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REVIEW

Application of Sensory and Consumer Science for the Development of Novel Food Products

Erick Saldaña[1] · Karina Eduardo[1] · Jhony Mayta-Hancco[1] · Nils Leander Huamán-Castilla[1] · Elias Escobedo-Pacheco[1]

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Abstract

Purpose of Review The application of sensory and consumer science (SCS) in developing novel food products that meet consumer demands has become increasingly important in recent years. In this context, this review article explores the significance of SCS in developing novel food products.

Recent Findings It highlights the instrumental of SCS in developing healthier food options by reducing sodium, sucrose, and fat while maintaining sensory appeal. It also outlines the transition from traditional sensory methods using trained panels to consumer-based methods that better capture consumer preferences and expectations.

Summary The paper proposes a sequence for developing novel food products based on SCS, focusing on both intrinsic (sensory properties) and extrinsic (packaging, labeling, etc.) factors. Conjoint analysis is the most representative method used to understand the impact of extrinsic factors on consumer preferences and predict purchase behavior. Lastly, the final product should be optimized based on consumer feedback and compared to competitors before the market launch. Overall, the paper emphasizes the importance of SCS in creating successful food products that align with consumer preferences and health trends.

Keywords Healthier products · Intrinsic and extrinsic properties · Conjoint analysis

Introduction

Applying SCS is crucial for developing novel food products that meet consumer demands, being considered a convergence of different sciences such as biology, chemistry, statistics, social sciences, gastronomy, food science, and food design, among others. It is, in the words of Worch et al. [1]: "the tastiest of all sciences." This new science uses different methods to identify food product attributes that drive consumer liking, facilitating product optimization. Traditionally, descriptive analysis performed by trained assessors provides sensory characteristics of food products [2]. These attributes subsequently correlate with consumers' overall liking via preference maps [3]. Despite the statistical advantages of preference maps, there are still some limitations, as the sensory space of the trained panel does not always coincide with the hedonic space of the consumers [4]. In this context, consumer-based sensory methods have gained prominence due to consumers' capability to describe the same product sensorially and hedonically [5].

The transition from traditional sensory methods using a trained panel to consumer-based methods to describe sensorially the products has been driven by the recognition that consumers can perform sensory analytical tests besides the hedonic ones [6]. Moreover, consumers have demonstrated the ability to demand more from their products (sensory quality, healthiness, sustainability, etc.) and to be more specific when expressing their expectations and desires. These consumers' demands cannot be captured by classical descriptive methods that focus on the intrinsic sensory properties of the product, so these new methods enable the capture of static and temporal sensory descriptions, emotions, and attitudes from the consumers' vocabulary [7••, 8••], being critical to the success of food products in the marketplace. Thus, the SCS focused on consumer perception has made it possible to go beyond the sensory and hedonic aspects, such as social responsibility [9], food literacy [10],

✉ Erick Saldaña
esaldanav@unam.edu.pe

[1] Escuela Profesional de Ingeniería Agroindustrial, Universidad Nacional de Moquegua, Prolongación Calle Ancash S/N, Moquegua 18001, Peru

sustainability [11], public policies [12, 13], and healthiness [14–16].

In response to the increasing demand for healthier food options, SCS has been instrumental in developing novel food products that cater to the current population's needs [17]. Researchers have focused on reducing salt, sugar, and fat levels in food products while maintaining their sensory appeal [18]. This has led to exploring alternative ingredients, flavor enhancers, and processing techniques. Reformulating food products to make them healthier poses challenges in maintaining their sensory characteristics [16]. Modifying the formulation of a product to reduce specific components may impact its sensory and hedonic experience. To overcome these drawbacks, food scientists used technological strategies such as the size reduction of salt crystals [15] and ultrasound to improve the salt dispersion in meat batters [19]. Another technology recently applied to animal products was the microencapsulation of fish oil incorporated during burger manufacture to protect EPA and DHA from oxygen while mixing meat and ingredients, avoiding lipid oxidation of the final product [20]. For this reason, sensory methods are essential at the intrinsic level (e.g., estimating to what level sucrose reduction affects the sensory and hedonic profile of the product) and extrinsic level (adding cues to inform consumers about the nutritional quality of the product), providing information that the most advanced instrumental techniques cannot reproduce. In this regard, the present critical review will focus on sensory methods for measuring consumer-based intrinsic sensory properties, followed by sensory methods for measuring extrinsic properties to formulate/reformulate a food product, focusing on the actual healthier trend, following the steps of Fig. 1.

Food (Re)Formulation Process

Figure 2A displays the evolution of the formulation/reformulation of foods in scientific research published in Scopus-indexed journals from 2010 to 2023. Thematic evolution shows two-time slices. The first slice, from 2010 to 2020, was associated with the impact of food reformulation on human health. On the other hand, the second thematic slice, corresponding to the papers published from 2021 to 2023, deals with reformulations to improve the nutritional aspects of the products, considering animal interventions and later in humans. In this second slice, the sensory dimension of taste appears as an object of interest for researchers, reflecting the current trend to look beyond the nutritional aspects of food and consider also the sensory quality of foods. Human research is a well-established (motor) theme in academia, while meat product reformulation has been gaining importance lately (emerging) based on its relevance and development (Fig. 2B). Figure 2C shows sensory analysis as an emerging ally for characterizing sodium reduction in meat products.

