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Descriptive sensory tests for evaluating *Coffea arabica*: a systematic review

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ABSTRACT

Coffee is a beverage whose price is closely related to the characteristics of its flavor, necessitating reliable sensory tests. To quantify their sensory attributes, classic sensorial methods such as Quantitative Descriptive Analysis (QDA) can be useful. However, uncertainties persist due to protocol variations, which made uncertain the quality of these protocols in evaluating coffee. This study aimed to conduct a systematic review to assess the quality of QDA protocols used for assessing *Coffea arabica*'s sensory attributes. The review encompassed various critical protocols control points, including pre-test procedures, coffee processing and preparation techniques, test application and data collection procedures. It was also summarized key attributes, highlighting factors impacting coffee's sensory traits and bias risk of the studies. As the main results, it was saw that the studies have many limitations, such as not citing or controlling critical points in the tests procedures and application, which made most studies having a medium-high bias rating. The primary sensory results findings of the studies included topics such as the impact of brewing time, chemical compounds associated with sensory attributes and the effect of various roasting techniques on the sensory qualities of coffee. In conclusion, standardizing sensory evaluations in future research could enhance consistency and accuracy, yielding less biased results.

Key words: *Coffea arabica*; coffee; sensory descriptive analyses; systematic review.

1 INTRODUCTION

Coffee is one of the most consumed beverages worldwide, known for its stimulating power caused by caffeine and the antioxidant and anti-inflammatory capacity of other compounds (Saud; Salamatullah, 2021). Its global industry moves billions of dollars annually, produced in more than 60 different countries, standing out Brazil, Vietnam, and Colombia as the biggest producers (United States Department of Agriculture - USDA, 2022).

In the domain of coffee evaluation, sensory analysis plays a central role in understanding and quantifying the sensory nuances that distinguish various coffee varieties and origins. The assessment of coffee's sensory attributes relies on a range of methods, with coffee official protocols (COP) being the most prominent and have been developed to establish standardized procedures for evaluating the quality of coffee. Among the best-known COP methods are the Brazilian Official Classification (COB), the Cup of Excellence (CoE) and the Specialty Coffee Association (SCA). These protocols are rooted in the assessment of sensory attributes that encompass aroma, flavor, acidity, body, and aftertaste (Pereira et al., 2021).

Despite the implementation of the Coffee Quality Protocol (COP), certain recognized biases persist. These include discrepancies in q-graders' observations (Di Donfrancesco; Guzman; Chambers, 2014), the absence of adequate control over the testing environment (Pereira et al., 2019; Pinheiro et al., 2021), the assessment of numerous samples during each session (Feria-Morales, 2002) and not well-established number of tasters (Pereira et al., 2018).

The application of classical descriptive sensory methods to coffee evaluation has a rich history, dating back to the emergence of the specialty coffee industry. Also, these tests provide a structured approach and for requiring high control of test application they can be a good solution to coffee sensory analysis, allowing for the identification and quantification of specific sensory attributes (Pereira et al., 2021). However, the landscape of coffee production and consumption has evolved significantly over time, with new coffee varieties, processing methods, and consumer preferences continually emerging, showing an even greater need for high quality coffee sensory tests (Li; Sakamoto, 2021).

The gold standard method for classical descriptive sensory analyses is Quantitative Descriptive Analysis - QDA®, which has well-defined evaluation processes, trying to control as many as possible biases before, during, and after the application of the sensory analysis (Aguiar; Melo; De Oliveira, 2019). These critical points include extensive training to have calibrated tasters, standardization of samples, well-defined univariate scales, control of the test application environment, and rigorous statistical analysis. QDA® methods also have disadvantages, such as the complexity of following the protocol, high expenditure on training inputs, delay in obtaining final results, among others (Issanchou, 2018).

Because of the rigidity of QDA® protocol studies are adapting it. In order to maintain the quality of these protocols, certain characteristics need to be upheld, such as appropriate training, calibration, and suitable intensity scales. Due to the various adaptations that these tests have been undergoing by the authors, it remains uncertain whether the tests still maintain their quality. Furthermore, few studies evaluated the quality

of quantitative descriptive sensory methods applied to coffee, considering the basic precepts of sensory analysis.

Providing a sensory description of coffee can enhance the product's perceived value, as discerning consumers tend to highly value premium-quality coffee. This, in turn, can lead to the coffee being marketed and sold at a higher price (Bemfeito et al., 2021). In this context, the method to assess this sensory description should be the most accurate and anchored to the principles of sensory science and its precepts for controlling physiological and psychological biases. Therefore, we prospected, through a systematic review, to analyze the quality of studies that applied QDA® methods and adaptations to coffee, with the aim of summarize the quality of the protocols used.

2 MATERIAL AND METHODS

This systematic review was based on PRISMA method (Systematic Reviews and Meta-Analyses), proposed by Moher et al. (2009). The aim of this study was to answer the following research question: 'What is the quality level of the quantitative descriptive sensory tests protocols for evaluating *Coffea arabica*?'

The bibliographic research was performed in 2023, in the following databases: Scopus, Science Direct, SpringerLink, Wiley online library and Web of Science. The complete review protocol with the search strategy will be made available upon request. The eligible criteria were articles that analyzed the sensory of *Coffea arabica*, by descriptive quantitative methods, with no time or language restriction. Excluding criteria were articles that do not focus on the sensory aspect of coffee samples, articles that do not analyzed sensory aspects by descriptive tests, articles that do not analyzed sensory aspect by descriptive quantitative tests, articles that analyzed sensory aspect by cupping or other official coffee protocol, and articles that were not found in full access, without DOI.

For data extraction, only data referring to Arabica type of coffee were considered for articles that had another type of species or sample. Data extraction was performed, based on the following information:

- Pre-test procedures – type of panel (trained, specialists in coffee/q-graders, untrained, etc.), quantity of tasters, hours of training, validation of the tasters training (if applicable), method of the survey of attributes, attributes analyzed;
- Coffee processing and brewing - coffee pre-processing method (fermented or not fermented), coffee processing method (instant, blended, decaffeinated, etc.), coffee methodology and level of roasting (light, medium, dark, other) and coffee type of brewing (infusion, expresso, French press, etc.);
- Test application – local control (cabins, light, temperature, etc.), samples serving control (quantity, temperature, recipient, etc.), saturation of the panel control (number of total samples analyzed, attributes per session, samples per session, available taste-cleansing), biases control (randomized presentation, codified samples, monadic serving, etc.).
- Results procedures – scales used to the collection of attributes, results expressed individually or in consensus, and type of statistical method applied

The main results and purpose of the article on using QDA® were also collected.

To analyze the frequency of the main attributes, only those that appeared twice or more were considered. Attributes that had the same meaning using different terms were grouped (i.e., 'flavor' and 'flavor').

Data quality analyses were performed based on the extracted data and on the study of Aguiar, Melo and Oliveira (2019). The assessed quality criteria were: eliciting their own attributes, having a trained panel, adequate number of tasters, validation of panel training, hours of training, results expressed as individuals (not consensus), use of unstructured scale, adequate type of statistical method, recording coffee roast level and type of brewing, adequate number of samples per session, adequate number of attributes per session, use of monadic, codified, randomized and balanced sample presentation, and perform sensory analyses with more than one repetition.

Based on the classification of Higgins et al. (2008), studies received 'yes', 'no', 'unclear' or 'not applied' for the requirements of three categories. Then based on the results of the sum of suitability they were classified as with low risk (70% or more suitability), medium risk (69 to 50% suitability) and high risk of bias (40% or less suitability).

3 RESULTS

3.1 Data collection

The detailed process of selection of the studies can be seen in Figure 1. The 108 selected articles analyzed were from studies with publication dates between 1971 and 2023. The articles were mainly from Europe (46.9%), North America (20.8%), and Asia (15.4%). Some also were from South America (14.6%), Oceania (1.5%) and Africa (0.8%). Regarding the type of descriptive quantitative sensory tests, 13.9% (n=15) cited performing QDA®, 85.2% (n=92) adapted QDA, and 0,9% (n=1) a time scanning descriptive analysis.

3.2 Pre-test procedures

The complete database with the extracted information will be made available on request. Attributes elicitation was unclear for 46.3% of the studies and from those studies that described this step, 50% (n=54) elicitate the attributes through group discussions during the training process.

