



Comparison of classic and emerging sensory methodologies

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Abstract

Purpose of Review Descriptive Analysis (DA) is the classic methodology for describing qualitatively and quantitatively food products. However, it is laborious, expensive, and requires much time for panel training. Emerging sensory methodologies (ESM) have been developed to obtain faster results at a lower cost. This review promotes an overview of the main ESM used as alternatives for classic DA.

Recent Findings The main applied methodologies are Check All That Apply (CATA), Rate All That Apply (RATA), Flash Profiling (FP), Preferred Attribute Elicitation (PAE), Pivot Profile, and Projective Mapping/Napping. Generally, ESM provides similar results to DA for products with intermediate to high differences and low to intermediate complexity.

Summary An overview of the main ESM used as alternatives for classic DA in the last 5 years is presented and discussed concerning advantages, limitations, challenges, and perspectives. Recommendations for application are suggested based on the different approaches available.

Keywords Classical descriptive analysis · Rapid sensory methods · Check All That Apply · Flash Profiling · Napping · Validation

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Introduction

Descriptive Analysis (DA) is the classic and reference methodology to describe qualitatively and quantitatively food products [1••]. In this methodology, the assessors are trained to identify and quantify the attributes of the products using unstructured intensity scales, and after assessor selection, they evaluate the products [2]. Its main advantages are the robustness and validity for quantifying and describing sensory characteristics [3]. However, it is laborious, expensive, and requires much time for panel training [1••]. Furthermore, the attributes are elicited and evaluated using trained assessors, which could not correlate with consumer evaluation [4••].

In this way, emerging sensory methodologies (ESM), mainly using consumers, have been developed to obtain faster results at a lower cost [1••]. These methodologies are usually easily understood by consumers and flexible [5]. The main applied methodologies are Check All That Apply (CATA) [3], Rate All That Apply (RATA) [4••], Flash Profiling (FP) [6], Preferred Attribute Elicitation (PAE) [7], Pivot Profile [8•], and Projective Mapping/Napping [9]. Validating these methodologies by comparison with DA is

essential to assess their suitability and effectiveness [1••]. This validation is commonly performed by comparing the Principal Component Analysis (PCA) map from DA with the configuration map originating from the ESM and using the Rv coefficient [6, 10].

Previous reviews concentrated efforts on the validation of rapid sensory methodologies [11], the evolution of sensory science [2], and the comparison between trained and consumer panels [12]. However, no previous review compared and discussed classic and ESM. In this way, this review aimed to present the main ESM used as alternatives for classic DA, presenting their advantages, limitations, challenges, and perspectives. The literature discussed in the review was selected based on the published year (2018–2023), the utilization of untrained consumers as assessors, and studies comparing the selected ESM and DA.

Classic Descriptive Analysis (DA)

Figure 1 summarizes the classic and ESM methodologies' main advantages and limitations. DA is considered the gold methodology for acquiring reliable, detailed, and reproducible data and tracing the sensory profile of food products. DA methodology consists of some steps, such as the recruitment and screening of potential assessors

(usually using basic odor and taste tests or discriminative tests), generation of attributes (using traditional or repertory grid methods), discussion to select and define the attributes and state the reference samples of the scale anchors, training of the assessors, the final selection of the trained assessors, and individual evaluation of the products [6]. DA data is analyzed using Analysis of Variance (ANOVA) and PCA [2].

Usually, 10–13 trained assessors are used, and high explanation rates (> 90% in the principal components of PCA) are obtained [1, 3, 4, 7]. Furthermore, greater detail of the characteristics of the products, precise quantification of the attributes, and high discrimination for samples, mainly in complex attributes and very similar or complex samples, have been reported [3, 4, 13]. These factors can be associated with the assessor's ability being statistically validated, guaranteeing their discriminate and repeatability abilities and the panel consensus [1••]. The training sessions command a high agreement level on attributes and product references, ensuring assessors understand the attributes in the same form and subsequently uniformly apply the terminology [14]. However, DA may be unsuitable for food industries due to difficulties in keeping sensory panels for a long time, dynamics of new product marketing, and extensive needed time up to results [6]. In this way, several ESM have been evaluated as alternatives to DA.