Figure 3 shows a two-dimensional representation of scientific articles' most commonly occurring words. The words were processed through multiple correspondence

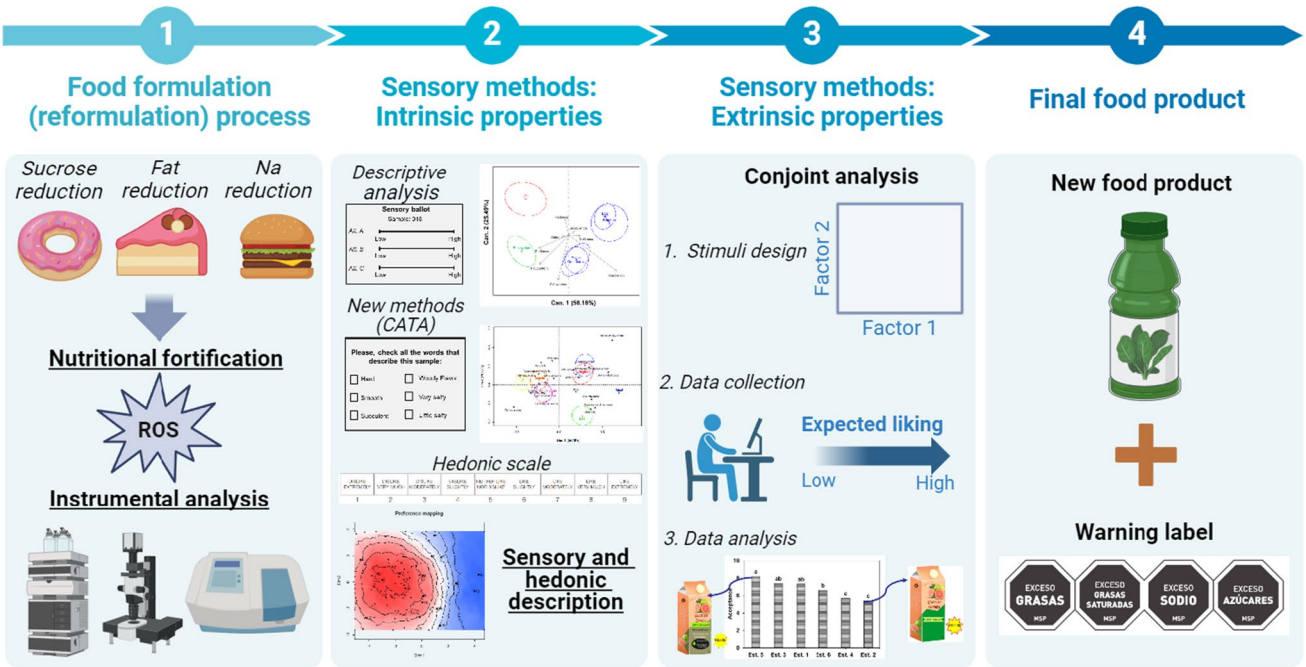

Fig. 1 Recommended sequence for developing novel food products applying sensory and consumer science