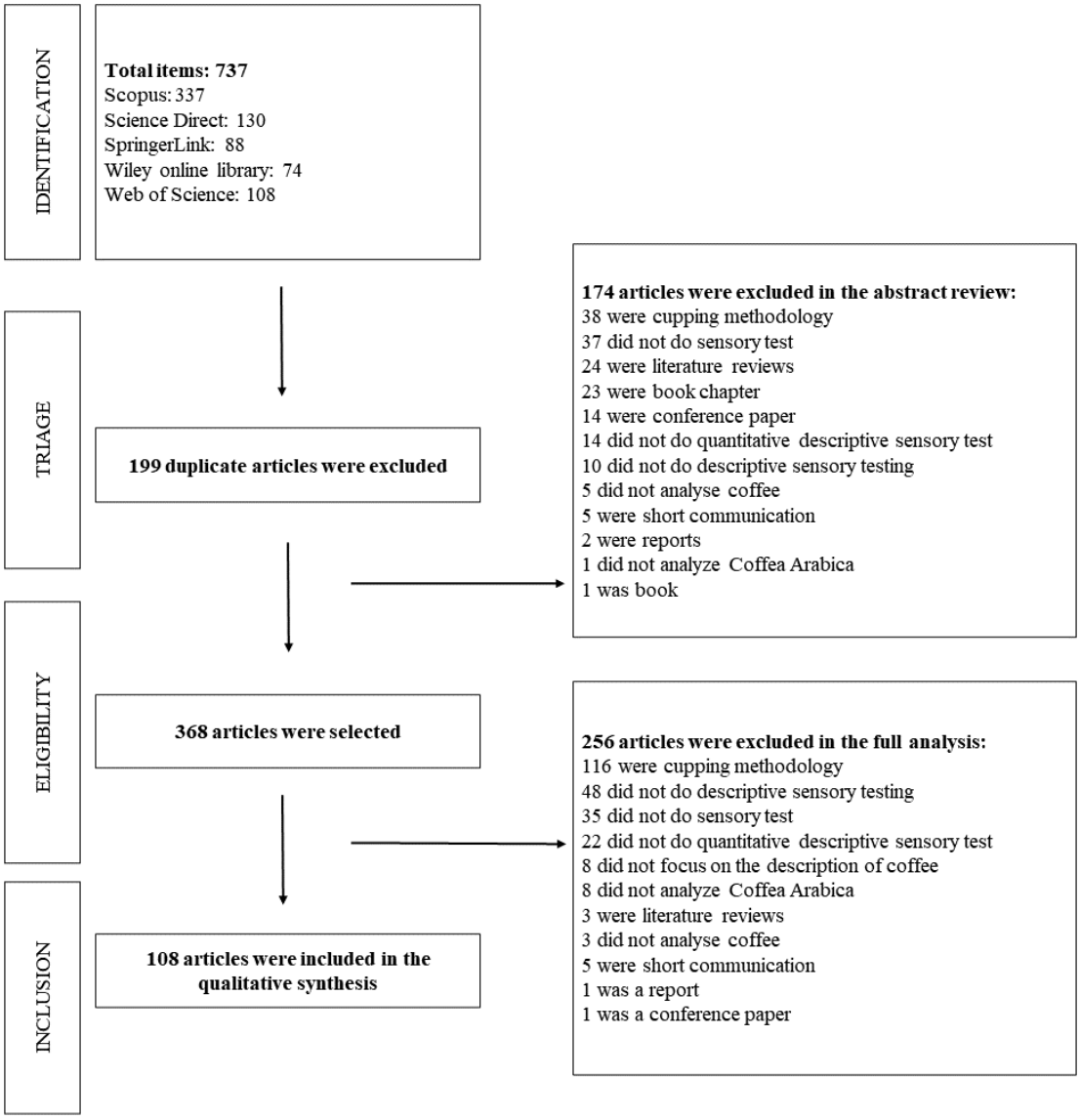

Figure 1: Result of the main attributes evaluated by the studies and their frequency of appearance.

Of the studies found, 16.7% of the studies cited the validation of the panel and 17.6% cited that the panel had the recommended hour of training. Despite that most studies cited using a trained panel (75.0%, n=81) and from the others, 8.3% cited using a panel with sensory analysis experience, 7.4% coffee specialist or q-graders, 2.8% untrained, 0,9% semi-trained and 8.3% did not specify the type of panel used. Also, regarding the training, 8.7% (n=9) studies mentioned using general references and not individual attributes for team training, with these samples having been chosen by the authors for being high-quality coffees.

With regard to the number of tasters, the articles found ranged from 3 to 46 tasters, with an average of 11 tasters, and 35% used fewer tasters than recommended.

The studies evaluated between 1 and 96 attributes with an average of 15 attributes, 47.2% of the studies evaluated between 1 and 10 attributes, 28.7% between 10 and 20, 22.2% more than 20 attributes (from 21 to 96), and 1.9% did not mention how many attributes they evaluated. Separating the attributes by categories, 69.4% studies evaluated aroma or odor attributes, 92.6% flavor or taste attributes, 64.8% mouthfeel attributes (body, astringency, viscosity, etc.), 29.6% appearance attributes, 22.2% general attributes (balance, global impact, overall, etc.) and 0.9% sound attributes. The main attributes evaluated by category can be seen in Table 1.

3.3 Coffee processing to brewing

Almost 72.2% of the articles did not cite the pre-processing method, 47.2% did not cite the level point of roasting and 11.1% did not cite the type of brewing method of the coffee samples.

Table 1: Top 10 main attributes cited by category.

Aroma	Flavor	Appearance	Aftertaste	Mouthfeel	Generalist
Aroma/odor general	Bitter	Color general	Aftertaste general	Body	Overall
Nutty	Sweet	Crema	Bitter	Astringency	Balance
Roast	Acid	Brownness	Astringent	Mouthfeel	Longevity
Chocolate	Sour	Oily	Sour	Viscosity	Quality
Burnt	Roast	Blackness	Flavor	Roughness	Clean cup
Fruity	Burnt	Turbidity	Metallic	Thickness	
Sweet	Nutty	Density		Refreshment	
Coffee	Fruity				
Earthy	Chocolate				
Bitter	Earthy				

Concerning coffee pre-processing, 8.3% used fermented coffee and 22.2% non-fermented coffee. The majority of the studies used the medium roasting point (40.7%), followed by the dark roasting point (23.1 %), and light roasting (26.9%). Regarding the roasting methodology, 2 studies made torrefacto roasting and the others made conventional method. The torrefacto roasting method is a roasting method that adds sugar to the beans to carry out the roasting, in this way, they gain a dark brown, intense aroma and a strong taste with a tendency to bitterness (Ludwig et al., 2013).

Most studies (76.9%) had not gone through any form of processing but of those that were processed, the main form of processing was the addition of an ingredient (20.4%), followed by blended coffee (15.7%), instant (7.4%), capsule (4.6%) and decaffeinated (4.6%).

The main method of brewing was the express technique (22.2%), followed by the drip method (21.3%), the classic cupping infusion method (16.7 %), and the filtered or strained method (14.8%). French press method (13.9%), cold brew (5.6%), and Turkish (3,7%) were also cited, as well as about 13% of other types of coffee preparation procedures. About 11% of the studies do not specify the type of brewing method and 2.8% evaluated the raw grain.

3.4 Test application

To conduct a sensory test with quality, some parameters are recommended to avoid biases related to the application of the tests. This includes individual cabins, adequate light spouse, suitable room temperature, and standardizing samples serving (quantity, temperature, container, etc.). Also, are recommended to control factors such as saturation of the panel, by controlling the number of total samples and attributes per session, and making available taste-cleansing, and in order to avoid association errors, randomizing presentation, coding samples and serving in a monadic way (Issanchou, 2018).

From the studies found, 34.3% of articles cited using individual cabins, 23.1% mentioned lighting control, and 13% room temperature control. In addition, 26.9% cited serving in a monadic way, and half cited randomizing the order of sample presentation and codifying blinded samples.

Almost 40.7% of articles do not cite controlling temperature while serving the samples. In addition, 51.9% of the studies described the recipient used in coffee presentation and 37.0% described the serving size.

The studies evaluated between 2 and 676 samples in total, with 57.4% evaluating from 1 to 10, 20.4% from 11 to 20, 19.4% more than 20 samples, and 3 did not make it clear how many samples were evaluated. About 16.7% of the studies evaluated more than 10 samples per session, 56.5% evaluated more than 10 attributes per session and 44.4% did not cite performing more than one repetition of sensory analysis.