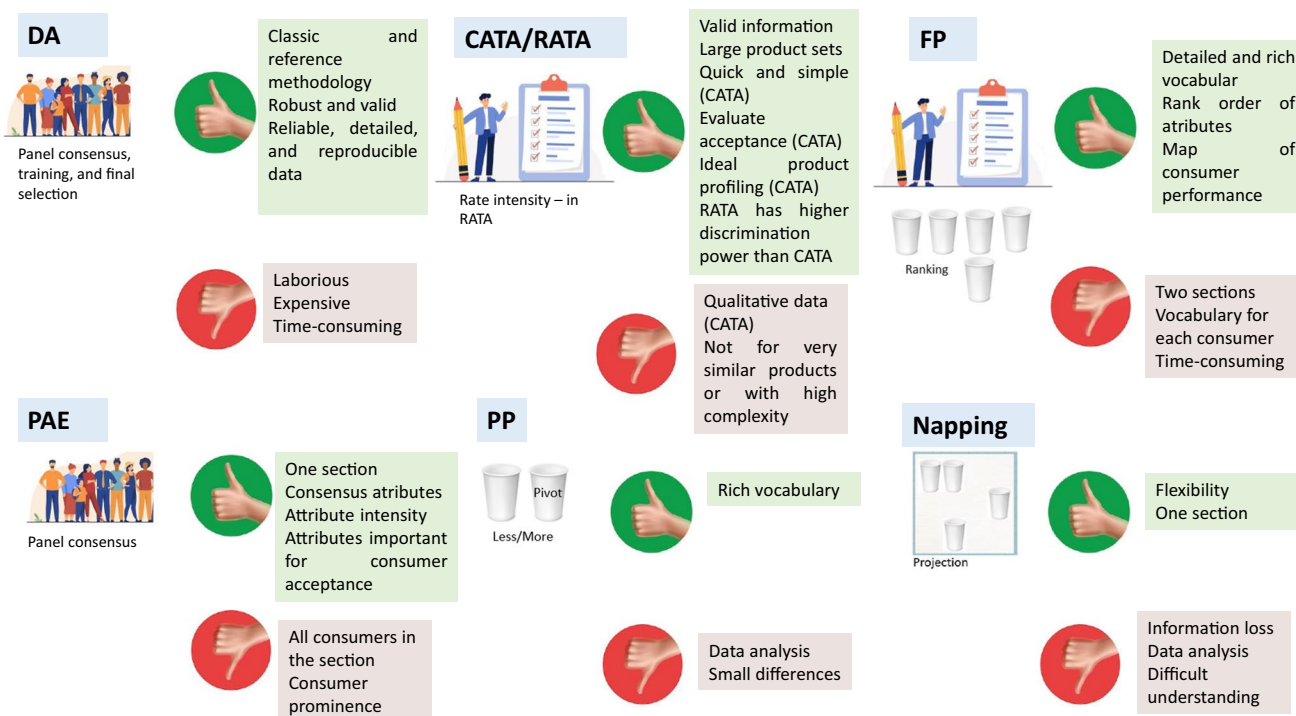


Fig. 1 Classic descriptive analysis and ESM main advantages, limitations, and recommendations. DA = Descriptive analysis, CATA = Check all that apply, FP = Flash Profiling, PAE = preferred attribute elicitation, PP = pivot profile, RATA = Rate All That Apply. Images: Freepik

Emerging Sensory Methodologies (ESM)

Table 1 presents the main studies that compared ESM to DA in evaluating food products.