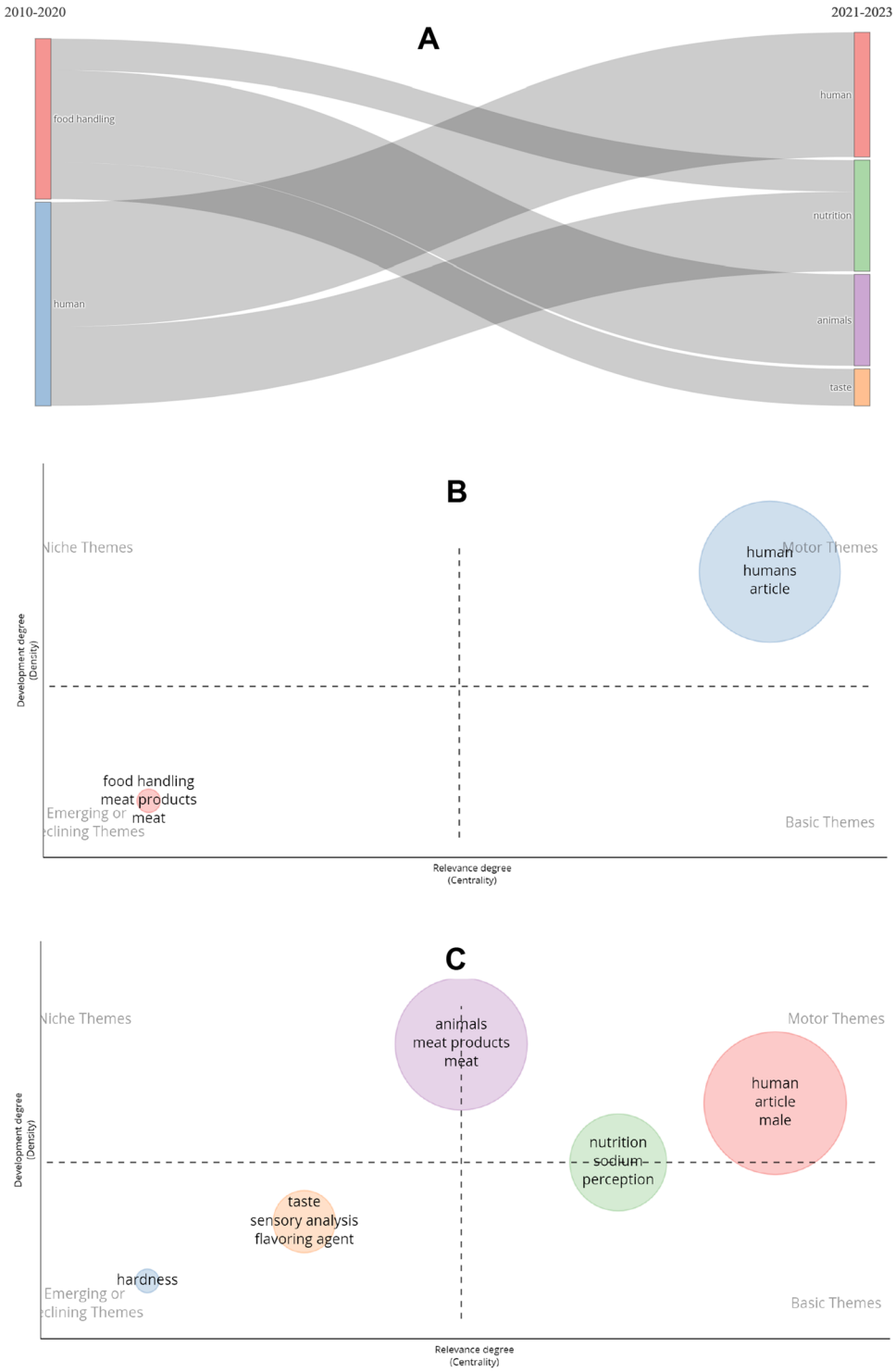

Fig. 2 Thematic evolution of food reformulation in the last 20 years

analysis [21], revealing three distinct word clusters. These clusters represent three types of studies that were conducted between 2010 and 2023. The first cluster, colored green, is related to the sensory characterization of meat and meat products. The second cluster, in blue, pertains to the study of consumer behavior towards reduced-fat products for individuals of different age groups. Finally, the third red cluster combines the previous two clusters and emphasizes the importance of reformulating foods to improve their nutritional profile by reducing fat, sodium, sugar, and calories. Such modifications can promote a healthier diet among consumers.

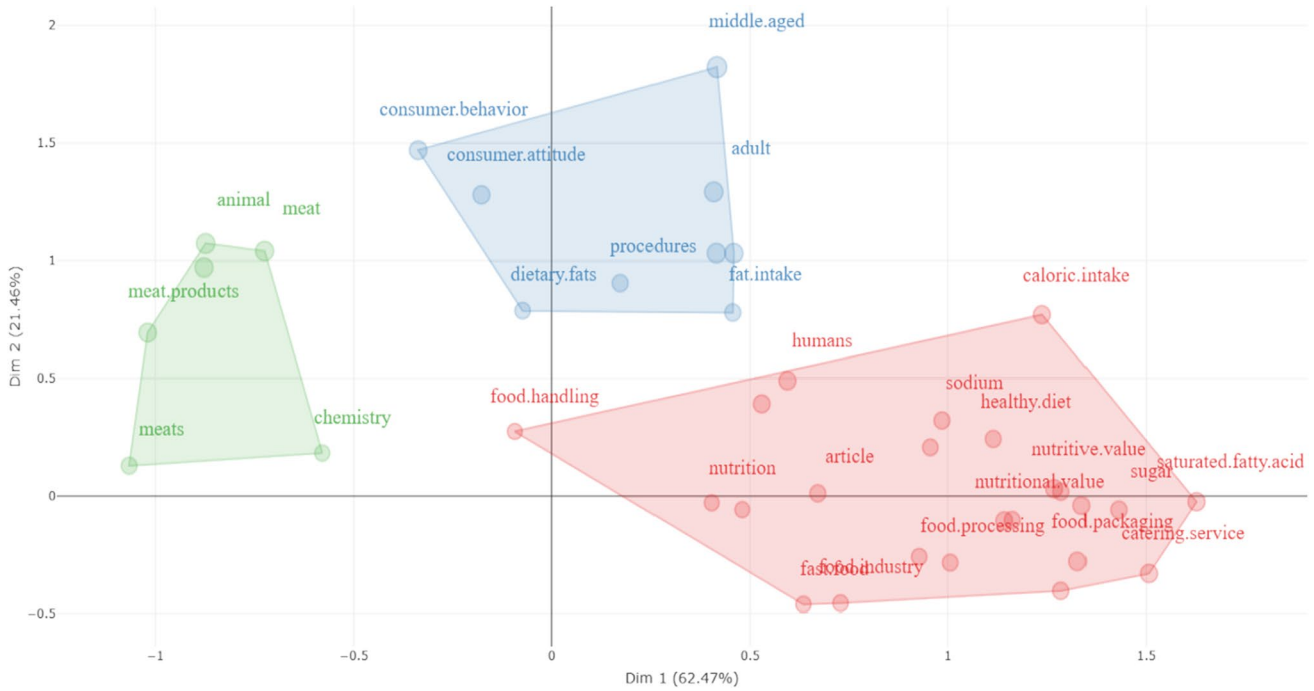

Fig. 3 Multiple correspondence analyses of the main published topics on food reformulation