Finally, 48.1% of the studies mentioned that they provided anything to clean the palate between samples, like water and/or crackers, 2.8% for cleaning the smell, and 13.9% specified the pause breaks between samples.

3.5 Results procedures

Most articles used a structured scale (45.4%, n=49), others used an unstructured (35.2%; n=38) scale, and 20.4% did not specify the type of scale used. The main scales used were a 15-point scale (0-none to 15-strong) and a 10 cm-unstructured scale (0-no detection to 10-strong intensity). Even so, 7.4% cited having results given by the team's consensus. In data analysis, 50.9% used inferential analysis, 33.3% used descriptive analysis (media and standard deviation) exclusively, and in 15.7% of cases, the method was unclear.

3.6 Risk of bias (RoB) assessment

Considering every phase of QDA® examinations, merely 10.2% of the investigations exhibited a low RoB, while 44.4% displayed moderate RoB, and 45.4% demonstrated a high RoB. Notably, the 'Pre-test' category showed the least adequacy, closely followed by the 'Test execution' stage (refer to Figure 2 for details). The complete table with individual article risk of bias ratings will be made available if required. The individual articles results of the RoB classification of the studies can be seen in Table 2.

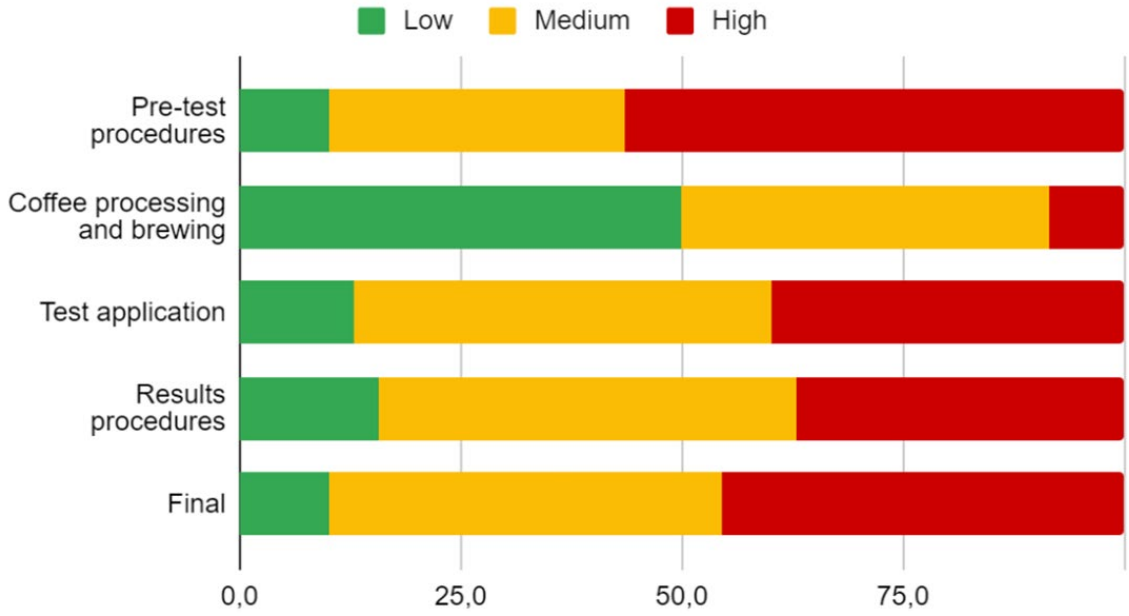

Figure 2: Risk of bias by assessed category.

Table 2: Result of the data extracted from the articles regarding main results and final classification of risk of bias.

Authorship	Main results	Risk of bias
Pangborn, Trabue and Little (1971)	Bitterness and sourness were the predominant flavor characteristics ascribed to coffee beverages prepared from distilled water and mineral solutions. Distilled water resulted in a beverage quite bitter and sour.	High
Williams and Arnold (1985)	Tests had similar descriptive results.	High
Wada (1987)	The samples were divided into 7 distinct groups defined by differences in sensory characteristics. However, the aroma profiles of the 32 Arabica coffee samples could not be characterized by multivariate analysis.	High
Morales (1989)	There is sort of changes in coffee, aroma and flavour, which occur as a result of keeping a freshly brewed coffee on a hot-plate 30 minutes holding-time at a temperature around 82 °C, can be considered to be the maximum for retaining flavour and mouthfeel quality of fresh coffee.	High
Rosa, Barbanti and Lerici (1990)	For those products stored at low temperature (ST < 5ºC), the sensory response is independent of the storage time; on the other hand, for storage temperatures higher than 5ºC, the beverage acceptance decreased faster the higher the storage temperature.	High
Gower and Dijksterhuis (1994)	It was demonstrated the feasibility of the GPA kind of analysis, especially combining information on quantitative and categorical variables.	High
Calvino, Zamora and Sarchi (1996)	The statistical methods showed similar results in the evaluation of the samples.	Medium
Prakash et al. (2000)	Pure instant coffee samples without any added flavor were high in coffee aroma and overall quality. In the case of RandG coffee, the experimental blends made using arabica bean, pea berry and chicory were found to be higher in coffee aroma and overall quality. Other commercial samples lacked coffee aroma and had higher musty, stale and fermented notes.	High
Mayer, Czerny and Grosch (2000)	Higher impact of both methional and the formate on the aroma of the brew and the lower aroma activity of 4-vinylguaiacol.	High
Cantergiani et al. (2001)	The defect sample was characterized as earthy/musty/mouldy and slightly chemical/medicinal.	Medium
Maeztu et al. (2001)	The main differences found in the samples were related to sensory parameters related to foam chemical characteristics and espresso flavor. The torrefacto samples presented more body and dark foam	High

Continue...

Table 2: Continuation.

Authorship	Main results	Risk of bias
Bücking and Steinhart (2002)	Coffee attributes were reduced more strongly by coffee creamer (10% fat) than by UHT milk (UHT milk; 0.3% fat). In contrast, milk-like attributes were enhanced more strongly by coffee creamer than by UHT milk. With the exception of the attribute "caramel", which increased after the addition of sucrose, all attributes showed lower intensity in the drink with sucrose.	High
Andueza et al. (2002)	Coffees prepared at 11 atm had the worst sensory quality, while those prepared at 7 and 9 atm had different foam characteristics. Coffees prepared at higher pressures had more key odors detected, and the sensory results were in accordance with the value of odor intensity obtained.	High
Kaneda et al. (2003)	The adsorption and desorption behavior of beverages on the lipid membrane in the buffer system could simulate the bitter reception reactions on the tongue, so that they could reasonably measure the sensory bitter characteristics, such as bitter intensity and duration.	High
Andueza et al. (2003)	The ideal grinding degree for obtaining a good quality espresso with natural A20:R80 was fine, however, for A20:R80 50% roasted, the ideal grinding degree was coarse.	Low
Decazy et al. (2003)	Most appreciated coffees were from Olancho and El Paraíso, altitude less than 1000 m and precipitation less than 1600 mm/a, having as main characteristics aromatic, slight bitterness, acidity, body.	Medium
Esteban-Díez and González-Sáiz; Pizarro (2004)	It is possible to use the NIR technique or a similar methodology in on-line or routine applications to predict the sensory quality of espresso samples from their respective roast spectra.	Medium
Narain, Paterson and Reid (2004)	Using the vocabulary created of 26 terms, 18 attributes were significant. Attribute distribution supported association to roast height, with aroma notes such as nuts and roasted linked to cluster 1 and fruity to cluster 3.	Medium
Avelino et al. (2005)	Coffee quality depends on the terroir, altitude and slope exposure.	Medium
Parat-wilhelms et al. (2005)	Pasteurized milk with a reduced fat content of 3.5 to 1.5% and with finer fat globules mainly affect coffee flavor and retronasal odor descriptors of white coffee beverage.	High
Geel, Kinnear and De Kock (2005)	Four types of consumers with different tastes were found, one preferring pure coffee, another coffee with added ingredients and two who did not prefer any.	High
Bonnländer et al. (2006)	The descriptive profile of the samples indicated that R-linalool elicits honey, flowery and caramel notes in espresso coffee. The intensity of the perception increases with increasing concentration. The sensory behavior of the S-isomer is ambiguous: in low concentration it elicits a woody note, which disappears with the increasing concentration of the compound and is substituted by an intense flowery note.	Medium
Boeneke, Mcgregor and Aryana (2006)	A fresh cold espresso drink sweetened only with sucrose would be the preferred formula and sugar was the ingredient that most impacted the characteristics analyzed.	Medium
Andueza et al. (2007)	Only some sensory attributes, such as bitterness, astringency and burnt, acrid and earthy/musty flavours were proposed as relevant to the selection of coffee water concentration in conventional roasted coffees and torrefacto roasted coffees.	High
Boeneke et al. (2007)	The trained panel found that as the degree of roast increased, the coffee flavor intensity increased. The between and French roasted treatments were shown to have a more intense flavor by the trained sensory panelists.	Medium
Kim et al. (2007)	Control sample, added sucralose and sucralose/acesulfame mix 75:25 and 50:50 had higher sweetness, caramel flavor, vegetable cream flavor, mouth coating, viscosity. Mix of 25:75 sucralose/acesulfame showed greater acceptance by consumers. Addition of sucralose/acesulfame 75:25 was not sensorially different from samples with high sugar concentration.	High
Pérez-Martínez et al. (2008a)	Among all of the tested additives, both sodium carbonate and sodium bicarbonate were the most effective to keep the coffee brew quality longer. In fact, a shelf life of 60days was proposed for these coffee brews, in comparison with the 20 days shelf life established for a coffee brew without additives.	Medium
Pérez-Martínez et al. (2008b)	The sensory analysis revealed that the aroma intensity and freshness of the coffee brews decreased throughout storage at both 25 and 4 °C. The changes in sensory characteristics were more intense in the coffee brews stored at 25 °C compared to those stored at 4 °C.	Medium