Check All That Apply (CATA)

CATA methodology consists of presenting the food product and a list with pre-selected terms to consumers and requesting them to select all they consider suitable for describing it [3]. The terms must be easily understandable and can be obtained using previous studies with the same products, qualitative preliminary tests, or tests with trained assessors [13]. Using 10 to 40 terms is suggested, and they must be provided in the list in random order for each formulation and consumer. Generally, there is no limitation on the number of attributes that can be selected by the consumer or the required time for evaluation. It is possible to incorporate sensory acceptance concomitantly into CATA, and it is advisable to perform it before the CATA test. Furthermore, the ideal profiling of the product can be assessed by asking consumers to select all the terms they consider appropriate for the ideal product. The CATA data are analyzed using non-parametric tests (Chi-square), Cochran Q test, Principal Coordinate Analysis, Correspondence Analysis (CA), Multiple Factor Analysis (MFA), and penalty analysis [1, 3].

In the last years, CATA has been constantly applied to evaluate several types of products, such as strawberries [14], wines [2], coffee [13], cheeses [16•], mortadella [17], and plant-based beverages [15]. The suggested number of consumers is 50–100, but a large range (30–216 consumers) is found in the literature because higher number is needed for products with high similarity or if the acceptance test is also performed [13–15].

Some studies compared CATA and DA in the time range evaluated in this review [3, 13–17]. Generally, DA and CATA provided similar information ($R_v = 0.760$) [3, 14, 16, 17], resulting in similar attributes to characterize the formulations [13, 17]. Furthermore, the citation frequency of an attribute in CATA correlated with attribute intensity in DA [14]. However, due to the qualitative nature of CATA, its discriminative power was lower for similar food products or products with high complexity, resulting in fewer significant attributes compared to DA [14]. In this way, if an attribute is presented in several samples but in different intensities, the products may not be distinguished using CATA [14]. On the other hand, consumers (CATA) better-identified attributes that contribute to preference than trained assessors (DA) [13, 16]

The main advantages of CATA are that it is quick and simple, the information is valid and reproducible, and it can be performed using untrained consumers [3].

Furthermore, it allows the observation of the relationship between attributes and acceptance and the ideal product profiling [13]. Finally, it does not need the simultaneous evaluation of all samples, allowing the utilization of large product sets [24]. The main limitation is that it provides only qualitative data, which may make the description and discrimination of formulations difficult. Based on our experience with the method, it is important to carefully select attributes to be included in the list because this will determine the test's accuracy. We recommend not applying CATA for similar products.

Rate All That Apply (RATA)

RATA is considered a variant of CATA with modifications to increase its limitations to discriminate formulations. In this methodology, the consumers receive the food product and a list with pre-selected terms. They are requested to select all attributes suitable for describing it and rate the intensity using a rating scale [4••]. The RATA data are analyzed using ANOVA, PCA, MFA, and Cochran Q test [4, 5]. In this way, RATA aims to improve the discrimination of formulations with high similarity and has a higher statistical power than CATA [5].

RATA has been applied to evaluate several types of products, such as orange juices, salami, and cheeses [4••], wine [5], and rice [18]. Previous studies have used 30–84 consumers [4, 5, 18].

RATA has been compared to DA [4, 5, 18]. Generally, both methodologies could discriminate samples ($R_v = 0.75–0.93$), but the discriminative power was correlated to the food difference grade, food matrix complexity, and the attribute type. Similar discriminative power was observed for commercial wines with distinguished differences (variety, region, and vintage) [5]. At the same time, DA showed a higher discriminative power (significant differences in 90–95% of the attributes compared to 44–73% in CATA) in products with similar characteristics [4••]. Furthermore, the accuracy of the methodology was correlated with the complexity of the matrix. In simple products, such as orange juice, DA and RATA resulted in similar conclusions considering the differences and similarities of the formulations ($R_v = 0.84$). The configurations differed for more complex products, such as salami and Camembert cheese ($R_v = 0.29$ and 0.62). Finally, agreement was observed for simple attributes (appearance, taste, and texture); however, a lack of agreement was reported in attributes of high complexity [4, 18].

