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Tea pairings: Impact of aromatic congruence on acceptance and sweetness perception

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ABSTRACT

Food pairing is a relevant tool for the food industry and for culinary professionals to develop successful flavor combinations and memorable experiences, but it could also be useful for encouraging consumers to adhere to a healthier diet. The general purpose of this study was to further investigate the perception of teas and butter cookies with and without aromatic congruence, deepening in sweetness perception. The experimental included: 1) a projective mapping test (30 semi-trained panelists) to group tea samples and choose representatives of each aromatic group; 2) the determination of the main volatile organic compounds using Solid Phase Micro Extraction-Gas Chromatography Mass Spectrometry (SPME-GC-MS) to prove the aromatic congruence of the designed tea-cookie pairings; 3) a consumer study (n = 89) to assess liking, sweetness perception, of the single samples and pairings, and the pairing principles of the congruent and non-congruent parings. Results of the projective mapping showed that the tea samples could be grouped into 3 main categories by their herbal, fruity-sweet, and brown-sweet notes, results also supported by the GCMS data. Harmony was positively correlated to liking, and Balance and Similarity seemed to be related to aromatic "congruence", although all pairings were similarly liked. Sugar content was similar in all the cookie samples and pairings, but sweetness perception was significantly influenced by the aroma of the samples, being the samples and pairings made with spearmint the least sweet ones. Pairing a tea with sweet aromas with the spearmint cookie, independently of the kind of sweet aromatics (e.g.: coconut, almond, vanilla, fruity, tropical), seemed to slightly increase sweetness perception, although significant differences were not detected with other spearmint cookie pairings. Findings of the present research sum knowledge to the food pairing area, but further research is needed in recommending appropriate methodologies for pairing assessment, as well as the potential uses of driven pairings in specific food cultures.

1. Introduction

Food pairing is a relevant tool for the food industry and for culinary professionals, bringing light to successful foods or food-beverage combinations for developing new gastronomic experiences. Beyond providing a pleasant and satisfactory experience by enhancing a whole meal, food and beverage pairings could have broader applications, such as nudging consumers towards healthier and more sustainable diets if making healthy-food pairings more sensorially appealing (Spence, 2022; Wang et al., 2019). Products are rarely consumed isolated in everyday meal experiences; matching foods, and foods and drinks, is a common practice. Indeed, a perfect match between a food and a beverage can increase acceptance and boost overall experience (Lahne, 2018). Probably the most researched pairing is the food and wine pairing, an ancient practice that has evolved depending on the different civilizations and ingredient availability, but a great interest has recently arisen to address the underlying principles behind a 'good pairing', not only between wine and food, but to pair flavors in general (Ahn et al., 2011; Arellano-Covarrubias et al., 2019; Cerretani et al., 2007; Donadini et al., 2008; Galmarini et al., 2016). Different theories have been formulated in this regard (see Spence, 2020a for a review), mainly proposed by chefs, sommeliers, and other culinary experts, but there is still a great gap in scientific knowledge.

The non-alcoholic beverage market is experiencing a significant

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growth in recent years, being tea the second most consumed beverage in the world after water and a product increasingly demanded by consumers (Statista, 2022), probably due to its potential health and mood related effects (Dou, 2019). The concept of 'tea pairing' or 'tea sommelier' is not new, although it is not widespread in Western cultures (Donadini and Fumi, 2014). Several haute cuisine restaurants have recently incorporated dishes paired with teas and infusions into their tasting menus (e.g., ESORA in Singapore, or Eleven Madison Park in New York), showing the application of tea-pairings designed to extol the sensory properties of the meal. The existence of a huge variety of teas and infusions allows an enormous combination of flavors and aromas to develop a new world of multisensory experiences for the consumer. There are approximately 1500 types of tea around the world, and almost as many ways of enjoying in it. In Middle East and East Asian countries, tea is an important part of the culture, and the process of brewing and drinking it is considered a ritual. In Europe (e.g., Spain), tea and infusions consumption is rapidly increasing as an alternative to coffee, and it is often served in-between main meals or at the end of a meal, often served together with a sweet dessert or snack. It has been reported that stimuli that have regularly been paired with sweet foods could enhance the associated taste quality (e.g.: vanilla odor), given previous co-exposure (Spence, 2015); therefore, pairing these generally non-caloric beverages with a dessert (e.g.: cookies, cake), could be used to enhance the sweetness perception of the dessert-experience and to reduce the intake of high-calorie desserts because of increasing sweet-satiety.

Aromatic similarity has been studied by several authors as a potential rule for a good pairing, relating it to concepts such as harmony, balance, and complexity (Eschevins et al., 2018; Galmarini, 2020; Paulsen et al., 2015). Also, the 'food-pairing' theory proposed by chef Heston Blumenthal and François Benzi in 2002, which led to the development of 'computational gastronomy', falls in line with a similar principle, suggesting that the more volatile compounds two products share, the better they will match with each other (Blumenthal, 2002). This theory has been used by numerous chefs as inspiration for meal design, but it seems to be too simple because most of the sensory modalities of ingredients and foods are forgotten in favor of the aromatic composition (texture, taste, appearance, mouthfeels), and because it does not consider assessor's characteristics such as culture and regional cuisine previous experiences, important factors that contribute to a 'successful match' (Ahn et al., 2011; Spence, 2020a). Besides, product's liking, as a determinant of 'pair liking', has been reported as a key element, but it is necessary to study in detail all the factors that contribute to a good pairing (Donadini and Fumi, 2014; Paz et al., 2021).