Continue...

Table 2: Continuation.

Authorship	Main results	Risk of bias
Pérez-Martínez et al. (2008c)	The storage temperature and the packaging in presence or absence of oxygen influence the changes not only of some typical coffee components, but also of certain sensory characteristics. Thus, the maintenance of coffee brew at 25 °C packaged in the presence of oxygen, results in general, in more accuted and quicker changes in most of the parameters studied than the maintenance of coffee brew at 4 °C packaged in the presence of oxygen and at both temperatures packed in the absence of oxygen.	Medium
Chiralertpong et al. (2008)	The malty, caramel, roasty, and coffee-like flavor intensities were not significantly affected by creamer addition. The roasty and coffee-like ratings both decreased to similar extents in the samples with the two added sweeteners. The ratings for caramel were considerably increased, again to a similar extent, by both sweeteners	Medium
Lindinger et al. (2008)	Sensory attributes citrus, flowery, acid, bitter, and winey are best discriminating the products and at the same time they were predicted most accurately by the instrumental data.	Medium
Seo et al. (2009b)	The sensory attribute pool as qualitative profiling consisted of 74 terms with their definitions and references. The pool included 16 unique sensory attributes specially influenced by Korean culture and linguistics, as well as other ones that had been mentioned previously.	High
Seo et al. (2009a)	The modified descriptive analysis, TSDA, was able to differentiate the coffee samples based on their sensory attributes, which indicates that the TSDA is applicable to hot beverages	Low
Manzocco and Lagazio (2009)	A storage effect was found for all sensory properties considered, with a decrease in bitterness and increase of acidiness and off-flavor scores.	Medium
Bhumiratana, Adhikari and Chambers (2011)	The result of this study indicated that aroma characters of coffee detected by the descriptive panel were mainly affected by the stage of preparation, and also by degrees of roasting because of the formation of aroma compounds.	Low
Aguilar et al. (2012)	The Dominican Republic produces a standard type of coffee which represents more than a third of production, but also different coffees, more full-bodied, or more acidic and fruitier likely to be part of the special coffees.	Medium
Kreuml et al. (2013)	Adverse effects were found on the quality of coffee beverages straight after 9 months storage of roasted coffee beans. After 18 months, changes in intensity of attributes indicates the oxidation processes increased	Medium
Gloess et al. (2013)	Espressi showed a higher concentration of the respective quantities than the lunghi. The overall uptake of coffee components is higher when drinking a lungo and therefore the sensory experience, is lower in a lungo.	High
Bicho et al. (2013)	The level of roasting influenced the sensorial characteristics of the samples. In Arabica coffee, maximum values were obtained in roast time T2 (9 min) for the acid flavor and overall quality but the other attributes showed the highest values in roast time T3 (11 min).	High
Chung et al. (2013)	The temperature and time for roasting coffee beans prior to brewing significantly affected the browning index, antioxidant activity, sensory color, aroma, and overall acceptability of the brews.	High
Masi et al. (2013)	Brews from coffee treated at temperature lower than 150 ◦C showed a sensory profile characterized by “no-coffee” attributes and resulted the less preferred by regular coffee consumers.	Medium
Ribeiro et al. (2014)	The physical, chemical and sensory characteristics of all samples allowed to obtain espresso coffee beverages with high quality, optimized with a higher content of bioactive compounds and peculiar characteristics when compared with other commercial blends.	Medium
Di Donfrancesco, Guzman and Chambers (2014)	The results indicate that the cupping method and sensory descriptive methods provide different information that cannot be used as an alternative to each other when describing coffee products.	Medium
Van Doorn, Wuillemin and Spence 2014)	The colour of a container influenced people’s ratings of the taste/flavour of a warm beverage.	High
Rendón, Salva and Bragagnolo (2014)	During the entire storage period, semi-washed coffee showed higher intensity of “rested coffee flavour” than natural pulped coffee.	Medium

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Table 2: Continuation.

Authorship	Main results	Risk of bias
Pereira et al. (2014)	The use of these starter cultures in wet processing resulted in coffee beverages with modified flavors, which reveals that yeasts have a complementary role when associated with coffee quality through the synthesis of yeast-specific volatile constituents.	High
Sanchez and Chambers (2015)	The main result related to sensory analysis is that the brewing method used to prepare coffee affects the intensity of flavor and mouthfeel attributes of the coffee samples.	High
Min et al. (2015)	The taste of a coffee mix is affected by the ingredients mixed into the coffee. The effects on the fragrance were confirmed in two types of coffee whiteners, but were more pronounced in the high-fat, viscous coffee creamer than in skim milk powder.	High
Conti and Prudencio (2015)	The degree of roasting of the beans was more critical than the coffee category (Traditional, Premium, Gourmet, Jacu and Civeta) for the sensory characteristics of the beverage.	Low
Masi et al. (2015)	Consumers with a higher number of fungiform papillae added more sugar to their coffee and gave higher flavor scores to the sweetened coffee samples than consumers with a low density of fungiform papillae. Coffees were mainly discriminated according to the degree of roasting.	Medium
Várvölgyi et al. (2015)	The sensory analysis gave quiet the same result as the GC–MS regarding the odor attributes. The electronic tongue measurement was suitable for distinguishing the types of coffees the electronic tongue and GC–MS analysis can just complete sensory analysis, they cannot be completely replaced.	Medium
Stokes, O'sullivan and Kerry (2016)	Coffee served at lower temperatures of 40.1 °C and below lacked the desirable sensory attributes compared with coffee served at the higher temperatures above 70.8 °C	Medium
Kıvançlı and Elmacı (2016)	For all samples the most intensely perceived flavor characteristic was found to be roasted/burnt character. The volatile composition and flavor of Turkish coffee is different than other coffee beverages such as espresso and filter coffee.	High
Jaramillo, Arango and Gutiérrez (2016)	If the water is brought to its maximum temperature and the beverage is taken from the first 30 seconds you can capture many coffee flavors.	High
Arango, Mejía and Agatón (2016)	It is possible to create a blend with 100% Arabica coffee from different regions of the country, making excellent espresso.	High
Kawaguchi et al. (2016)	The sensory characteristics of the flavored dairy beverages were significantly influenced by homogenization pressure.	High
Stokes, O'sullivan and Kerry (2016)	Instant coffee had less acceptance and lacks the desirable aromas and flavors associated with fresh filter coffee as determined from the descriptive analysis.	Medium
Labbe et al. (2016)	Crema is an important component of the coffee espresso experience since its absence induced low expectations in coffee espresso quality, overall taste, bitterness and smoothness	Medium
Pereira et al. (2016)	The inoculated process resulted in a complex coffee beverage, with noticeable hints of fresh fruit like banana, orange and pineapple, and full bodied with very smooth sensation due to the lactic acid.	Medium
Han, Kim and Lee (2017)	There was influence of storage temperature, presence of lid and time of analysis in the samples.	Medium
Steen et al. (2017)	The serving temperature of coffee influenced the intensity of flavour. The release of volatiles from the BourbonCaturra coffee was exuberated above 40ºC and coffee below 44 ºC facilitated the translucence of non-'roasted' coffee flavours.	Low
Siebert, Berger and Nieter (2018)	The enzymatic treatment did not significantly affect the aroma and taste profile of filter coffee.	Medium
Scholz et al. (2018)	The combination of latitude, longitude, temperature and altitude was efficient in characterizing a terroir and allowed for the identification of modifications in the chemical composition and sensory attributes.	Medium
Siebert, Berger and Nieter (2018)	The treatment of brewed coffee with *Rhizoctonia solani* enzyme solution at ambient temperature is a simple and effective technique to improve health beneficial properties of the beverage without noticeably changing the aroma and taste profile.	Medium
Angeloni et al. (2019)	The sensory evaluation found differences in flavor profiles, as measured in terms of bitterness, sweetness, sourness and global intensity. Cold drip coffees were recognized as being more bitter.	Medium