RATA has some advantages, such as the information being valid and reproducible, it can be performed using untrained consumers, and it does not need the simultaneous evaluation of all samples, allowing the utilization of large product sets. The main

Table 1 Studies comparing classic descriptive analysis with emerging sensory methodologies (2018–2023)

Emerging sensory methodology	Food-product	Formulations	Sensory methodology	Rv value	Main results	Reference
CATA	Strawberries	Albion (<i>Fragaria</i> x ananassa cv Albion cultivar) Melba (<i>Fragaria</i> x ananassa cv Melba cultivar) San Andreas (<i>Fragaria</i> x ananassa cv San Andreas cultivar)	DA (n = 12 trained assessors) CATA (n = 131 consumers)	0.760	CATA resulted in a fewer significant attributes The citation frequency of an attribute in CATA correlated with attribute intensity in DA	[14]
CATA	Vegetable and berry beverages	Cranberry Blackberry Blackcurrant Beetroot Raspberry Strawberry	DA (n = 10 trained assessors) CATA (n = 131 consumers)	Not determined	CATA was an adequate method to evaluate consumer responses beyond liking	[15]
CATA	Wine	Control (without the wood chip) AAMF (with American oak chip in alcoholic and malolactic) AMF (with American oak chip in malolactic) FAMF (with French oak chip in alcoholic and malolactic) FMF (with French oak chip in malolactic) AFMAF (with American and French oak chip in alcoholic and malolactic)	DA (n = 10 trained assessors) CATA (n = 129 consumers)	Not determined	DA resulted in a greater characterization of the products DA and CATA provided similar information	[3]
CATA	Coffee products	Commercial products (Luwak, Nescafe, Good Day Moc, Kopiko 78, ABC, Torabika, Indocafe), both read to drink and instantaneous	DA (n = 12 trained assessors) CATA (n = 30 consumers)	Not determined	Several attributes were assessed in both methods Consumers were good in identifying attributes that contribute to preference	[13]
CATA	Camembert-type cheese	T (with thermophilic culture) O (with homofermentative mesophilic culture) LD (with heterofermentative mesophilic culture)	DA (n = 10 trained assessors) CATA (n = 92 consumers)	Not determined	CATA resulted in a better understanding of the consumers' preference CATA confirmed the results of DA	[16]

Table 1 (continued)

Emerging sensory methodology	Food-product	Formulations	Sensory methodology	Rv value	Main results	Reference
CATA	Mortadella	A1 (with 16% animal fat) A2 (with 8% animal fat) A3 (with 8% animal fat+8% pre-emulsion fat (30% oil mixture+0.5% milk protein concentrate+0.5% sodium alginate)) A4 (with 8% animal fat+8% pre-emulsion fat (30% oil mixture+1% milk protein concentrate+0.75% sodium alginate)) A5 (commercial)	DA (<i>n</i> =12 trained assessors) CATA (<i>n</i> =84 consumers)	Not determined	DA and CATA provided similar maps	[17]
RATA	Orange drinks, salami, and Camembert cheese	Commercial products (4 orange juices, 5 salami, and 5 Camembert cheeses)	DA (<i>n</i> =7–11 trained assessors) RATA (<i>n</i> =50–53 consumers)	0.75–0.93	Attributes were significantly and positively correlated in the methodologies Agreements in attributes related to simple appearance, taste, and texture Lack of agreement in attributes of high complexity In simple products, such as orange juice, DA and RATA resulted in similar conclusions considering the differences and similarities of the formulations (Rv=0.84). The configurations were different for more complex products, such as salami and Camembert cheese (Rv=0.29 and 0.62)	[4•••]
RATA	Wine	Commercial wines from different variety, region, vintage, and retail prices	DA (<i>n</i> =7–11 trained assessors) RATA (<i>n</i> =84 consumers)	0.97	Both methodologies could discriminate samples Similar discriminative power	[5]
RATA	Cooked rice	0% EC (electric rice cooker) 1% EC (electric rice cooker with 1% rice protein hydrolysate) 0% PC (pressure-cooker) 1% PC (pressure-cooker with 1% rice protein hydrolysate) 0% WRT (water-retort) 1% WRT (water-retort with 1% rice protein hydrolysate)	DA (<i>n</i> =6 trained assessors) RATA (<i>n</i> =30 consumers)	Not determined	Agreements in attributes related to color, sweetness, and bitterness Lack of agreement in attributes of high complexity (odor and after-taste)	[18]