Limited research has focused on tea pairings; in a recent systematic review on different methods used for pairing food with different beverages, Rune et al. (2021) only came up with two results on pairing tea with food (Donadini and Fumi, 2014; Sato and Kinugasa, 2019), and the aim of both studies was to increase the associated food liking (chocolate and bonito stock respectively) and not to understand the success of the pairing itself. The present study aimed to test whether (1) aromatic congruence would impact liking of two single products (teas and butter cookies) compared to consuming them together (tea with butter cookies), and (2) sweetness perception of a dessert/snack (cookies) could be enhanced by using specific tea/infusions pairings, because of the presence of sweet related-volatile compounds in the teas/infusions.

2. Material and methods

The protocol and procedures used in this study were approved by the Basque Culinary Center scientific committee (BCC22/1703), which stated a waiver consent. All articles from the Declaration of Helsinki and the 2016/679 EU Regulation on the protection of natural persons regarding the processing of personal data and on the free movement of such data were met. The experimental procedure was explained and a written consent indicating voluntary participation was obtained from each participant prior to beginning the study.

2.1. Phase I. Tea samples selection and aromatic characterization

To select at least 3 tea samples with remarkable aromatic differences to conduct the pairing consumer study, a first market mapping test was conducted. Twenty different samples of teas and infusions available at the Spanish supermarkets and with different ingredients were chosen to include a wide variety of aromas in the test (Table 1). A projective mapping technique/Napping® was used to group and explore the aromatic profile of the samples (Pagès, 2005; Risvik et al., 1994). A total of 30 semi-trained panelists (57% females, mean = 32 years, SD = 8.59) from the food science field (chefs, gastronomes, nutritionists, researchers in sensory analysis) were recruited and trained in the performance of the technique and the use of sensory descriptors prior to beginning the test. A set of different volatile compounds (0.5 ml of an ≈ 1000 mg kg^{-1} stock of single pure substances in distilled water to ensure suprathreshold concentration; flavor grade from Merck KGaA, Darmstadt, Germany) prepared in 2 ml microcentrifuge tubes (Eppendorf Iberica, Spain) and their corresponding descriptors were used to train the panelists and ensure an appropriate description of the odor stimuli. The set of key odorants included compounds such as vanillin (sweet, vanilla), cinnamaldehyde (spicy, cinnamon), anethol (sweet, spicy), hexanal (green, grass, metallic), isoamyl acetate (sweet, fruity),

Table 1
Tea samples used for selection stage.

Code	Product name *	Ingredients *(as reported in the packaging)*
981	Chamomile, Honey & Vanilla [a]	Chamomile, natural vanilla, and honey flavorings with other natural flavorings
538	Ginger chai [a]	Ginger root, licorice root, cinnamon bark, cloves
761	Rooibos, Strawberry & Vanilla [a]	Rooibos, natural strawberry flavouring with other natural flavorings, natural vanilla flavouring
670	Orange & Cinnamon [a]	Black tea, cinnamon, orange flavouring, orange pieces
905	Raspberry & Pomegranate [a]	Hibiscus, natural raspberry, pomegranate, and strawberry flavorings with other natural flavorings
710	Earl Grey [a]	Black tea, bergamot flavouring
156	Infusi gustosi [b]	Apple, carob, hazelnut, licorice root, blackberry leaves, natural flavouring, chicory root, vanilla beans
351	Jasmine Green Tea [c]	Ecological green tea, jasmine flowers
278	Hibiscus-Ginger Green Tea [c]	Green tea, hibiscus, ginger, licorice
497	Ginger-Lime Green Tea [c]	Green tea, ginger, natural lemon flavor, lemon zest, lime zest
546	Relax Herbal Tea [d]	Rooibos, tilia, lemon balm, mint
415	Chocolate dreams [d]	Rooibos, cocoa, rose petals and flavorings
325	Rooibos coconut caramel almonds [e]	Rooibos, coconut, coconut and caramel flavorings
740	Mango-Passion fruit Red Tea [e]	Red tea, mango, sunflower, cornflower blue, mango and passion-fruit flavorings
183	Moorish Green Tea [e]	Green tea, spearmint, mint flavouring
204	Cinnamon-Lime Red Tea [e]	Red tea, cinnamon, lemon, lemongrass, lemon and cinnamon flavorings
390	"Infusueños" with Passiflora [f]	Balm, rooibos, lavender flower, *Passiflora*, flavorings, honey
634	Vanilla White Tea [f]	Tea, flavouring, vanilla
872	Blueberry with Hibiscus [f]	*Rosa rubiginosa,* hibiscus, beetroot, green tea, cinnamon, flavorings, blackberry leaves, blueberries
952	Turmeric & Cacao [g]	Cinnamon, cacao, turmeric, blackberry

Brand
[a] Twinings of London™ - R. Twining and Company Sp. Z o. o. (Swarzędz, PL).
[b] Bonomelli S. r.l (Zola Pedrosa, IT).
[c] SCOP Ethiquable (Fleurance, FR).
[d] Tealand (Vitoria-Gasteiz, ES).
[e] Mushutea - Andabar Coffee and Tea Sl. (Barcelona, ES).
[f] Hornimans - Jacobs Douwe Egberts (Amsterdam, NL).
[g] Pompadour Ibérica S.A. (Alicante, ES).

benzaldehyde (fragrant, sweet, almond), geraniol (sweet, floral, fruity), limonene (citrus, mint), 1-octen-3-ol (mold, earthy), among others, which were chosen because of having been previously identified in tea and infusions samples (Zhou et al., 2020).

Approximately 1 g of each tea/infusion mix was poured into 1.5 ml microcentrifuge tubes and coded with random three-digit numbers. Following the Napping® instructions (Pagès, 2005), panelists were asked to sniff each sample and place them on a DIN A3 paper (297 × 420mm) according to their similarities or differences, so that the closer the infusions would be positioned to each other, the greater their similarity. In addition, participants were asked to provide at least 3 words to describe the sensory characteristics of each sample/group of samples. The duration of the task was about 20 min. The x and y samples' coordinates of each participant were measured using a 1 × 1cm gridded stencil and recorded for subsequent analysis.