Continue...

Table 2: Continuation.

Authorship	Main results	Risk of bias
Giacalone et al. (2019)	The results indicated a significant increase in aroma compound concentration associated with prolonged roasting time and temperature, resulting in an increase in sensory attributes typically associated with the roasting process and flavor intensity. Normal roast generally obtained values close to average with respect to sensory attribute intensity and aroma compounds concentration.	High
Pineau et al. (2019)	Machine parameters influence appearance, modulate specific odor and flavor attributes, but only marginally impact taste/aftertaste. The high actionability of a two-step data analysis approach, which has actually proven to be efficient to drive product innovation and renovation in hundreds of cases covering multiple food and beverage categories.	High
Scholz et al. (2019)	The beverage sensory attributes depended on the concentration of proteins, lipids, and sucrose in combination to CQA isomers in beans, varying over the vertical profile and planting designs of coffee plants.	High
Di Donfrancesco et al. (2019)	The three sub-regions of origin, the different altitude of the farms, shading level or processing factors such as fermentation and drying, did not seem to produce homogeneous differences among samples. It is also likely that differences were ameliorated by a combination of effects such as an interaction of altitude, temperature, shading, and fermentation.	High
Paulino et al. (2019)	A preference for the blends that included the different specialty coffees reflected a more discriminated response to the RC (Roasted Coffee) components. including random parameters in the model, represented by the experiments, made it possible to compare the effect of each component simultaneously for each of the experiments.	High
Chapko and Seo (2019)	Brewed coffee samples served at 70 and 55 °C differed with respect to sensory attributes from those served at 40 and 25 °C. Product temperature-induced changes in sensory perception were observed in both fresh and old (served 15 min and 90 min after brewing, respectively) brewed-coffee, indicating that changes in sensory perception were due to product temperature, but not a confounding factor such as freshness level of brewed coffee.	Low
Bhumiratana et al. (2019)	In general, coffee aroma, citrus, and acidity elicited negative feelings while cocoa aroma, tobacco, bitter, roast, burnt, and body generated positive emotions.	Low
Siridevi et al. (2019)	Organoleptic characteristics of starter fermented coffee records better quality compared to natural fermented coffee.	High
Frost, Ristenpart and Guinard (2019)	Factor analysis showed roast as the primary source of variation, geometry, independent of the other two factors, altered three attributes, and grind influenced six attributes. Geometry, although not as significant a driver compared to very different roast levels and a large difference in grind size, still showed unique interactions.	Medium
Orfanou, Dermesonlouoglou and Taoukis (2019)	The lowest loses of coffee shelf life were at aw = 0.52 at T = 35 °C to 45 °C. The temperature dependence of aftertaste, aroma quality loss, and off-flavor production was not statistically significant for $0.15 < aw < 0.33$ ($P > 0.05$); the aroma intensity was the most sensitive parameter.	High
Adhikari, Chambers and Koppel (2019)	There was no interaction between temperature and coffee type, in general the sensory properties were most intense at 70 °C for coffee.	High
Zhang et al. (2019)	The fermentation duration was found to have the greatest impact on the sensory quality of the brews, followed by the processing type and the application of a soaking step. A long fermentation duration had a positive impact on the fruity and acidity notes and a negative impact on the cereal and floral notes.	High
Scholz et al. (2019)	The sensory evaluation showed significant differences in coffee and sweet aromas and sweet and acid tastes between the years and processes. The MFA technique enabled the simultaneous analysis of the groups of variables acquired on the same set of samples without the predominance of a group of variables in the description of the samples because the influence is balanced.	Medium
Song, Hwang and Lee (2019)	The sensory evaluation of the eight commercial cold brew coffee samples revealed significant differences in most sensory attributes, except for “fruit” aroma, “dark chocolate” aroma, “bitter” aroma, and “sweet” taste. Titratable acidity and soluble solids showed significant positive correlations with earth aroma and smoothness characteristics.	High

Continue...

Table 2: Continuation.

Authorship	Main results	Risk of bias
Cui et al. (2020)	Roasted coffee beans had significant differences in baked, chocolate-like, and herbal flavor, and Nankang coffee had a stronger baked flavor than the other three samples. In ground powder coffee, there was no significant difference among different samples. In brewed coffee, the sour attribute had significant differences among different samples, and acidity was also rated higher than that of baked coffee beans and ground powder coffee.	Medium
Ramírez-Rivera et al. (2020)	The Analytic Hierarchy Process technique is a reliable alternative for the selection of sensory attributes.	High
Seninde, Chambers and Chambers (2020)	The results showed that the sensory characteristics of the coffee were influenced by the degree of roasting, coffee to water ratio, and brewing method. The degree of roasting influenced the bitterness and other sensory characteristics of the coffee samples. A higher coffee to water ratio coffees were characterized by significantly higher intensities for attributes. Samples that were brewed using the slow-drip method had a darker brown color and higher intensities for coffee-like flavor attributes.	Medium
Frost, Ristenpar and Guinard (2020)	Flavors and mouthfeels were shown to increase with both total dissolved solids (TDS) and percent extraction (PE), while several increased with TDS but decreased with PE. Importantly, sweetness exhibited an inverse correlation with TDS irrespective of roast, while dark chocolate flavor and blueberry flavor decreased with TDS for medium roast.	Medium
Muñoz et al. (2020)	A large number of phenolic compounds and high antioxidant capacity were observed in green coffee than roasted one. Identification of the antioxidant properties of both types of coffees and linking them with their sensory qualities, can lead to more satisfying outcomes.	High
Münchow et al. (2020)	The direction of the effects for both colour and time were similar, with darker roasts/ longer roasting times associated with an increase in bitterness and a decrease in acidity, fruitiness, and sweetness. Toasting time keeped colour constant and had a systematic effect on flavour.	High
Batali et al. (2020)	Some sensory attributes in brewed coffee are negatively correlated with total dissolved sugars. Perceived sweetness was not due to any monosaccharides extracted during the brew, since both the total and free monosaccharide concentrations were well below the detection threshold of any sugars.	Low
Alstrup et al. (2020)	Fast roasting favored a chemical composition that offers a higher sensory perception of Fruitiness, Sweetness and Acidity in the cup. Longer development times led to a change in the chemical profile, providing a more Roasted, Nutty+Chocolate, and Bitter sensory perception.	Medium
Khamitova et al. (2020)	Arabica samples with different heights of perforated discs (4 mm-7 mm) highlight that the highest sweetness and aftertaste are found particularly in 4 mm, in filter basket B with 14 g, and in filter basket A with 12 g.	High
Quintero et al. (2021)	Deterioration reactions for concentrated coffee stored at 25 ◦C first trigger an aroma reduction, followed by an increase of undesirable acidity, which is essential to understand the development of these sensory attributes and their relationship with the chemical composition of the product.	Medium
Córdoba et al. (2021b)	Cold dripping method generated beverages with higher bitterness and roasted flavors, and cold immersion and hot brewing (French Press) coffee beverages showed remarkable intensity in sweetness attributes.	Medium
Elmacı and Gok (2021)	The results of the sensory analysis indicated that the flavor characteristics of Turkish coffees was significantly influenced by roasting method. Turkish coffee samples prepared from fully washed–lightly roasted beans were generally perceived to be significantly different than brews prepared from natural–lightly roasted beans. However, flavor attributes that were significantly different at light roasting were no longer different in medium and dark-roasted natural and fully washed beans. Several perceptual differences were observed in between two panels due to the difference in language and culture.	Medium
Gao, Tello and Peterson (2021)	Three of the ten compounds evaluated, namely 4-caffeoylquinic acid, 5-caffeoylquinic acid, and 2-O-β-D-glucopyranosyl-atractyligenin were identified as bitter modulators in coffee, and significantly decreased the perceived bitterness intensity of the brew.	High

Continue...