Table 1 (continued)

Emerging sensory methodology	Food-product	Formulations	Sensory methodology	Rv value	Main results	Reference
FP	Huajiao	ZB1-ZB5 (red) ZA1-ZA3 (green)	DA ($n=13$ trained assessors) FP ($n=13$ consumers)	Determined but values not provided	Both methodologies could discriminate samples, and the positioning of the formulations in the map and the overall classification were similar A better discrimination power was reported for FP	[6]
FP	Wine	11 wines with different ethanol content	DA ($n=14$ trained assessors) FP ($n=20$ consumers)	0.858	FP could separate wines similarly to DA (based on ethanol content) More attributes were elicited in FP	[19]
FP	Coffee products	Commercial products (Luwak, Nescafe, Good Day Moc, Kopiko 78, ABC, Torabika, Indocafe), both read to drink and instantaneous	DA ($n=12$ trained assessors) FP ($n=30$ consumers)	Not determined	Several attributes were assessed in both methods Conflict of interest statement Nothing declared	[13]
FP	Fermented soybean curd	P1-P2 (GD origin) P3-P5 (HK origin) P6-P7 (ZJ origin) P8 (BJ origin) P9-P11 (HK origin, different ingredients) P12 (ZJ origin, different ingredients)	DA ($n=10$ trained assessors) FP ($n=10$ consumers)	0.852	Similar words or words with similar meanings were elicited Similar number of attributes for aroma, flavor, and texture FP generated lower number of attributes in appearance and aftertaste FP exhibited a higher divergence between assessors	[20••]
FP	Fermented soybean curd	P1-P2 (A origin) P3-P8 (B origin) P9-P11 (C origin) P12 (D origin)	DA ($n=10$ trained assessors) FP ($n=10$ consumers)	0.965	Similar configuration maps for FP and DA	[21]
FP	Ricotta cheese	WB1-WB4 (water buffalo with different concentrations of milk whey and salt) S1-S1 (sheep milk with or without cream) C1-C2 (cow mil with or without milk and citric acid)	DA ($n=10$ trained assessors) FP ($n=10$ consumers)	0.882	Both methodologies elicited sensory attributes typical of the analyzed product or easily recognized, while those requiring training were not elicited in FP Similar configuration maps for FP and DA	[22]
PAE	Yogurt	SUC (sucrose, 120 g/L) SUCR (sucralose, 0.2 g/L) XYL (xylitol, 120 g/L) XYL-O (xylitol, 120 g/L + oligofructose, 60 g/L) XYL-P (xylitol, 120 g/L + polydextrose, 60 g/L)	DA ($n=15$ trained assessors) PAE ($n=20$ consumers)	0.920	Both methods elicited 10 attributes 7 attributes were similar (color, brightness, acid taste, sweet taste, bitter taste, creaminess, and consistency) The sensory profile was similar in both methods ($R_v=0.92$, $p=0.02$)	[1••]

Table 1 (continued)