Intrinsic Sensory Properties of Foods

The intrinsic sensory properties of foods (ISPF) refer to their color, aroma, taste, and texture [22, 23], which are determined by their chemical composition and physical structure [24]. Sensory characteristics of food products are traditionally measured using discriminant, descriptive, and affective methods [2]. Among these, descriptive methods are considered the most sophisticated and complete [25]. Descriptive analysis (DA), the most representative and extensively used descriptive method [26], involves training judges to evaluate samples based on a detailed protocol, repeatedly rating the intensity of attributes glossary in different samples. This approach ensures that DA has sufficient statistical power to detect even subtle differences between attributes for some treatments at univariant (analysis of variance—ANOVA) and multivariant (principal component analysis—PCA) levels [27]. Despite all the statistical advantages of DA, such as considering sample heterogeneity as a factor within the ANOVA model [28, 29], it also has some drawbacks related to the time needed for panel training and replicated final evaluation. This has led academia and industry to look for alternatives to reduce the time required to sensorially profile a product, such as eliminating the training [30] or reducing the number of repetitions in the final evaluation [26, 31].

New methodologies have emerged to enable sensory profiling of food products based on consumers' perceptions [32]. This approach has the advantage of saving time and preserving the consumer's vocabulary [33]. However, it is essential to interpret the results cautiously, as there may be variations in consumers' sensory perception due to biological individual differences between consumers, which should be analyzed more deeply [5]. For the reasons described above, sensory profiling with consumers has become popular in industry and academia, helping to align sensory profiling with acceptance to identify the drivers of liking [34]. It has also enabled the study of dynamic sensory properties based on consumers' responses, recognizing that sensory perception is a process that changes during tasting [14, 35]. Below, we have compiled a summary of various novel and reformulated products characterized by ISPF Table 1.

After conducting sensory profiling and acceptance tests, the product with the best performance is chosen. Then, the extrinsic sensory properties, such as labeling, packaging, and price, are examined. In the next section of this review article, we will focus on the extrinsic sensory properties of food products.

Extrinsic Sensory Properties of Foods

Expectations are present in our daily lives and play a crucial role in our experiences with products and services [56]. External cues, such as packaging color, influence expectations and contribute to increasing or decreasing them, impacting purchase decisions of food products [57,

Table 1 A non-exhaustive summary of ISPF methods used to study the sensory properties of novel and reformulated foods