Table 2: Continuation.

Authorship	Main results	Risk of bias
Rabelo et al. (2021)	Only with the presence of 10.8% of Quaker beans in a tasting cup, the beverage of coffee is negatively altered. Quaker beans caused greater astringency and bitterness to the beverage and negative aroma and flavor sensory notes.	Medium
Vezzulli et al. (2021)	There was generally a good discrimination of the three roasting levels by increased perception of roasted taste, bitterness, spicy notes, body, odour intensity and darkness of 'crema' colour from light to dark roast; at the counter part, a decrease in astringency, acidity and vegetable notes was observed.	High
Córdoba et al. (2021)	Results indicate that coffee bean quality affects the sensory attributes in hot and cold coffee brewing. Cold and hot brew coffees are better differentiated by the brewing method than by coffee bean quality.	Medium
Batali et al. (2021)	Perceived sour intensity correlates weakly with pH, but strongly with titratable acidity	Low
Šeremet et al. (2022)	Bitterness, astringency and acidity were more pronounced in espresso than in Turkish and filter coffees. Arabica decaffeinated brews were evaluated as more bitter.	High
Ma et al. (2022)	The sensory wheel constructed from the lexicon showed that Yunnan coffee had unique sensory characteristics. Different roasting levels affected the sensory properties of Yunnan coffee, with darker roasts having more bitter and burnt flavors.	Medium
Roman-Maldonado et al. (2022)	Vanilla-smell and nutty aroma were the main drivers of liking for cluster 1; astringency, acidity and bitterness for cluster 2 and roasted smell and taste for cluster 3. The drivers of disliking were green, earthy and roasted notes for cluster 2.	Medium
Quintero et al. (2022)	Acceptance of concentrated liquid coffees was associated with improved aroma, sweetness, and global score, as with lactones such as feruloyl-quinolactone, caffeoyl quinolactone, and 4-caffeoyl-1,5-quinolactone, and significant oxygen levels in the headspace. Elevated acidity resulted in rejection.	Medium
Lomolino et al. (2022)	The sensory analysis of the espresso and moka coffees seemed to confirm that for the same coffee, the extraction method changes the profile of the beverage's perceptions. Coffee with moka, extracted at low pressures, has much lower sensory profiles than the two espresso coffees obtained at high pressures. Different pressure intensities to the coffee extraction affect the quality of crema and the solubilization of organoleptically active compounds.	High
Chung et al. (2022)	Negative drivers of liking were rancid oil, greasy, astringent, and rice bran. For all consumers, the more similar a plant-based milk coffee was to dairy milk coffee, the more positive sensory experiences were perceived.	Medium
Elmaci, Gok and Tokusoglu (2022)	The combination of roasting and brewing techniques results in a unique sensory property. Turkish and Brazilian assessors perceived the coffee samples differently, especially in sweet, sour, and pungent attributes.	Low
Vezzulli et al. (2022)	Caffeine accumulated highly in Filter vs. Espresso, although at the sensory profile, bitterness was more perceived in Espresso. Vegetal aroma carried by pyrazines, pyridines, and phenolic acids were markers of Espresso. The extraction process played a hierarchically higher role in driving the chemical composition of the beverages when compared to coffee specie.	High
Rune et al. (2022)	All solutions were found to influence the perceived attribute intensity of coffee, although the specific effect directions were dependent on the basic taste (BT), the coffee, and attribute. Only exposure to the BT bitter increased the intensity of more attributes than it decreased.	High
Batali et al. (2022)	Brew temperature had a significant impact on the sensory properties of coffee. There were far fewer differences between room (22 ◦C) and refrigerator (4 ◦C) temperature brews than between either of those temperatures and the hot (92 ◦C) brews.	Low
Pinsuwan et al. (2022)	Results indicated that coffee ID, roasted, ashy, pipe tobacco, bitter taste, rubber, overall sweet, balanced/blended, fullness and longevity were the key sensory attributes driving liking. While sour aromatic, sour taste, fruity, woody, musty/earthy, musty/dustyand molasses decreased liking. An increased roast level from light to dark tended to increase the intensities of desirable attributes, while decreasing the intensities of undesirable attributes.	Medium
Carcea et al. (2023)	The lower is the roasting temperature, the higher is the acid taste in the espresso. Cream and body of drink are increased as roasting temperature increases.	High

Appropriate quantity of training hours was reported by 17.6% of the studies and 16.7% confirmed the alignment of the panel or the reproducibility of tasters by analyzing the p value of analysis of variance. The coffee processing description category was the one with the highest amount of adequacy as 50% of the articles had a description of the infusion and roasting method. The other 41.7% contained one process and 8.3% neither.

The use of individual was specified cabins 34.3%, and 26.9% indicated adherence to a monadic approach. In contrast, the remaining categories (randomized way of serving and codified samples) achieved a 50% adequacy rate, contributing to a substantial RoB in the test application process. Because of the lack of information and high inadequacy in the way of applying the tests, 13% of articles were found with low risk of bias, with 47.2% with medium risk and 39.8% with high risk in this category (Figure 2).

About the results procedures, most studies evaluated the results individually and not in consensus, half applied inferential analysis and 31.5% used an unstructured scale while the others used structured scale, which resulted in a low amount of low risk, but many studies with medium risk of bias.

3.7 Objectives and main results of the studies

The main objective and results of the studies can be seen in Table 2. The studies were found using the quantitative descriptive analysis mainly associated with changes in the preparation of the beverage (15.7%) – different brewing methods, different water types, different coffee to water ratio, among others. -, evaluating the relationship between chemical and sensory characteristics (13.0%), changes in the roasting process (13.0%) and the addition of ingredients (11.1%) – milk, sweeteners, fruit flavors, etc.

To a lesser extent, they also used the sensory method to observe storage effects (i.e. temperature, time, oxygen exposure), different serving modes (serving vessel and serving temperature), sensory characteristics related to consumers (i.e. preference for pure coffee, processed coffee, coffee with ingredient addition), statistical methods to analyze sensory results, different post-harvests processes, to characterize varieties, edaphoclimatic conditions (i.e. coffee from different altitudes, climates, rain level), physical and sensory characteristics, to compare sensory tests (classical QDA versus free-choice profile, time scanning and cupping) and to develop a sensory vocabulary.

Research into the influence of various additives on the sensory characteristics of coffee has produced diverse findings. Chicory and pea berry were found to have a positive impact in instant coffee, but in the same study fruit flavors showed a negative impact (Prakash et al., 2000). Creamers showed mixed results, with a negative impact in blended coffee in one study (Bücking; Steinhart, 2002), but in others the creamers seam not to have influenced the sensory attributes (Chiralertpong et al., 2008) and having a positive impact (Min; Kwon; Park, 2015). Sweeteners also showed mixed results depending on the type of sweetener, with sucrose and sucralose being more preferred and more positively associated with sensory attributes (Boeneke; Mcgregor; Aryana, 2006; Bücking; Steinhart, 2002; Kim et al., 2007; Min; Kwon; Park, 2015).

Different types of processed milk (Parat-Wilhelms et al., 2005) and basic tastes solutions were found having a significative influence on coffee sensory attributes as also shelf-life extenders, with sodium carbonate and sodium bicarbonate being most effectives to keep the coffee brew quality longer (Pérez-Martínez et al., 2008a). R-linalool and s-linalool (Bonnländer et al., 2006) and cocoa, coffee silver sink and golden coffee (Ribeiro et al., 2014) showed positive impact on sensory notes, while enzyme of *Rhizoctonia solani* do not showed influence on sensory attributes (Siebert; Detering; Berger, 2019), but all of these compounds showed a benefit of adding nutritional properties to the beverage.

