013.07.050.*

Valentin, D., Cholet, S., Nestrud, M., & Abdi, H. (2016). Projective mapping and sorting task. In J. Hort, S. Kemp, & T. Hollowood (Eds.) *Descriptive Analysis in Sensory Evaluation.* London: Wiley-Blackwell*.*

Varela, P., Berget, I., Hersleth, M., Carlehög, M., Asioli, D., & Næs, T. (2017). Projective mapping based on choice or preference: An affective approach to projective mapping. *Food Research International,* 100, 241-251. https://doi.org/10.1016/j.foodres.2017.08.049.

Varela, P. & Salvador, A. (2014). Structured sorting using pictures as a way to study nutritional and hedonic perception in children. *Food Quality and Preference,* 37, 27-34. http://dx.doi.org/10.1016/j.foodqual.2014.04.009.

Vidal, L., Jaeger, S. R., Ares, G. (2014a). What is the best parameter to estimate the degree of similarity between two-dimensional sample configurations?. Poster session presentation at Sensometrics 2014, Chicago.

Vidal, L., Cadena, R. S., Antúnez, L., Giménez, A., Varela, P., & Ares, G. (2014b). Stability of sample configurations from projective mapping: How many consumers are necessary?. *Food Quality and Preference*, 34, 79-87.

Wakeling, I. N., Raats, M. M. & MacFie, H. J. H. (1992). A new significance test for consensus in generalized procrustes analysis. *Journal of Sensory Studies,* 7, 91-96.