2.1.1. Projecting mapping data analysis

A Multiple Factor Analysis (MFA) was performed using the data from the projective mapping (Pagès, 2005). The x and y coordinates of each sample were measured in centimeters, and the frequencies of mention of the different attributes mentioned by the panel were counted. Terms used to describe each sample were computed in a mention frequency table. To reduce the number of descriptors, only the ones used by at least 10% of respondents were included in the final analysis. The resulting table had the products in the rows and the x, y coordinates and attribute frequencies as columns (as many x, y tables as panelists). Coordinates (x, y) of the teas/infusions for each panelist were used as active variables, and attributes as supplementary variables.

2.2. Phase II. Consumer study

2.2.1. Participants

Consumers were recruited from Basque Culinary Center consumers' database. The inclusion criteria were: to be above 18 years old; absence of non-communicable-diseases, known food allergies or dietary intolerance, and/or pregnancy; and willingness and availability to participate in the study. Ninety-five participants were recruited and a total of 89 consumers (57% females, mean = 35.14 years, SD = 9.33) completed the 3-sessions study. Participants signed an informed consent and received a coffee voucher as a reward.

2.2.2. Samples

In addition to the 3 samples selected after the mapping stage, butter cookies were chosen to pair with the teas because of being a usual combination in the country in which the study was conducted. Thus, 3 different cookies were designed and developed considering the 3 chosen teas: Moorish green tea (GreenT), mango and passion fruit red tea (RedT), and rooibos coconut caramel and almond tea (RooibosT) (details in the results and discussion paragraph). For the testing, the tea samples were prepared following manufacturer's instructions: 8 g l^{-1} of GreenT and RedT were infused in water at 90 °C for 3 min, while RooibosT was infused for 6 min.

The 3 cookie samples were made using the aforementioned aromatical similarity approach and consisted of: a spearmint and tea cookie (MintC) to match the green tea sample; a passion fruit and lime cookie (FruitC) to match the red tea sample; and a vanilla and coconut cookie (VanillaC) to match the rooibos tea sample. The process of making the butter cookies samples was the following (% in w/w): powdered sugar (16%) and butter (27%) were mixed in a food processor during 3–5 min until getting a homogeneous paste. Then, egg yolk (7%) was added and mixed until fully integrated. At this step, the different ingredients (2%) for the 3 different samples were added: 1) green tea with spearmint (MintC sample); 2) lime zest and freeze-dried passion fruit (FruitC sample); 3) vanilla beans and coconut flakes (VanillaC sample). Then, plain flour (48%) was added and mixed for 5 more minutes until forming a dough that was chilled in a refrigerator at 5 °C for approximately 1 h. The chilled dough was then rolled out until 1 cm thick and cut into ø 5 cm pieces and baked at 175 °C for 15–17 min (RATIONAL SCC 61 oven, RATIONAL Aktiengesellschaft, Germany).

2.2.3. Tasting procedure

The tasting sessions were conducted in a sensory lab with individual booths and controlled temperature and relative humidity (21 ± 2 °C; 55 ± 5% RH); the illumination was a combination of natural and nonnatural light (fluorescent). To avoid sensory fatigue, the test was divided in 3 different sessions, and each participant completed the 3 sessions to assess all the samples and pairings. The sessions were held in different days. During the sessions, participants had to assess 1 type of cookie (coded with 3 digits-random numbers and served in disposable plates), the 3 samples of tea (also coded with 3 digits-random numbers and served in transparent 40 cl glasses), and the corresponding pairings with the cookie of the session. The presentation order was randomized by consumer, guaranteeing that the cookies and the teas were assessed in a different order, but following the below sequence: first the butter cookie, then each of the tea samples, and lastly the pairing of the evaluated butter cookie with the 3 teas. Therefore, each sample, as well as 9 different tea-cookie pairings (aromatically congruent and non-congruent) were assessed throughout the 3 sessions. This tasting procedure was chosen considering that the cookies would cause a higher carryover effect than the teas, and because no standardized methodology has been reported yet to assess beverages and food pairings (Rune et al., 2021). Water was provided to cleanse palate between samples and participants were asked to wait at least 3 min between samples and rinse their mouth drinking water.

Data were collected using RedJade® software (RedJade Sensory Solutions, LLC, Palo Alto, USA) via personal mobile phones or tablets. The subjects were asked to rate liking (9-point hedonic scale with anchors 1 = dislike extremely, 5 = neither like-not dislike, 9 = like extremely) and sweetness perception (gLMS scale with the labels "no sensation", "barely detectable", "weak", "moderate", "strong", "very strong", and "the strongest sensation imaginable" in the 0, 1.4, 6, 17, 35, 51, and 100 cm of the scale respectively) of the individual products and the pairings. In addition, a Check-All-That-Apply (CATA) question was included to assess aromas and flavors present in the tea and cookie samples, including the terms: coconut, mint, mango, green tea, rooibos tea, vanilla, sweet flavor, bitter, herbal, chocolate, tropical, intense, nuts, artificial/chemical, spearmint, almond, passion fruit, red tea, black tea, citrus, sweet odor, caramel, floral, berries, tasteless, acid, fruity, spiced. The terms were chosen based on projective mapping results (terms used by assessors) and were complemented using the ingredients list of the different teas. Finally, four questions related to the overall perception of the pairings were included to ask about Complexity, Harmony, Similarity, and Balance (7-point Likert categorical scale labeled from "strongly disagree" to "strongly agree" for the statements: "The combination of flavors and aroma of this tea and this cookie give rise to a complex pairing"; "The combination of flavors and aroma of this tea and this cookie complement each other well"; "The flavors and aromas of this tea and this cookier are similar"; "The flavors and aromas of this tea and this cookie are balanced", respectively) as stated in previous research about pairings (Eschevins et al., 2019; Paulsen et al., 2015; Spence, 2020b).