The sensory quality of coffee can be influenced by storage methods. It appears that lower temperatures help preserve its sensory characteristics over time, whereas higher temperatures can lead to decreased acceptance and alterations in its attributes (Orfanou; Dermesonlouoglou; Taoukis, 2019; Pérez-Martínez et al., 2008b; Rosa; Barbanti; Lerici, 1990). The presence of oxygen in packaging has been observed to expedite changes in coffee components and sensory traits, while the duration of storage can reduce bitterness, and increase acidity, but potentially compromise overall quality (Pérez-Martínez et al., 2008c). Furthermore, the length of storage time has been linked to a reduction in the intensity of most sensory attributes (Kreuml et al., 2013) and an increase in acidity and off-flavor scores (Manzocco; Lagazio, 2009; Quintero et al., 2021).

Grain defects, such as earthy/musty and chemical/medicinal characteristics (Cantergiani et al., 2001) and "Quaker" beans (Rabelo et al., 2021), negatively affect coffee's sensory quality. However, one study found that the brewing method was more important to differentiate the samples than the grain's quality (Córdoba et al., 2021c). Processing methods also were assessed, with the evaluation of blends of coffees from different geographical origins for making a good quality espresso (Arango; Mejía; Agatón, 2016). Enzymatic treatment of grains succeeded in breaking down chlorogenic acid for better grain and beverage quality (Siebert; Berger; Nieter, 2018).

Various analytical tools and methods have been employed to predict sensory quality in research. For instance, studies have utilized analytical instruments like those examining lipid membrane behavior (Kaneda et al., 2003) and Near-infrared (NIR) techniques (Esteban-Díez; González-Sáiz; Pizarro, 2004). Additionally, fast online analytical approaches (Lindinger et al., 2008), GC-MS analyses (Várvölgyi et al.,

2015), and LC-MS (Quintero et al., 2022) have contributed to predicting sensory quality.

Furthermore, some studies have revealed correlations between specific chemical properties and sensory attributes. For example, pH, titratable acidity, and soluble solids were found to be linked to sourness (Batali et al., 2021; Song; Hwang; Lee, 2019), while flavors and mouthfeels were observed to increase with higher levels of total dissolved solids and percent extraction (Frost; Ristenpart; Guinard, 2020).

Moreover, certain chemical compounds have been associated with particular sensory characteristics. For instance, methional and formate have been linked to aroma (Mayer; Czerny; Grosch, 2000), acids have been associated with bitterness (Gao; Tello; Peterson, 2021), and macronutrients, sugars, caffeine, and phenolic compounds have shown relationships with various sensory attributes (i.e., sweetness, bitterness, among others) (Batali et al., 2020; Muñoz et al., 2020; Scholz et al., 2018; Vezzulli et al., 2022).

In four studies, factors related to edaphoclimatic conditions were evaluated with sensory descriptive analysis, such as altitude, precipitation level and temperature, with all studies founding that these factors have an influence on sensory beverage characteristics, such as aroma, bitterness, body and acidity (Avelino et al., 2005; Decazy et al., 2003; Di Donfrancesco; Guzman; Chambers, 2019; Scholz et al., 2018).

In other five studies the effect of fermentation and different vias of post-harvest processing were evaluated, founding that fermentation with staters cultures influenced positively beverage characteristics such as flavor and aroma (Pereira et al., 2014, 2016; Siridevi et al., 2019; Zhang et al., 2019) and that the post-harvest vias wet or semi-wet can influence significantly the coffee aroma, sweetness and acidity (Scholz et al., 2019)

The degree of roasting (Bhumiratana; Adhikari; Chambers, 2011; Boeneke; Mcgregor; Aryana, 2007; Conti; Prudencio, 2015; Cui et al., 2020; Elmaci; Gok, 2021; Vezzulli et al., 2021), the duration of roasting (Alstrup et al., 2020; Bicho et al., 2013; Chung et al., 2013; Giacalone et al., 2019a; Münchow et al., 2020), roasting temperature (Carcea et al., 2023; Chung et al., 2013; Giacalone et al., 2019a; Masi et al., 2013), and the roasting method (Maeztu et al., 2001) all have an impact on the bitterness, acidity, sweetness, aroma, and flavor of coffee. Most of these studies have shown that darker roasts, longer roasting times, and higher roasting temperatures are associated with increased bitterness and decreased acidity, fruitiness, and sweetness.

Various factors related to coffee brewing have been identified as influential on sensory characteristics, including the choice of brewing method (Angeloni et al., 2019; Córdoba et al., 2021a; Elmaci; Gok; Tokusoglu, 2022; Gloess et al., 2013; Lomolino et al., 2022; Sanchez; Chambers, 2015; Šeremet et al., 2022; Stokes; O'sullivan; Kerry, 2017) that can influence intensity of flavor and mouthfeel attributes, bitterness, sweetness, sourness and others. Also the beverage characteristics can be affected by extraction and homogenization pressures (Andueza; Peña; Cid, 2003; Kawaguchi et al., 2016), the degree of coffee grinding (Andueza; Peña; Cid, 2003), the coffee-to-water ratio (Andueza et al., 2007; Seninde; Chambers; Chambers, 2020), disc height and basket size and geometry (Frost; Ristenpart; Guinard, 2019; Khamitova et al., 2020), as well as the temperature and duration of the extraction process (Jaramillo; Arango; Gutiérrez, 2016).

Espresso pressure extraction at lower than 11 ATM seem to result in better sensory quality (Andueza et al., 2002), while the ideal grinding to this method seen to be the finest (Andueza; De Peña; Cid, 2003). Espresso also seems to have better characteristics than lungo (Gloess et al., 2013) and then moka (Lomolino et al., 2022) method, fresh filtered seems to be better than instant (Stokes; O'sullivan; Kerry, 2016), but Turkish and filter better than espresso (Šeremet et al., 2022).

For the coffee to water ratio, coffees with higher ratios seem to be characterized by significantly higher intensities for attributes (Seninde; Chambers; Chambers, 2020), also being cited influencing bitterness, astringency and burnt, acrid and earthy/musty flavours (Andueza et al., 2007). Higher water extraction temperature seems to capture more flavors (Jaramillo; Arango; Gutiérrez, 2016) and hot brewing methods seem to be more sweet and less bitter than cold ones (Córdoba et al., 2021a).

The choice of serving vessel (Van Doorn; Wuillemin; Spence, 2014), the time interval before brewing (Morales, 1989), and the temperature (Adhikari; Chambers; Koppel, 2019; Batali et al., 2022; Chapko; Seo, 2019; Han; Kim; Lee, 2017; Steen et al., 2017; Stokes; O'sullivan; Kerry, 2016) were also identified as significant factors influencing the sensory characteristics of coffee. Notably, temperature was found to have a pronounced impact on coffee's flavor, aroma, and mouthfeel. Collectively, these studies suggest that coffee served at temperatures below 40.1°C may lack certain desirable flavor and aroma attributes compared to coffee served at temperatures above 70.8°C.

Consumer preferences exhibit variability driven by cultural and personal inclinations. Studies in this realm have revealed that some consumers favored pure coffee, while others lean towards coffee with additives (Geel; Kinnear; De Kock, 2005). Furthermore, the presence of crema in espresso is favored by some (Labbe et al., 2016), and the inclusion of aromas such as vanilla and nutty notes can enhance overall liking (Bhumiratana et al., 2019; Roman-Maldonado et al., 2022). Conversely, undesirable qualities such as rancid oil and greasy notes tend to lead to disliking among consumers (Chung et al., 2022).

The roast level of coffee beans also appears to impact consumer preferences as darker roasts degrees seems to have more desirable attributes by consumers (Pinsuwan et al., 2022). The density of tongue papillae also seen to influence

preferences for sweetness attributes, as consumers with a higher number of this structure were found adding more sugar and giving higher flavor scores to sweetened coffee samples (Masi et al., 2015).

In a series of four studies, a sensory quantitative method was employed to characterize coffee samples from various countries (Wada et al., 1987), specifically from the Dominican Republic (Aguilar et al., 2012), prepared using the Turkish method (Kivançli; Elmaci, 2016), and originating from Yunnan (Ma et al., 2022).