Emerging sensory methodology	Food-product	Formulations	Sensory methodology	Rv value	Main results	Reference
PAE	Yogurt	Seven vanilla commercial yogurts	DA (<i>n</i> = 10 trained assessors) PAE (<i>n</i> = 42 consumers)		Desirable sensory attributes were elicited in both methodologies. The sensory profile was similar in both methods ($R_v = 0.877$, $p = 0.0011$)	[7]
PP	Wine	HV (Hunter Valley) MV1-MV2 (McLaren Vale) MV2 (McLaren Vale) FR1 (Crozes-Hermitage, Rhone Valley) FR2 (Cornas, Rhone Valley) CV (Clare Valley) EV (Eden Valley) BV (Barossa Valley) CB (Canberra) HC (Heathcote) BE (Beechworth) YV1 – YV2 (Yarra Valley) AH (Adelaide Hills) GR (Grampians, NZ Hawkes Bay)	DA (<i>n</i> = 12 trained assessors) PP (<i>n</i> = 11 consumers)	0.67–0.69	Similar space configuration Some attributes were provided only in PP, mainly associated with general judgments, DA attributes were more detailed	[8•]
Napping	Scotch Whisky Spirit	A = 73.5% ABV B = 73.0% ABV C = 66.3% ABV D = 62.9% ABV E = 62.1% ABV F = 60.7% ABV G = 34% ABV H = 33.2% ABV I = 29.3% ABV	DA (<i>n</i> = 17 trained assessors) PP (<i>n</i> = 17 consumers)	0.906	Both methodologies grouped the products in a similar form	[9]
Napping	Strawberry	Albion (Fragaria x ananassa cv Albion cultivar) Melba (Fragaria x ananassa cv Melba cultivar) San Andreas (Fragaria x ananassa cv San Andreas cultivar)	DA (<i>n</i> = 12 trained assessors) CATA (<i>n</i> = 131 consumers)	0.936	Consumers were as reliable as the trained panel in discriminating the formulations DA could assess smaller differences The increase in the number of consumers improved the stability of the formulation configurations	[23]

ABV alcohol by volume, CATA check all that apply, DA conventional descriptive analysis, FP flash profiling, PAE preferred attribute elicitation, PP pivot profile, RATA rate all that apply

limitation is its lower discriminative power for products with subtle differences or high complexity than DA [4••]. Based on our experience with the method, we recommend using RATA for formulations that share the same attributes but in different intensities. Furthermore, we suggest not including several samples in the same set (> 12), as fatigue can decrease the number of selected attributes by consumers.

Flash Profiling (FP)

FP was developed by joining the terms obtained using free choice profiling with a subsequent comparative ranking evaluation [22]. In FP, the consumers receive the formulations and are asked to generate a provisional and individual list of sensory attributes that contribute to discriminating them. Then, they are asked to summarize and categorize the attributes and define the final list with the sensory attributes. Finally, they receive all formulations simultaneously and are asked to rank them on each attribute [6]. The FP data is analyzed using Generalized Procrustes Analysis (GPA), Canonical Variate Analysis (CVA), and MFA [2, 19].

Flash Profiling has been applied to characterize several food products, such as wine [19], fermented soybean curd [20, 21], coffee [13], cheese [22], and huajiao [6]. Studies have used 10–30 consumers [21].

Previous studies have compared FP to DA [6, 13, 19, 21, 22]. Generally, both methodologies could discriminate samples, and the positioning of the formulations in the map and the overall classification were similar (R_v 0.852–0.965) [6, 6, 13, 19, 20, 22]. Similar words or words with similar meanings were elicited [20••], and the number of elicited attributes converged with DA when they were typical of the analyzed product or easily recognized [22]. In some cases, more attributes were elicited in FP, resulting from consumers' free selection of attributes, not needing a consensus as in DA [19]. However, attributes requiring training for identification [22] or difficult to define were not elicited in FP [21]. As expected, FP exhibited a higher divergence between assessors, which could be attributed to the lack of training [20••]; however, the obtained information could be easily understood by consumers [22].