2.2.4. Volatile composition of the samples

The determination of volatile organic compounds (VOCs) of samples was carried out following the method described by Sánchez-Bravo et al. (2022). The VOCs extraction was done using a Shimadzu AOC-6000 Plus autosampler (Shimadzu Corporation, Kyoto, Japan) with a headspace solid-phase micro extraction (HS-SPME) method and a SPME 50/30 mm DVB/CAR/PDMS fiber (1 cm). The sample preparation was directly conducted in the autosampler considering the manufacturer recommended times/temperatures for each of the types of tea used (6 min of maceration at 90 °C for RooibosT, and 3 min of maceration for GreenT and RedT, and then a 15 min period of fiber exposure), using the weight/volume ratio indicated by the manufacturer, and previously reported in the tasting procedure (8 g l^{-1}). Although sample matrix was different, same temperature and extraction time were used for the cookies to obtain comparable chromatograms; 3 g were weighed in the vial before putting it into the autosampler. Constant agitation (500 rpm) was used in all samples.

To separate VOCs a Shimadzu GC2030 with an SLB-5ms column (30 m, 0.25 mm, and 0.25 μm) chromatograph was used. Helium was the carrier gas, with a split ratio of 1:10, a purge flow in the injector of 6 ml·min-1, total column flow of 0.6 ml·min-1, and temperature of injector of 230 °C. The oven program was the following: (i) initial temperature of 50 °C, and hold 1 min, (ii) ramp of 2 °C min-1 up to 100 °C, (iii) ramp of 3 °C min-1 up to 180 °C, and (iv) ramp of 20 °C min-1 up to 230 °C and hold 5 min.

For the identification, the chromatograph was coupled with a Shimadzu TQ8040 NX mass spectrometer detector. The parameters of the mass spectrometer were mass range 35–400 m/z, scan speed 5000 amu/s, event time of 0.100 s, temperature of the interface of 280 °C, and temperature of the ion source of 230 °C. A commercial alkane standard mixture (Sigma-Aldrich, Steinheim, Germany) was used to calculate the retention indexes (Kovat's index). NIST 17 Mass Spectral and Retention Index libraries were used for the identification of compounds. Only compounds with spectral similarity >90% and with a deviation of less than 10 units of linear retention similarity were considered as correct hits.

Because the aim of the present study was not to characterize the volatile composition of the samples, but to look for aromatic congruence in specific sample pairs, the results presented in this manuscript do not include an extensive description of the volatile composition of the samples but show the compounds that may significantly contribute to the congruence/incongruence of the pairing based on its Area% and threshold.

2.2.5. Consumer study data analysis

Analysis of variance (ANOVA) followed by a post-hoc test (Tukey's HSD) was carried out on liking, sweetness perception, and agreement questions of the single teas/cookies and the combinations. gLMS scale data used for sweetness perception was transformed ('unlog') and normalized for the analysis (Kershaw and Running, 2019). Significant differences were determined with a significance level of 0.05 unless stated otherwise. Pearson's correlation coefficient matrix was calculated using the average ratings of each pairing to explore the relationships between the studied variables.

Cochran's *Q* test (Manoukian, 1986) was carried out to identify significant differences among butter cookies and teas for each of the descriptors included in the CATA question. Pairwise comparisons based on the McNemar–Bonferroni approach were performed to identify significant differences among the descriptors (Meyners et al., 2013). All statistical analyses were performed using XLSTAT (XLSTAT Version, 2021.5, Addinsoft, USA) (Addinsoft, 2022).

3. Results and discussion

3.1. Phase I. Samples characterization and selection

Fig. 1 shows the spatial arrangement of the samples according to their characteristics. The first two dimensions of MFA accounted for