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Yogurt	Investigate the effects of yogurt with added natural sweeteners on temporal sensory profile, liking, satiety, and post-consumption measures	Sugar reduction	Temporal dominance of sensations	Attributes: Sweet, sour, bitter, creamy, fruity, mouth coating, licorice, astringent Samples: Greek-style natural yogurt added of xylitol, stevia, and monk fruit	Protocol: Evaluation of overall preference, satiety, and other post-consumption attributes Data analysis: Canonical variate analysis and analysis of variance	Xylitol stood out as the most suitable sugar substitute for yogurt, avoiding negative sensory attributes, while yogurt sweetened with monk fruit and stevia showed additional negative attributes	[36]
Yogurt	Evaluating the relationship between flavors (vanilla and strawberry) and sweetness	Sugar reduction	Time intensity and temporal dominance of sensations	Attributes: Sweet taste, strawberry flavor, sour taste, and fermented milk flavor Samples: Yogurt samples with 0% and 25% sugar reductions added of vanilla and strawberry aromas	Protocol: Time-intensity analysis and temporal dominance of sensations performed by a trained panel, followed by an acceptance test by consumers Data analysis: Analysis of variance and principal component analysis	Adding flavor is possible to reduce 25% of the sugar content in yogurt	[37]
Black tea, chocolate milk, and natural yogurt	The study aimed to compare the sensory profiles of different sweeteners to sucrose in black tea, chocolate milk, and natural yogurt and to evaluate the consistency of an individual sweetener across each matrix	Sugar reduction	Rate-all-that-apply	Attributes: Different, depending on the food sample Samples: Black tea, chocolate milk, and plain yogurt added eight sweeteners	Protocol: Participants rate the intensity of all attributes that apply to describe each sample sensorially Data analysis: Mixed analysis of variance followed by Bonferroni test	Sucrose-allulose mix, aspartame, erythritol, palatinose, and sucralose taste more like sucrose in all foods. Acesulfame K, stevia, and Luo Han Guo have a bitter, chemical taste and less sweetness	[38]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Water solutions with three different types of sweeteners	The study aimed to explore the impact of sweeteners on aroma and taste intensity and how cultural differences influenced the relationship between vanilla aroma and sweetness	Sugar reduction	Descriptive sensory analysis	Attributes: Liquorice aftertaste, liquorice flavor, drying mouthfeel, sweet taste, vanilla flavor, vanilla aroma Samples: S = sucrose, ST = sucrose + tagatose, TR = tagatose + reb. A, SV = sucrose + vanilla flavor, STV = sucrose + tagatose + vanilla flavor, TRV = tagatose + reb. A + vanilla aroma	Protocol: Consumers were asked to rate sweet aroma intensity, sweet taste intensity, and overall liking Data analysis: Mixed analysis of variance followed by the Tukey test	Consumers in both countries rated the vanilla-flavored samples as having a higher sweetness intensity than the unflavored samples Vanilla aroma enhances the sweetness intensity of the different sweeteners	[39]
Dairy desserts	The study evaluated the feasibility of using cross-modal interactions to reduce the sugar content of products targeted at children	Sugar reduction	Temporal check-all-that-apply and temporal dominance of sensations	Attributes: Soft, creamy, sweet, hard, off-flavor, vanilla flavor Samples: Five vanilla milk desserts, including a control sample with 12% added sugar and four sugar-reduced samples prepared with 7% added sugar	Protocol: Children were given six milk dessert samples and asked to evaluate each using TCATA or TDS after placing a spoonful in their mouths and pressing the "start" button on the screen Data analysis: Analysis of variance, Tukey test, principal component analysis, and agglomerative hierarchical cluster	A sugar reduction of up to 40% is feasible in vanilla milk desserts for children	[40]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Snack foods	Reduce the salt content of snack foods, maintaining saltiness perception and acceptability	Sodium reduction	Descriptive sensory analysis and consumer acceptance	Attributes: Aroma (overall intensity, oil, potato, appearance, golden color, amount of dark edges, amount of blemishes/black marks, greasy/oily, amount of speckles, texture, crispiness, hardness, crunchiness, greasiness, thickness of cut, speed of breakdown, particles on fingers, oiliness on fingers), flavor (initial overall flavor, overall flavor during eating, initial saltiness, saltiness during eating, sweetness, oil, standard potato, reconstituted potato, earthy), aftertaste (overall aftertaste intensity, sweetness, saltiness, oil, standard potato, reconstituted potato, greasy mouthfeel) Samples: Nine potato chip products varying in salt content (six standard, one crinkle cut, one thick cut batch fried, one reconstituted baked)	Protocol: During the sessions, panelists rated the appearance, aroma, flavor, texture, and aftertaste of different potato crisp products. Additionally, 93 consumers participated in consumer acceptance testing for the products Data analysis: Analysis of variance, Tukey test, and principal component analysis	The salt reduction was achieved without losing perceived saltiness intensity or impacting consumer taste, validating the physicochemical design rules for the formulation of model salt particles. Results indicate that direct salt reduction can be successful up to 15%	[41]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Burger	Determine the effect of NaCl reduction and the addition of long-chain polyunsaturated fatty acids (PUFA) on the quality characteristics of hamburgers	Sodium reduction	Check-all-that-apply	Attributes: Salty, fatty, spicy, juicy, tender, seasoned, grilled, beef, characteristic, aromatic, and tasty Samples: Six different burger treatments were manufactured, with particular attention to the incorporation of fish oil to classify the product as a source of EPA/DHA	Protocol: Consumers rated their overall liking using a 9-point category hedonic scale and performed the check-all-that-apply questions Data analysis: a mixed analysis of variance with pairwise comparisons and correspondence analysis	Incorporating nonencapsulated fish oil in burgers is suggested to conserve EPA after cooking, as microparticles increase hardness, chewiness, and oxidation, negatively impacting sensory attributes and overall liking	[42]
Fully cooked coarse grind sausages	Develop and test four biphasic gels (BPGs) as pork fat substitutes in fully cooked coarse grind sausages	Fat reduction	Descriptive sensory analysis	Attributes: Smoked sausage aroma, other aroma, first bite firmness, creaminess, moisture release, smoked sausage flavor, off-flavor, external color, external appearance, and internal appearance Samples: Four different formulations were created by combining an Oleo gel (OG) phase made up of 92.5% high oleic soybean oil and 7.5% rice bran wax, with one of two hydrogel (HG) phases containing either water and 7% or 8% gelatin. The OG and HG phases were mixed in ratios of 7:3 or 6:4 OG:HG. In total, the experiment produced four test formulations	Protocol: Sensory attributes were evaluated on a 15-cm-long unstructured line scale Data analysis: A mixed analysis of variance, pairwise comparisons using the Tukey–Kramer test	The biphasic gels allowed for a significant reduction in fat while maintaining the sensory quality and texture of the sausages	[43]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Chicken mortadella	Development of chicken mortadella with total and partial replacement of chicken skin by green plantain biomass (GBB)	Fat reduction	Temporal check-all-that-apply	Attributes: Fat flavor, smoked, spicy, salty, chicken mortadella flavor, soft, firm, juicy, fibrous Samples: F0 (control treatment formulated with 100% chicken skin), F1, F2, F3, and F4 (25, 50, 75, and 100% replacement of chicken skin by GBB, respectively)	Protocol: Each participant evaluated five samples using the temporal check-all-that-apply method and rated the samples using an unstructured 9-point hedonic scale Data analysis: Analysis of variance, Tukey test, and penalty analysis	Replacing up to 100% of chicken skin with GBB is possible, resulting in a healthier emulsified meat product that consumers receive well	[44]