In another set of three studies, QDA tests were conducted to compare them with other sensory evaluation methods. One study involved a comparison with the free-choice profile method (Williams; Arnold, 1985), another with a time-scanning descriptive test (Seo et al., 2009), and the third with a cupping method (Di Donfrancesco; Guzman; Chambers, 2014). Only the study that performed cupping founded that the test performed had discrepant results from the QDA.

Lastly, in five separate studies, various statistical approaches were employed to analyze sensory data. These included Principal Component Analysis and Cluster Analysis (Calvino; Zamora; Sarchi, 1996), Fisher's Least Significant Difference (Pineau et al., 2019), The least squares method (Paulino et al., 2019), Analytic hierarchy process (Ramírez-Rivera et al., 2020) and General Procrustes Analysis (Gower; Dijksterhuis, 1994). All of the studies found that the statistical methods performed were efficient for discriminating sensory characteristics of the samples.

In two additional studies, QDA tests were conducted to aid in the development of a sensory vocabulary for characterizing the samples. (Narain; Paterson; Reid, 2004; Seo; Lee; Hwang, 2009). In certain studies, QDA test was carried out not specifically to analyze sensory alterations, but rather to establish correlations between sensory analysis and physical, chemical, and statistical analyses. Nevertheless, it's important to highlight that caution should be exercised when interpreting these findings due to the potential for bias in the sensory protocols employed in the studies reviewed here.

In summary, several factors have been identified as influencing the sensory characteristics of coffee. Studies suggests that certain methods like espresso pressure extraction at lower pressures, fresh filtered brewing and coffee served at higher temperatures tend to result in better sensory quality. Additionally, the roast level of coffee beans plays a significant role, with darker roasts often being favored for their desirable attributes. Furthermore, the use of certain additives, such as vanilla and nutty notes, can enhance overall liking among consumers. These factors collectively contribute to enhancing the sensory experience of coffee, making it a complex and multifaceted beverage with a wide range of flavor profiles to cater to diverse preferences.

4 DISCUSSION

Coffee is a complex beverage with sensory description being more associated with the quality of samples rather than the quantity of attributes, making it difficult for the panel to distinguish specific attributes (Giacalone et al., 2016). So that, the right choice of attributes, a good panel training and validation process for a descriptive test requires greater care, which was not seen in most of the studies found here.

Attributes elicitation in sensory analysis is carried out considering the main characteristics of the samples in order to be more relevant (Issanchou, 2018). When this procedure is not done or is not well conducted, it can be difficult to know whether the attributes evaluated are actually relevant to describe the samples. This factor was considered problematic for the studies, as almost half of them did not mention having taken this step.

Training, calibration, and validation steps are a set of well-described procedures in QDA and adaptations that differentiates and generates more reliable results than others descriptive methods (Aguiar; Melo; Oliveira, 2019). Also, a panel trained in a non-validated way could generate invalid data with several biases, being recommended by Issanchou (2018) at least 80 hours of sensory training for achieve reliable and consistent level of sensory discrimination. It's concerning that fewer than a quarter of the studies acknowledged this crucial step in classic descriptive analysis.

Another worrying problem in the studies was the portion of articles that did not meet the criterion of the minimum number of tasters required, as the number of judges is critical to the power of statistics in sensory analysis. Stable results in descriptive analysis are generally provided by at least 8 well-trained and validated panelists (Heymann et al., 2012) with some studies suggesting 16 or more for semi-trained panel (Silva et al., 2014).

Pre-processing, roasting, and brewing are the post-harvest procedures that most affect sensory quality, so when these steps are unknown, is not clear whether there are sensory effects of the evaluated treatment itself (Seninde; Chambers, 2020; Velásquez; Banchón, 2023). Many studies omitted details about pre-processing or roasting points, despite mentioning the brewing method, potentially introducing bias into this category.

Also was recurrent in the studies the lack of description of the location and method of applying the tests. The way as classical sensory tests are applied is very important for concentration and good description of the tasters and the location must be suitable, comfortable, with the least number of parallel stimuli and avoiding direct contact or interactions between tasters (Issanchou, 2018).

Little data was also found on controlling how samples were served. It is recommended to serve the samples in a

blinded, monadic, and random way, to avoid comparisons between samples, mismatched attempts, and guesses by the tasters (Issanchou, 2018), besides effects of fatigue or psychological biases. Sample temperature control is also a critical step of sensory analysis since in coffee this temperature can affect attributes felt by tasters, like the aromas that are more felt at higher temperatures (Batali et al., 2022; Chapko; Seo, 2019).

Also considering how the test is applied, the evaluation of more than 10 samples per session is not recommended because it can generate sensory fatigue (Issanchou, 2018) and 2 to 4 repetitions of the analyses are requested for statistical purposes (Kemp et al., 2018). Palate cleansing is considered to be valuable in sensory evaluation to remove any residual before and between samples in order to continually reestablish a baseline oral environment and doing so allows for the least influence on perception thereby providing more reliable result (Vickers; Morris; Savaria, 2008). Despite this, a great inadequacy of studies in these aspects was seen and did not even cite information on these aspects, generating inadequacy in the risk of bias.

Regarding the procedures for collecting and analyzing results, the main problems were the erroneous type of collection scale (mostly structured) and authors bringing results given by the team in consensus. Unstructured scales are recommended in quantitative descriptive tests to avoid the errors related to choosing a preferred number and to obtain better discrimination power and parametric analyses (Lim, 2011). Results expressed and calculated individually for team members are more recommended, as consensus can generate results that do not match the actual assessment of the team, being influenced by tasters with strong personalities over the shy ones (Issanchou, 2018).

Despite this, most studies used inferential statistical analysis, improving aspects of risk of bias in the results collection category. Inferential analysis is recommended for analyzing descriptive quantitative sensorial data, as they consider several factors such as possible errors and interaction problems between samples and tasters, as well as making it possible to analyze whether there were significant differences among samples (Issanchou, 2018).

In the end, coffee brewing and processing was the category with the lowest risk of bias, but with only 50% of the studies being adequate. This elevated and moderate risk of bias observed in the final categorization stems from the aforementioned deficiencies, indicating potential unreliability in the reported findings.

Authors have already come up with new ways to adapt the QDA method to coffee trying to maintain the crucial characteristics of the test, such as Aguiar, Celestino and Oliveira (2021) which proposed a protocol model using the official QDA and Nascimento, Celestino and Oliveira (2023) that proposed an adaptation to coffee of the shorter version of the QDA test, the ODP test created by Silva et al. (2012). Despite this, subsequent research should address the considerable limitations identified in the existing literature, particularly the omission of pre-test and test application preparation details, as also perform better data collection and analysis of results.

Furthermore, investigations should focus on enhancing the rigor of the sensory testing process itself, including controlling variables such as the testing environment, sample serving conditions, panel saturation and addressing potential biases through randomized presentation, codified samples, and monadic serving. Lastly, rectifying erroneous data collection and analysis methods is paramount to advancing the field's scientific rigor.

5 CONCLUSIONS

This study is the first to evaluate the quality of coffee protocols using quantitative descriptive tests (QDA), regarding pre-test, coffee processing, test application and results procedures. With the exception of the description of the coffee processing and preparation method category, all others had a higher medium to high risk of bias classification. As a result, most studies also had a medium-high bias rating at the end.

The main results of the studies founded cover topics such as the impact of brewing time, chemical compounds related to sensory attributes, impact of different roasting techniques, brewing temperatures, additives, and processing methods in sensory qualities of coffee. According to these results it was found the importance of factors like brewing procedure, packaging, storage temperature, serving conditions and the use of additives in determining the sensory profile of coffee, what provides valuable insights into the complex interplay of factors that shape the taste and aroma of coffee beverages. However, it should be noted that due to the high risk of bias in the sensory protocols used, these results should be considered with caution.

However, it is essential to address some concerns regarding the standardization of QDA protocols, training of sensory panels, and the potential influence of external factors on sensory perception, as has already been proposed by some authors. Future research should focus on refining and harmonizing QDA methodologies, ensuring their reproducibility and reliability across different settings and populations. This study underscores the continued need for scientific rigor tests in sensory evaluation within the field of food science, particularly in the context of coffee, a world important and much appreciated beverage.

6 AUTHORS' CONTRIBUTION

Conceptual Idea: Nascimento, M.O.; Oliveira, L.L.; Methodology design: Nascimento, M.O.; Oliveira, L.L.; Data

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