FP has some advantages, such as using untrained consumers, generating a more detailed and rich vocabulary due to the freedom to consumers describe the formulations, and resulting in the rank order of formulations for each attribute. Furthermore, a map can be performed to evaluate consumer performance [6, 13]. The main limitations are that it needs two sections (one for attribute elicitation and list definition and the other for product evaluation), each consumer generates its vocabulary (which makes the semantic interpretation very difficult), and there is a limitation in the number of formulations (as they are presented simultaneously). Furthermore, it is time-consuming as consumers must re-tasting formulations to rank them for each attribute

[13, 19]. Based on our experience with the methodology, the task may be very difficult with products that depend on temperature or have a persistent flavor. Using it in large set formulations, quality control, and product stability is not advisable due to the high variance among consumers [20••].

Preferred Attribute Elicitation (PAE)

PAE methodology was applied and discussed for the first time by [7]. The methodology consists of presenting the food formulations to consumers and requesting them to record the attributes contributing to discrimination using paper ballots. Then, the attributes are written on a whiteboard, and the panel, by consensus, groups them (conventionally in appearance, aroma, flavor, and texture). A discussion is performed to narrow down the number of attributes by grouping antonymous or synonymous and excluding those that would not be easily assessed. Furthermore, the scales (usually 7 or 9-point scales) and their anchor terms for intensity are defined by panel consensus. Then, the consumers are asked to rank the chosen attributes according to their importance for product acceptance. They are informed that the same order can be used for attributes equally important. After a short break (usually 10–15 min), the consumers receive the formulations in a monadic form and evaluate each attribute intensity using the scales [1, 7]. The original method also performs, at the first step, an evaluation of consumer acceptance using 9-point hedonic scales [7]. The PAE data is analyzed using GPA (intensity of attributes) and Friedman test (attribute importance order) [1, 25].

In the last years, PAE has been applied to evaluate meat [26], vegan frozen desserts [25, 27], almond-fermented beverages [28], minimally processed fruits [29], dulce de leche [30], cheese [31], and yogurts [1••]. The minimum number of consumers was determined to be 19 [31], but studies have used 8–22 [25, 29]. The PAE section was reported to last 60–120 min [28, 31].

Two studies compared PAE and DA, but only one was published in the time range evaluated in this review [1, 7]. The authors [1••] observed that both methods elicited 10 attributes, and 7 were similar. The other 2 attributes had different nomenclature but similar meanings. Furthermore, the sensory profile was similar in both methods ($R_v = 0.92$, $p = 0.02$). The study demonstrated that the PAE methodology could characterize the products like the DA with the advantage of providing the attributes most important for accepting the products.

The main advantages of PAE are that it requires only one section, can be performed using untrained consumers, use attributes defined by panel consensus, quantify the intensity of the product attributes, and provides information about the most important attributes for product acceptance [1••]. The main limitations are the necessity

of all consumers simultaneously in the section and the possible prominence of some consumers during the discussion and definition of the attributes [1••]. Based on our experience with the methodology, it is important to define the attributes accordingly to all consumers to avoid misinterpretation. PAE demonstrates significant results for food product characterization, but further studies are needed considering other matrices to verify its suitability.

Pivot Profile (PP)

PP is a sensory methodology that captures the differences between formulations through free comments using the evaluated product and a reference (pivot) [32]. In PP, the consumers receive the formulation and the pivot and are asked to write the attributes based on how it differs from the pivot (less or more). The definition of the attributes is not mandatory, but it is important not to use hedonic terms. The PP data is analyzed using CA [8•].

Only one study compared PP and DA in the time range evaluated in this review. The authors [8•] observed that both methods had similar sample space configurations, with intermediate R_v values (0.67–0.69). Furthermore, some attributes were provided only in PP, mainly associated with general judgments, resulting in a more powerful and richer overview of the formulations. However, DA provided more nuanced and detailed attributes, which may be associated with training and tasks. In PP, the consumers focus on eliciting the most salient attributes that differ from the pivot, while a general characterization is requested in DA.