Cream cheese	The study aimed to analyze the sensory attributes of commercial cream cheese and assess their influence on consumer preferences	Fat reduction	Check-all-that-apply	Attributes: White, matte milky, light yellow, bright, and sweet Samples: Five commercial cream cheese samples were analyzed, two traditional and three low-fat formulations	Protocol: 102 participants were given five samples to evaluate using the check-all-that-apply methodology and then rated acceptance on a 9-point hedonic scale Data analysis: Two-way analysis of variance and Tukey test	Consumers prefer firmer, whiter, and more opaque cream cheese with a mild taste and milk flavor over sweet ones. Appearance was a decisive attribute for acceptance, and the study's results can aid in predicting consumer acceptance and reducing uncertainties in product development	[45]
Beef burger	Evaluate the effect of the *Agaricus bisporus* (AB) mushroom as a fat substitute in beef burgers	Fat reduction	Check-all-that-apply	Attributes: Juicy, tender, aromatic, tasty, seasoned, grilled, fatty, salty, rancid, fibrous, brittle, dry Samples: A control (0% AB, 20% fat) and three treatments with partial fat substitution: AB 5% (5% AB, 15% fat); AB 10% (10% AB, 10% fat); AB 15% (15% AB, 5% fat)	Protocol: 209 participants evaluated four burger samples using check-all-that-apply questions and acceptance Data analysis: A mixed analysis of variance, Tukey test, correspondence analysis, and principal coordinate analysis (PCoA)	AB's partial substitution of animal fat is a promising strategy to develop a low-fat hamburger	[46]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Bologna sausage	To investigate the effects of salt and fat reduction on bologna sausage's dynamic sensory perception, with emulsion gel as a fat substitute	Salt and fat reduction	Temporal check-all-that-apply and temporal dominance of sensations	Attributes: Bologna flavor, saltiness, fat flavor, spicy, juicy, firm, soft Samples: Control bologna (NF-PF/NS) and reformulated samples (NF-PF/RS, RF-EG/NS, RF-EG/RS, RF-PFRG/NS, and RF-PFEG/RS). NF-normal fat (20%), RF-reduced fat (10%), PF-pork back fat, EG-emulsion gel (4% SPI, 16.5% INUL, 50% SO), NS-normal salt (2%), RS-reduced salt (1%)	Protocol: Regular consumers evaluate samples using either the temporal check-all-that-apply or the Temporal dominance of sensations Data analysis: Analysis of variance, Tukey test, and correspondence analysis	Temporal dominance of sensations and temporal check-all-that-apply are two temporal methods for evaluating the sensory perception of reformulated meat products. The study found that the flavor of bologna was the most liked factor, while the flavor of fat was the main aversion factor. Therefore, researchers recommend masking the fat flavor in future studies to improve acceptance	[47]
Biscuit	Apply temporal sensation dominance to assess fat levels (full fat, reduced by 30% and 50%) and fat quality (butter or margarine) of cookies in an industrial setting	Fat reduction	Temporal dominance of sensations	Attributes: Crunchy/compact, crumbly/melting, sticky, sweet, salty, buttery lasting, buttery, toasted/biscuit, oily, and raw dough Samples: Full fat, 50% fat-reduced, 30% fat-reduced butter Full fat, 50% fat-reduced, 30% fat-reduced margarine	Protocol: Twenty-seven subjects participated in the temporal dominance of sensations test of the six biscuits Data analysis: Dominance rate curves and principal component analysis	Clear differences in sensory experience were found between products with 50% less fat and full-fat products, highlighting the importance of flavor and texture in the consumption experience	[48]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Black pudding	To investigate the feasibility of reducing fat and sodium content in black pudding by evaluating its sensory acceptability, composition, and physicochemical characteristics	Salt and fat reduction	Ranking descriptive analysis	Attributes: Amount of grain, fat, spiciness, saltiness, juiciness, hardness, and off-flavor (intensity) Samples: Twenty-five formulations of black pudding were prepared, varying in fat content from 2.5 to 20% (w/w) and sodium content from 0.2 to 1.0% (w/w)	Protocol: Each participant ranked the attributes of black pudding samples and rated acceptance on a 10-cm line scale Data analysis: Analysis of variance and Tukey test	Sodium content significantly impacted the sensory acceptance of black pudding, with samples containing more sodium being more acceptable. It is possible to reduce the fat content in black pudding	[49]
Dry-cures hams	To evaluate the impact of salt and intramuscular fat content on the sensory characteristics of Iberian and Serrano cured hams using the time-intensity method	Salt and fat reduction	Time intensity	Attributes: Hardness, fibrousness, saltiness, overall flavor, cured and juiciness Samples: 20 samples of dry-cured Iberian ham and 28 samples of dry-cured Serrano ham were used	Protocol: Time-intensity analysis performed by a trained panel Data analysis: Analysis of variance and principal component analysis	The reduction of salt content from 5.5 to 3.5% in the final product does not appear to affect the perceived saltiness in Iberian dry-cured hams with an intramuscular fat content ranging from 8 to 16%	[50]
Freshwater fish burgers	To investigate the impact of reducing and substituting salt (NaCl) in burgers made from pacu (*Piaractus brachypomus*), an Amazonian freshwater fish	Salt reduction	Check-all-that-apply	Attributes: Dry, hard, salty, compact, seasoned, aromatic, off-flavor, characteristic, grilled, tender, juicy, fishy, tasty, fatty, and spicy Samples: In the first stage, five treatments were evaluated with NaCl concentrations ranging from 0.5 to 1.5 g/100 g In the second stage, NaCl was replaced up to 50% by potassium chloride (KCl) or calcium chloride (CaCl 2)	Protocol: Consumers rated their overall liking on a 9-point hedonic scale and answered check-all-that-apply questions Data analysis: A mixed analysis of variance was followed by the Tukey test and Cochran test, followed by correspondence analysis	The burger achieved up to 75% reduction in NaCl through two stages. It is essential to study NaCl reduction first before incorporating substitutes	[20]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Smoked bacon	To analyze the sensory characteristics of smoked bacon using the temporal sensation dominance (TDS) technique	Artificial smoke reduction	Temporal sensation dominance	Attributes: Smoked, hard, tender, roasted, juicy, woody, crunchy, fatty, fibrous, and salty Samples: Eight samples of smoked bacon, six were subjected to conventional smoking using different reforestation woods, and two were made with liquid smoke	Protocol: Consumers evaluated the samples using temporal dominance of sensations Data analysis: Analysis of variance, Tukey test, and canonical variance analysis	Temporal sensation dominance differences in dominant sensations rate, trajectory, and duration are promising for capturing sensory changes in smoked bacon	[51]
Smoked bacon	A descriptive analysis investigated the sensory profile of bacon smoked using reforestation woods and liquid smoke	Artificial smoke reduction	Descriptive sensory analysis	Attributes: Shine, fat content, redness, yellowness, saltiness, smokiness, fattiness, succulence, and chewiness Samples: Bacon smoked with *Eucalyptus citriodora*, *Acacia mearnsii*, *Bambusa vulgaris*, liquid smoke, commercial sample, and negative control (unsmoked bacon)	Protocol: The panel evaluated all samples for nine sensory attributes using an unstructured 10-cm scale in three replicates Data analysis: A mixed analysis of variance, Tukey test, and principal component analysis	The smoking process intensifies the "saltiness" and differentiates unsmoked from smoked bacon, leading to changes in sensory characteristics	[52]
Beef burger	To investigate the impact of pineapple by-products and canola oil as substitutes for fat on the sensory and physicochemical properties of low-fat hamburgers	Fat reduction	Quantitative descriptive analysis	Attributes: Cohesiveness, appearance brown color, flavor beef burger, odor beef burger, texture springiness, texture tenderness, texture juiciness Samples: Conventional (CN) and four low-fat formulations (CT, PA, CO, PC) with varying fat percentages were tested	Protocol: The panelists evaluated samples using a 10-cm scale Data analysis: A three-factor analysis of variance, Tukey test, and principal component analysis	Low-fat beef burgers were tougher and more cohesive, but pineapple by-products and canola oil were as tender as the control in instrumental texture	[53]