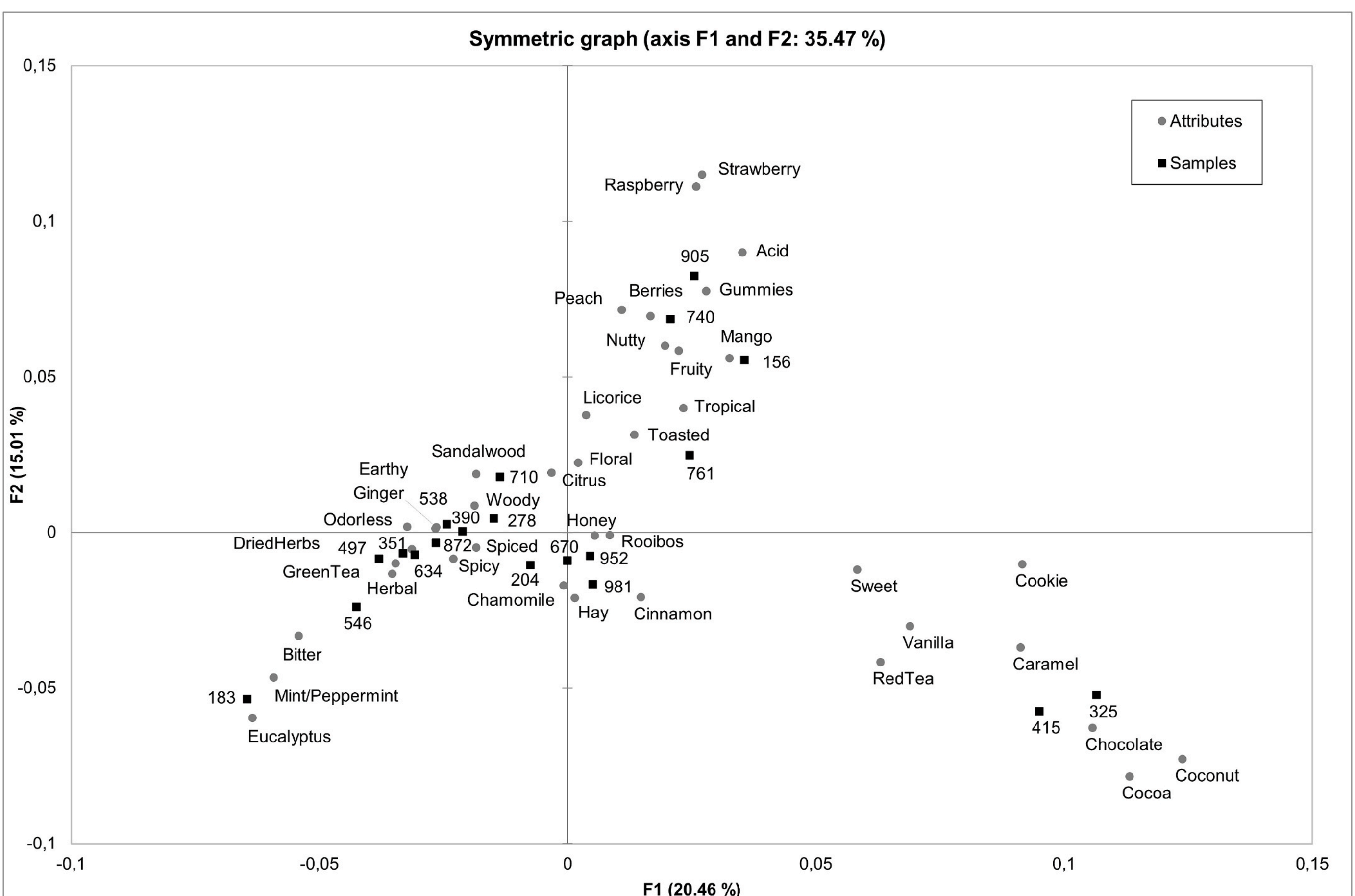

Fig. 1. Multifactor analysis of projective mapping of the tea/infusion samples.

approximately 34.5% of the variance of the experimental data. The first dimension was positively correlated terms such as sweet, vanilla, chocolate, cocoa, caramel, and cookie, which mainly described 2 of the samples (415 and 325, Table 1). On the other hand, it was negatively related to attributes such as herbal, mint/peppermint, and green tea, which mainly characterized samples 183 and 546. The second dimension was positively correlated with fruity, floral, berries, raspberry, and peach, characterizing samples 905, 740, and 156. Some of the descriptors given to the samples had been previously reported in different tea lexicons (de Godoy et al., 2020; Koch et al., 2012; Lee and Chambers, 2007), and were probably linked to the presence of specific ingredients in the different teas/infusions. Kim et al. (2018) reported a potential dynamism in the tea lexicons due to changes in the blended tea materials or ratios, and the samples tasted in the present study were chosen because of their ingredient variability. Although some samples were considered a mix of different aromas and intensities (e.g.: samples 670 and 952, those mainly sited in the center of the symmetric graph), the map of the different teas/infusions tasted during Phase I seemed to have 3 clearly different drivers: 1) sweetness, caramel, and "brown aromatics" (defined by Cherdchu et al., 2013, as "rich, full aromatic impression always characterized as some degree of darkness, generally associated with other attributes, and which can be found in nuts, brown sugar, coffee, and coconut"), 2) fruitiness, and 3) herbal notes. These 3 flavor categories can also be found in the Rooibos sensory wheel reported by Koch et al. (2012).

From this spatial distribution, 3 different samples were selected for the consumer study (Phase II) to represent the three categories: a predominantly sweet tea, sample 325 (RooibosT); a more herbal tea with notes of mint/spearmint, sample 183 (GreenT); and a predominantly fruity tea, sample 740 (RedT).

3.2. Phase II. Consumer study

VOCs determination of the tea samples showed that some of the main compounds found in the different samples had "sweet" as a descriptor, such as D-limonene in the GreenT sample, ethyl vanillin in the RooibosT, and octanoic acid ethyl ester and dodecanoic acid ethyl ester in the RedT, being potential candidates for sweetness enhancement (Table 2). Compared to the cookie samples, the tea samples showed a greater number of volatile compounds (data not shown); all cookie samples shared a similar volatile composition but had distinctive volatiles coming from the ingredients added to trigger the aromatic congruence with the chosen teas. The teas and cookies samples did not share the general volatile composition, but some of them (aromatically

Table 2
Volatile organic compounds of the tea and cookie samples. Legend. KI (Exp.) = experimental Kovats index, KI (Lit.) = literature Kovats index. Area% being the mean of 3 replications ± standard deviation. Main compound/s of each sample are highlighted in bold type.