The main advantages of PP are that there are no restrictions on the used terms, resulting in a rich vocabulary. The main limitations are the difficulty in data analysis (removing errors, eliminating connectors and auxiliary terms, grouping synonyms, managing ambiguous terms, and denoting important terms) and the lower power on attributes related to small differences among formulations [8•]. Based on our experience, we recommend using PP when the most discriminating attributes are required. Furthermore, it is important to carefully select the pivot formulation because this will determine the attributes elicited by consumers and, consequently, the test's accuracy.

Projective Mapping (PM)/ Napping

In PM or Napping, the consumers receive the formulations simultaneously. They are asked to project them on a paper sheet or computer screen according to their criteria, grouping close formulations and leaving different formulations apart. Additionally, they can write words/attributes representing the group of formulations, denoting the Ultra-Flash Profiling. This method

produces a graphical representation of the formulations based on consumer perception, and the distance between formulations can be calculated [33]. It is suggested to include a replicate formulation to help evaluate consumer performance [33]. The difference between PM and Napping is mainly the space format, as PM usually uses a rectangular space (60×40 cm), and Napping uses a square space (60×60 cm). The data is analyzed by measuring the coordinates of each sample and using GPA or MFA for PM or MFA for Napping [33].

PM/Napping has been applied to characterize food products, such as Scotch Whisky Spirit [9], and strawberries [23]. Studies have used 17–131 consumers [9, 23]. A previous study [9] determined that the minimum number of consumers in PM/Napping to produce a similar output to DA would be 90 for similar food products. The number could be decreased by at least 50 for products with more differences [33].

Previous studies have compared Napping to DA [9, 23]. Generally, both methodologies grouped the formulations similarly ($R_v=0.906$ – 0.936) [9, 23]. Although DA was more robust in assessing smaller differences, the increase in the number of consumers improved the stability of the formulation configurations [23]. Furthermore, incorporating a familiarization step, i.e., explaining the method before task application, may improve consumer performance [33]. Due to the nature of the task, the consumers may unintentionally ignore some sensory attributes during the projection and denotation of attributes for the group [23].

PM/Napping has some advantages, such as it can be performed using only one section, is extremely flexible to the consumer, and presents the formulations simultaneously. The main disadvantages are the possible loss of information, the limited number of products to be evaluated, the laborious data analysis, and the difficulty to be understood by naïve consumers [23]. Based on our experience with the methodology, we recommend its utilization with 6–12 formulations with perceptible differences and low to medium complexity.

Conclusions

ESM have gained attention due to the practicality of use and lack of consumer training. However, evaluating if these methodologies could be used as alternatives to DA with satisfactory efficacy is important. We could observe that studies commonly validate the ESM by comparing the distribution of the formulations in the configuration maps, determining the R_v coefficients between the ESM and DA configurations, and comparing the explanation percentage for the map's dimensions.

The selection of ESM should be conducted based on the expected result. Still, by analyzing the studies it can be observed that the characteristics of the formulations are of paramount importance, as it affects the consumer accuracy in evaluating the products [4••]. The product complexity and the degree of

difference are important characteristics to be considered. Generally, ESM provides similar results to DA for products with intermediate to high differences and low to intermediate complexity. For products with subtle differences or high complexity, it is recommended to include a step of familiarization with the formulations and the experimental protocol, which could result in improved consumer ability to discriminate the formulations.

Literature provides much more works of application of the methodology in different food products than validation before use. In this way, future works should evaluate the ESM for different food matrices and compare it to DA to denote their real applicability and limitations. Furthermore, many ESM were not discussed in this review due to the lack of validation studies in the time range evaluated. However, they have been constantly applied, such as Free Listing [34], Polarized Projective Mapping [35], Polarized Sensory Positioning [36], Sorting [37], among others. In this way, there are many opportunities for studies to validate those methodologies.

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Declarations

Competing interests The authors declare no competing interests.

Conflict of interest statement Nothing declared.

Human and Animal Rights and Informed Consent This article contains no studies with human or animal subjects performed by any authors.

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Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

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