Table 1 (continued)

Product category	Objective	Reformulation strategy	ISPF method	Attributes and samples	Protocol and data analysis	Conclusion	Reference
Mazamorra morada	To assess the sensory characteristics of purple mazamorra based on the type and amount of potato, sweet potato, and corn starch	Sugar reduction	Check-all-that-apply	Attributes: Purple, bright, sweetness, acid, fruity, thick, gelatinous, homogenous, bitter, cinnamon, slight purple, slight bright, slight sweet, slight acid, slight fruity, slight thick, slight gelatinous, slight bitter, and slight cinnamon Samples: Ten samples varying potato starch, sweet potato starch, and corn starch	Protocol: Consumers rated their overall liking using a 9-point hedonic scale and check-all-that-apply questions Data analysis: Cochran test, correspondence analysis, internal preference mapping	Samples with potato starch or a combination of all three starches had the highest acceptance rates. The CATA questionnaire and ideal profile were used better to understand the consumer's perception of mazamorra morada	[54]
Mortadella	To investigate the effect of two fat levels on the sensory texture of mortadella and compare it to texture profile analysis data	Fat reduction	Texture profile and descriptive analysis	Attributes: Oiliness, wetness, roughness, hardness, springiness, chewiness, grittiness, particles in the palate, and particles on the teeth Samples: Two samples of traditional and low-fat mortadella of a Brazilian commercial brand	Protocol: The trained panel evaluated the intensity of nine textural attributes of the two samples using a 10-cm unstructured linear scale. Data analysis: a mixed linear analysis of variance, Pearson correlation analysis, and multiple factor analysis (MFA)	Low-fat mortadella was perceived as harder than traditional mortadella	[55]

58]. Conjoint analysis (CA) is the most representative method used to analyze the extrinsic features of different foods in SCS. It is an experimental approach where consumers are asked to rate their expected acceptance or purchase intention for product profiles with specific extrinsic factors [59]. These factors vary at specific levels according to an experimental design. This analysis aims to measure the impact of product attributes on consumer preferences and predict consumer behavior [60].

In summary, the CA process involves three stages, as shown in Fig. 4. The first stage is the stimuli design. This consists of selecting the factors and levels of interest and arranging them in a full or fractional factorial scheme. The second stage is data collection. Consumers are presented with the stimuli and asked to rate their expected acceptance or purchase intention. Finally, the data analysis of CA provides information on the relative importance and utility of different factors and levels. This helps in selecting the high-performing stimuli.

The CA is commonly accompanied by additional measurements, such as sensory characteristics obtained through free or attribute-based descriptions [57, 58]. In recent times, even intrinsic and extrinsic variables have been combined to simulate an actual consumer situation, increasing the ecological validity of the test [61, 62].