COMPOUND	KI (exp)	KI (lit)	Area %	Odor Threshold (ppb) [a]	Descriptor [b]	COMPOUND	KI (exp)	KI (lit)	Area %	Odor Threshold (ppb) [a]	Descriptor [b]
GreenT						MintC					
D-Limonene	1028	1030	2.9 ± 0.8	4–229	sweet, citrus	Hexanal	785	787	13.1 ± 0.2	4.1–22.8	fresh, green
Isomenthone	1133	1133	2.7 ± 0.5	630	minty, peppermint	2-Heptanone	875	875	13.4 ± 0.4	1-1330	cheesy, sweet
Menthyl alcohol	1158	1160	2.9 ± 0.6	950-2500	mentholic, peppermint	**Carvone**	1240	1245	**42.6 ± 0.3**	**2.7–600**	**minty, licorice**
Pulegone	1234	1237	4.0 ± 0.6	130	peppermint, herbal	TOTAL			**69.0**		
Carvone	1240	1245	**52.4 ± 4.9**	**2.7–600**	**minty, licorice**						
8-p-Menthen-2-yl acetate	1305	1309	8.2 ± 1.0	1 ppm	minty, spearmint						
TOTAL			**72.9**								
RooibosT						**VanillaC**					
Benzaldehyde	955	960	4.6 ± 0.9	100-4600	almond, fruity	Hexanal	785	787	8.1 ± 0.7	4.1–22.8	fresh, green
Limonene	1028	1030	3.3 ± 0.9	4–229	sweet, citrus	Furfuryl alcohol	842	844	4.4 ± 0.6	1-2000	bready, sweet
Cinnamaldehyde	1265	1268	**61.3 ± 3.4**	**50–750**	**spicy, cinnamon**	**2-Heptanone**	875	875	**39.3 ± 0.8**	**1–1330**	**cheesy, sweet**
γ-n-Amylbutyrolactone	1359	1360	12.8 ± 1.0	7	creamy, oily	2-Nonanone	1087	1091	12.1 ± 0.4	5–200	fruity, sweet
Ethyl vanillin	1450	1453	2.6 ± 1.0	100	sweet, vanilla	Safranal	1195	1201	5.8 ± 2.9	na	herbal, spicy
Dodecanoic acid	1560	1567	3.1 ± 0.7	10,000	fatty, coconut	TOTAL			**69.7**		
TOTAL			**87.6**								
RedT						**FruitC**					
Octanoic acid	1158	1164	9.0 ± 1.6	910	fatty, rancid	β-Pinene	982	980	5.9 ± 0.1	140	herbal, woody
Octanoic acid ethyl ester	1195	1193	**21.5 ± 1.5**	**5–92**	**fruity, sweet**	**D-Limonene**	1028	1030	**69.2 ± 0.2**	**4–229**	**sweet, citrus**
Decanoic acid	1369	1374	**19.5 ± 3.1**	**2,2–102**	**fatty, citrus**	γ-Terpinene	1059	1060	17.4 ± 0.2	na	terpenic, sweet
Decanoic acid ethyl ester	1381	1389	**21.4 ± 0.7**	**8–12**	**sweet, fruity**	TOTAL			**85.4**		
γ-Decalactone	1569	1471	4.3 ± 0.5	1–11	fruity, fresh						
Caryophyllene oxide	1576	1581	3.5 ± 0.2	na	woody, sweet						
TOTAL			**79.3**								

[a] Furia and Bellanca (1975).
[b] TGSC Information System.

"congruent") shared some specific compounds or descriptors: MintC and GreenT shared the compound carvone (minty, licorice); Vanilla C and RooibosT shared the descriptors sweet and spicy, coming from compounds such as cinnamaldehyde, ethyl vanillin, 2-heptanone and safranal; and finally, FruitC and RedT shared the descriptors sweet and fruity (e.g.: citrus) coming from the esters of the tea and the D-limonene of the cookie sample. Because of the volatile composition results, is seemed that the MintC and GreenT shared a distinctive herbal aroma compared to the other 2 teas and cookies samples, which shared the "sweet" descriptor, but with 2 different hints: spicy and fruity. Different lexicons have been reported in which fruity and brown/spicy notes are also described as having a sweet component, but with different characters and references (e.g.: Cherdchu et al., 2013; Lee and Chambers, 2007). Therefore, although the 3 cookie samples were designed to be different and pair with a specific tea, the results of the volatile composition suggested that 2 of them could have been considered somehow "congruent" with 2 of the tea samples.

ANOVA results of the consumer test showed significant differences in liking and sweetness perception among the single samples (cookies and teas). The spearmint-tea cookie (MintC) was less liked and perceived as less sweet that the other two samples. Tea samples were similarly liked, but considered different regarding sweetness, being the green tea sample (GreenT) perceived less sweet than the rooibos tea (RooibosT) and red tea (RedT) (Table 3).

Cochran's *Q* test on CATA question results showed significant differences for the mentioned attributes among samples (teas and butter cookies) (Table 4). MintC and GreenT shared descriptors such as spearmint, mint, green tea, and herbal. FruitC and RedT were described with the terms mango, passion fruit, tropical, and fruity. VanillaC and RooibosT were associated with coconut, almond, and vanilla. The term sweet aromatics was linked with both RedT and RooibosT, as well as with FruitC and VanillaC. These results supported the results of the volatile composition characterization, because the RedT and RooibosT shared the sweet aroma but differed in other descriptors. Therefore, results suggested that the samples designed to be aromatically congruent with specific teas were in fact congruent from a sensory descriptors perspective.

Results of the cookie-tea pairings showed no significant differences in liking among the different combinations (Table 5). Significant differences were found in sweetness perception between the combination VanillaC – RooibosT and MintC – GreenT, being the first one perceived as significantly sweeter than the second one. The cookies had a similar base, but different ingredients were added to match the aroma of teas, changing their sensory profile, and making the MintC sample less sweet than the other samples. In addition, the GreenT sample was perceived less sweet (Tables 3 and 4) and more bitter (Table 4) than the other 2 tea samples, and therefore the MintC – GreenT pairing was the least sweet. Bitterness has been reported as having a suppressive effect on sweetness when combined (Green et al., 2010), therefore the bitterness of the green tea may have slightly offset the sweetness of the tea sample and the pairing. Although previous studies have suggested that there is an innate preference for sweet tastes and flavors and a negative bias toward bitter and sour tastes (Ventura and Worobey, 2013), results of the present research did not support these findings, being all tea samples and pairings equally liked.