Based on the suggestions in this review, after selecting the ideal extrinsic properties for the product, further analysis needs to be conducted on the best intrinsic and extrinsic conditions with target product purchasers. The following section will provide more details on this.

Final Food Product

The food industry needs to choose a prototype product with optimized properties based on the expectations of the target consumer before launching the final product in the market. This prototype will be compared to a competing, top-selling product. The selected products will be sent to the homes of potential consumers, who will evaluate them under actual consumer conditions, considering several factors such as sensory profile, acceptance, suitability for use, and purchase intention. Additionally, the sensory and hedonic characteristics of the ideal product may also be required as both the prototype and the commercial product may differ from the ideal product.

Suppose you want to create a functional and refreshing drink that contains antioxidant compounds extracted from agro-industrial waste and germinated quinoa. Optimizing its sensory and hedonic profile using DA and an acceptance scale would be best to achieve this. Next, you should estimate the relative importance of extrinsic properties and determine the best levels of the factors through CA. This will help you select the best extrinsic profile. Finally, it would be best to verify the product's suitability by combining the best extrinsic conditions with the best prototype. After conducting home use tests, the samples should be represented in multivariate biplots with the prototype, commercial, and ideal products. An in-depth analysis of the biplot will reveal whether the product is ready to be launched on the market or if further optimization is necessary.

Based on the review recommendations, we encourage the academic and industrial community to follow the sequence proposed in this review, which may initially seem time-consuming and complex. However, empirical

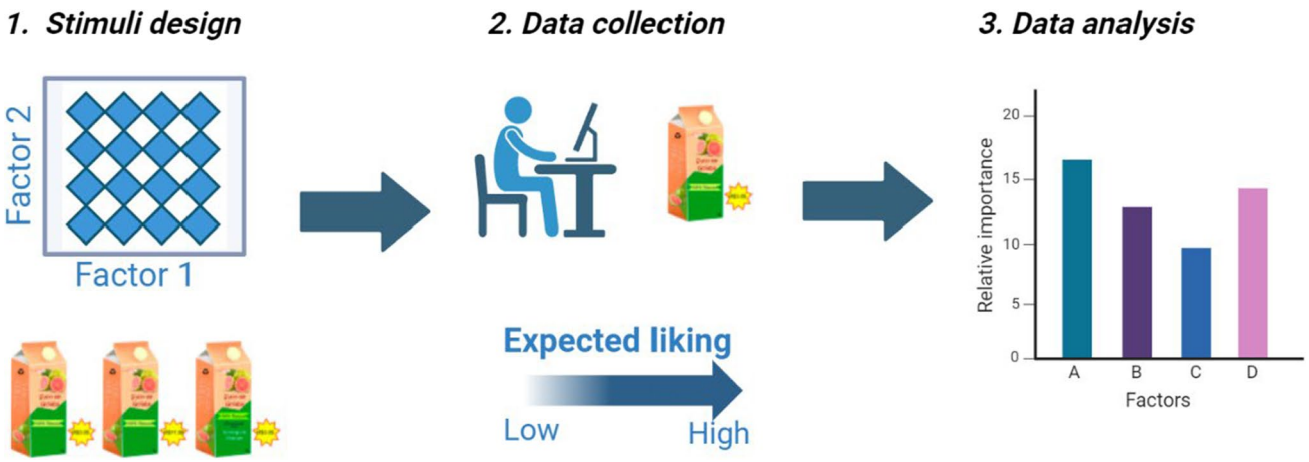

Fig. 4 Steps to implement the CA

evidence shows several success stories in developing foods widely sold in today's market.

Concluding Thoughts and Upcoming Trends

The SCS is crucial for developing novel food products that meet consumer demands. It highlights the transition from traditional sensory methods using trained panels to consumer-based methods that better capture consumer preferences and expectations. Based on the literature, this review suggests a detailed and multifaceted approach to food product development and reformulation using SCS, which, despite being time-consuming, has proven successful in bringing competitive products to market. It emphasizes the importance of combining intrinsic and extrinsic sensory and consumer insights to align product characteristics with consumer preferences for healthiness and sensory quality.

Based on the themes and conclusions provided in the paper, the upcoming trends in food product development and reformulation using SCS may include the following:

a. Health-conscious formulations: With SCS aiding in creating food products with reduced salt, sugar, and fat, we can expect a continued trend towards health-conscious formulations that maintain the original sensory appeal of the product.
b. Technology integration in SCS: The use of advanced technological strategies, such as microencapsulation, ultrasound, and size reduction of salt crystals, in maintaining or enhancing the sensory attributes of reformulated, healthier products is expected to grow.
c. Consumer-driven sensory analysis: A significant trend involves shifting from expert-driven to consumer-driven sensory analysis methods. Consumers' ability to describe their sensory experiences in their own words provides more diverse data for product development.
d. Extrinsic properties of foods: There will be an increasing focus on how packaging, branding, and other extrinsic factors influence consumers' sensory expectations and perceptions, affecting their purchase decisions.
e. Food literacy: A growing trend in consumer empowerment and education about food choices, termed food literacy, will likely emerge as a key focus area, influencing how consumers perceive and value different sensory attributes about health and wellness.

These trends represent a future where food product development is increasingly consumer-centric, health-oriented, and technologically advanced, with SCS playing a pivotal role in guiding the industry.

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Declarations

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- •• Of major importance

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