Table 3
Mean scores and p-values for the liking and sweetness perception of the butter cookies and tea samples. Legend. Different letters within the column indicate different post hoc groupings by Tukey's HSD ($p < 0.05$).

Butter cookie	Liking	$logSweetness_n$	Tea	Liking	$logSweetness_n$
VanillaC	7.2 a	0.21 a	RooibosT	6.1	0.22 a
FruitC	7.0 a	0.15 a	RedT	6.0	0.01 a
MintC	6.3 b	−0.37 b	GreenT	6.1	−0.3 b
p-value	0.001	0.001	*p-value*	0.821	0.002

Even though MintC and GreenT were rated less sweet than the rest of the samples, when combined with non-congruent teas/cookies, sweetness was slightly enhanced (Table 5). Previous research has shown that vanilla could be used to enhance the perception of sweetness in cookies (Romeo-Arroyo et al., 2022). It is known that olfactory stimuli that have regularly been paired with sweet-tasting foods (e.g., vanilla, strawberry) could enhance the associated taste quality (Spence, 2015). Therefore, it is possible that using a pairing with a non-sugary beverage with sweet descriptors (e.g.: RedT and RooibosT, sweet and fruity, and spicy and sweet, respectively) help boosting sweetness. If a beverage such as tea, with no added sugar, can enhance sweetness of an experience/pairing because of its aromatics, it could potentially aid to reduce the quantity of sugar added to the dessert/snack without affecting the enjoyment of the whole experience.

As commented, no significant differences were found in liking between pairings but the pairings that received higher scores were the ones in which the cookie matched the tea (Table 5). The principles of aromatic similarity suggest that pairings of products that share aromatic compounds would be preferred over pairing with less aromatic concordance (Eschevins et al., 2018). Complexity understood as "the combination of flavors and aromas of tea and cookie give rise to a complex pairing" was similarly rated in all pairings. According to Eschevins et al. (2018) and Harrington et al. (2010), complexity enhanced the sensation of "match". The present results did not show differences in complexity between pairings; however, Pearson's correlation analyses suggested a potential positive correlation between complexity and liking (0.762). A higher consumer sample could help confirming or denying this relationship. Paulsen et al. (2015) indicated that complexity was significantly correlated with liking when harmony was rating with high scores.

Significant differences were found for Harmony ("the combination of flavors and aroma of tea and cookie complement each other well"), Similarity ("the flavors and aromas of tea and cookie are similar"), and Balance ("the flavors and aromas of tea and cookie are balanced") among pairings. The pairing VanillaC – RooibosT was perceived as the more harmonious combination, and significantly differed from the pairing of the same cookie with the other two beverages, and from the pairings MintC – RedT and FruitC – GreenT. In general, Harmony was rated with higher scores in the "congruent" combinations, but the RooibosT sample seemed to be harmonious with the 3 cookies samples, probably because the sweet and brown flavor of this tea matched the aroma of the cookies-base. Pearson's correlation showed a positive linear correlation between liking and harmony (0.882), although a higher perceived harmony did not significantly increased liking.

Balance was highly correlated to Similarity (0.958 in Pearson's correlation analyses) and, even though significant differences were found among some pairings in the Balance response, this did not significantly affect acceptance. The most balanced pairing, as well as the most similar, was the MintC – GreentT pairing, being significantly different from the VanillaC – GreenT and MintC – RedT pairings. These results suggested that the idea of aromatic "congruence", supported by the descriptors assigned in the CATA test, could be somehow related to the response given by consumers to the concepts Balance and Similarity. Previous studies have shown that a "harmonic ideal match" has the potential to increase acceptance, whereas a poor balance can move the experience in the opposite direction (Donadini et al., 2012; Paulsen et al., 2015). A similar trend was observed in the present research because the pairing with the lower acceptance scores was the one with the lower Harmony and Balance ratings, although no significant differences were observed in this regard.

The evaluation of food and beverage pairings is a complex task, and it needs to be somehow standardized to ease data gathering and interpretation. Rune et al. (2021) reviewed the methods used in food and beverage pairing research, finding mixed results in terms of methodological approaches, and showing that further research is needed to enable comparing results of the different investigations. In the present

Table 4
Results of the CATA question for the different single samples showing the significant differences among cookies and teas (Cochran's Q test). Legend: bold to indicate the terms which were significantly different among teas and cookies samples but "congruent" in the designed pairing.

CATA Term	Cookies samples				Teas samples			
	VanillaC	FruitC	MintC	*p-value*	RooibosT	RedT	GreenT	*p-value*
Coconut	**0.212 a**	0.094 b	0.071 b	0.012	**0.148 a**	0 b	0 b	<0.0001
Spearmint	0 b	0.047 b	**0.600 a**	<0.0001	0.034 b	0.011 b	**0.670 a**	<0.0001
Mint	0.012 b	0.059 b	**0.553 a**	<0.0001	0.011 b	0 b	**0.807 a**	<0.0001
Almond	**0.412 a**	0.259 b	0.224 b	0.027	**0.057 a**	0 b	0.011 ab	0.030
Mango	0 b	**0.071 a**	0 b	0.002	0 b	**0.261 a**	0.011 b	<0.0001
Passion fruit	0 b	**0.106 a**	0 b	0.000	0.023 b	**0.273 a**	0 b	<0.0001
Green tea	0 b	0.024 b	**0.306 a**	<0.0001	0.011 b	0.023 b	**0.489 a**	<0.0001
Red tea	0.012	0.035	0.024	0.607	0.125 a	0.261 c	0 b	<0.0001
Rooibos tea	0.047	0.012	0.012	0.223	0.250 a	0.114 b	0.011 b	<0.0001
Black tea	0.012 b	0 b	0.059 a	0.030	0.034 ab	0.091 a	0.011 b	0.029
Vanilla	**0.565 a**	0.176 b	0.118 b	<0.0001	**0.420 a**	0.023 b	0 b	<0.0001
Citric	0.047 b	0.694 a	0.082 b	<0.0001	0.011	0.057	0.011	0.102
Sweet taste	0.741 a	0.576 ab	0.400 b	<0.0001	0.102	0.125	0.034	0.084
Sweet aromatics	**0.329 a**	**0.247 ab**	0.129 b	0.009	**0.398 a**	**0.364 a**	0.057 b	<0.0001
Bitter taste	0.047	0.024	0.071	0.368	0.011 b	0.034 ab	0.114 a	0.008
Caramel	0.106	0.071	0.047	0.327	0.227 a	0.034 b	0 b	<0.0001
Herbal	0 b	0.082 b	**0.541 a**	<0.0001	0.068 b	0.091 b	**0.636 a**	<0.0001
Floral	0.012	0.094	0.094	0.056	0.080	0.148	0.068	0.142
Chocolate	0.012	0	0.012	0.607	0.045 a	0 b	0 b	0.018
Berries	0	0.024	0	0.135	0 b	0.250 a	0 b	<0.0001
Tropical	0 b	**0.082 a**	0.035 b	0.025	0.023 b	**0.295 a**	0.023 b	<0.0001
Tasteless	0.047	0.035	0.012	0.368	0.057	0.091	0.045	0.368
Intense	0.106	0.059	0.094	0.522	0.080	0.011	0.068	0.092
Sour taste	0 b	0.200 a	0.024 b	<0.0001	0.011	0	0	0.368
Nutty	0.247 a	0.118 b	0.118 b	0.032	0.034	0.011	0.011	0.368
Fruity	0.024 b	**0.341 a**	0.047 b	<0.0001	0.057 b	**0.420 a**	0 b	<0.0001
Artificial/chemical	0.012	0.047	0.047	0.325	0.045	0.023	0.011	0.097
Spicy	0.153	0.224	0.235	0.368	0.375 a	0.034 b	0.023 b	<0.0001

Table 5
Mean scores and p-values for the butter cookies-tea pairing combinations. Legend. Different letters within the column indicate different post hoc groupings by Tukey's HSD ($p < 0.05$).

Pairing	Liking	$logSweetness_n$	Complexity	Harmony	Similarity	Balance
VanillaC – RooibosT	6.4	0.28 a	4.8	5.2 a	4.4 ab	4.9 ab
VanillaC – GreenT	6.0	−0.06 ab	4.5	4.3 b	2.8 e	4.2 b
VanillaC – RedT	5.9	0.01 ab	4.4	4.3 b	3.1 de	4.2 b
MintC – RooibosT	6.3	0.12 ab	4.8	4.9 ab	4.0 bc	4.7 ab
MintC – GreenT	6.2	−0.25 b	4.5	4.8 ab	5.0 a	5.0 a
MintC – RedT	5.8	−0.13 ab	4.3	4.2 b	3.1 de	4.2 b
FruitC – RooibosT	6.0	0.08 ab	4.8	4.7 ab	3.8 bcd	4.7 ab
FruitC – GreenT	5.9	−0.08 ab	4.3	4.3 b	3.3 cde	4.5 ab
FruitC – RedT	6.4	0.03 ab	4.8	4.7 ab	4.1 bc	4.7 ab
p-value	0.186	0.013	0.053	<0.001	<0.0001	0.001

research, a sequential and mixed approach was used: first, consumers evaluated the cookie and the tea in a sequential tasting method, and then consumers followed a mixed tasting, assessing the beverage and food simultaneously. It is possible that a different methodological approach would have led to slightly different results, but further research on tea-pairings is needed to establish the best method. Some authors have recently suggested the use of temporal dominance of sensations for food and beverages pairings tasting (Di Monaco et al., 2014; Galmarini et al., 2016; Paz et al., 2021), but up to date this method has not been compared with another kind of pairings tasting.

Besides improving the tasting methodology, cross-cultural studies should be conducted to determine the different perception of tea-pairings and their potential utility to encourage healthier diets. Because assessing pairings is a complex matter in which abstract concepts are assessed (e.g.: Harmony, Complexity, Balance), a deeper understanding of consumers' perception of the whole experience is needed, considering cultural differences, and adapting the methodology accordingly.

4. Conclusions

Results from this study provided insights regarding the overall perception of tea pairings with butter cookies from a consumer perspective. Different teas were assessed using a mapping technique and 3 aromatic drivers were identified to group the samples: sweetness, caramel ("brown aromatics"); fruitiness; and herbal notes. The samples selected considering these groups were assessed by a consumer panel and their volatile composition was analyzed, confirming the presence of compounds with descriptors also linked to the consumers' responses. The pairings designed to be aromatically "congruent" with the tea samples were similarly liked as the rest of the pairings, although Harmony was positively correlated to liking, and Balance and Similarity seemed to be related to aromatic "congruence". Sweetness perception was affected by the aromatics of the samples, being the MintC and GreenT samples, and the MintC – GreenT pairing, the least sweet ones. Sweetness perception of the MintC sample slightly increased when paired with the aromatically "sweet" teas (RooibosT and RedT) although significant differences were not detected. Using a "sweet" tea combined with desserts or sugary snacks could be a promising tool for reducing added sugar consumption, but further research should examine the best methodology to develop this kind of pairing study, and the different approaches needed in different cultures (e.g.: depending on tea consumption habits).

Authorship contributions

Elena Romeo-Arroyo: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing - original draft preparation. María Mora: Conceptualization; Data curation; Formal analysis; Methodology. Luis Noguera-Artiaga: Data curation; Formal analysis. Laura Vázquez-Araújo: Conceptualization; Validation; Project administration; Resources; Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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