

Review

# Aromachology Related to Foods, Scientific Lines of Evidence: A Review

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**Abstract:** Smell is the second-most used sense in marketing strategies in the food industry. Sensory marketing appeals to the senses with the aim of creating sensory experiences and converting them into specific emotions associated with a specific product. There is a strong relationship between sensory marketing, aromachology, and neuroscience. In this review, studies were searched on the use of scents in food experiences such as restaurants and food establishments, and a critical evaluation was performed on their aims, target population, place of the study, scents tested, foods tested, and measured parameters, and the main findings were reviewed. Case studies carried out by private companies are also presented. A small number of scientific studies on aromachology related to food are available, and most of them are conducted in artificial laboratory conditions. Methodological procedures largely diverge among studies, making them very difficult to compare and extrapolate results. There is a clear need for research on aromachology related to food in the fields of sensory marketing and appetite modulation. After a brief presentation of the state of the art, we briefly mention future improvements and ideas for future research.

**Keywords:** scent; neuroscience; sensory marketing; consumer



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## 1. Introduction

Smell/aroma is directly related to human emotions; it is the main trigger for human emotions after sight. In fact, it has been reported that 75% of human emotions are created through smell/aroma [1]. The olfactory bulb is part of the brain's limbic system (seat of emotions, desires, and instincts), and that is why smells can trigger strong emotional reactions. This explains the strong link between smells, emotions, and memories. In practice, it is possible to use this evidence to influence and promote certain feelings [2]. Herz [3] reviewed scientific studies on the mechanisms mediating the effect of odours on mood, physiology, and behaviour. Two main types of studies were reported—one investigating pharmacological and the other psychological mechanisms of action. The author concluded that the psychological interpretation of odour effects was the most comprehensive interpretation, showing that odours have clear psychological effects.

Scents use has been evaluated for different purposes such as sensory marketing of different goods or services, well-being, cosmetics, etc. [4]. Regarding our field of interest, foods and food-related stores and environments, scents have been tested for several purposes: to study their impact on appetite, food consumption, food sales, evaluating shopping experience, etc. Sensory marketing can be defined as marketing that involves the senses of consumers and studies the perception, emotion, learning, preference, choice, evaluation, knowledge, judgment, and purchasing behaviour based on the senses [5]. Sensory marketing appeals to the senses with the aim of creating sensory experiences and converting them into specific emotions associated with a specific product.

Smell is the second-most used sense in marketing strategies in the food industry [6]. Therefore, aromas play an important role in marketing strategies [6]. The memory of smell is the most intense of all the senses, and only about 20% of olfactory sensations are forgotten. Human beings even maintain very old memories and feelings related to smell [1]. Aroma marketing has two main modalities: (i) the use of the unique smell/aroma of the product itself, with the possibility of creating an aroma that identifies the company with the product/brand and (ii) the use of an ambient smell/aroma in spaces (restaurants, supermarkets, small shops, public spaces) [2].

Ambient scent is defined as a scent that is present in the environment but does not emanate from a particular object [2]. These ambient scents have been classified based on (i) the affective quality of the aroma (how pleasant the aroma is), (ii) the level of arousal of the aroma (how likely is it to elicit a physiological response), and (iii) the intensity of the aroma (how strong it is). Several authors pointed out that stores that use ambient scents give their customers the feeling that they spend less time looking at products and trying them [7,8].

In the 1970s, fragrances began to gain prominence as a tool for retailers aiming to improve the indoor environment by introducing specific scents [9]. Origins of olfactory marketing seem to be in the 1980s when British supermarkets realised that fresh baking bread aromas increased selling bread and other products [10]. This moved them to introduce bakery as a new department area. However, the difficulty of introducing aromas in a supermarket for increasing sales can be illustrated by the fact that customers can smell fresh bread aromas and buy the bread but can prevent them from buying other goods [6]. This reduction in their willingness to buy is due to the fact that their sensory perception and emotions are, to some extent, satisfied by purchasing the bread [2]. That is a case based on the scent of a product itself. However, most recent studies have focused on ambient aroma, and analysed the influence of aroma on the purchase intention of consumers [2].

In 1982, the Olfactory Research Fund coined the term ‘aromachology’, relevant to marketing. This area of expertise deals with the temporary effects of fragrances on human behaviour, feelings, well-being, moods, and emotions [11]. Aromachology, as defined by the Sense of Smell Institute in 1982, is the scientific discipline studying psychological and physiological effects of inhaling aromas and examining, feelings and emotions elicited by odours stimulating olfactory pathways. Aromachology research must follow empirical scientific methodology—goals, hypothesis, materials and methods (aroma, subject population number and representativity as well as the control group), and proper statistical data analysis—and be published in peer-reviewed reputable journals [11]. Under these premises, if a study is conducted using the internet, many publications that may be found regarding odour effects on mood and behaviour should not be taken into consideration since they do not follow such premises, and their results may not be taken as scientifically sound. In the present review, only studies following the requirements have been included. At present, focusing on the general scientific literature on aromachology, there are many scientific lines of evidence reporting that inhaling aromas may elicit feelings such as relaxation, sensuality, happiness, or exhilaration [12–15]. There are also scientific lines of evidence on the physiological effect of scents. As an example, in a study on rats, Shen et al. [16] presented evidence that the scent of grapefruit oil excited sympathetic nerves, innervating white and brown adipose tissues and the adrenal gland, inhibiting the vagal nerve innervating the stomach, increasing lipolysis and heat production (energy consumption), and reducing appetite and body weight in rats; the opposite effect was observed for lavender, mainly due to linalool, which enhanced appetite and body weight [16].

The most common use of scents is for marketing purposes. Scent sensory marketing is about much more than simply spreading a pleasant fragrance in a space. It may be, starting from the brand identity of a company (and its values) and studying its target consumer, to create an aroma that exemplifies company identity (and values). The expression ‘scent marketing’ has been used to describe the use of essences to create an environment, and promote products or position a brand, and therefore, scent marketing can be defined as the strategic use of the olfactory experience and essences in relation to commercial

products [17]. There are three types of scents used in environments [6,18] known as (i) head, (ii) heart, and (iii) basic. Head scents are generally small, light molecules that give a refreshing and invigorating sensation. These are typically fresh citrus or green notes, including lemon, lime, neroli, bergamot, grapefruit, and cooler herbal notes such as lavender, thyme, and basil. The molecules responsible for heart-like scents tend to be larger and can take anywhere from five minutes to an hour to develop. They can include different ingredients, such as flowers, spices, woods, resins, and grasses. Lastly, the basic-type scent molecules are the largest and heaviest. They are aromas such as woods, resins, oakmoss, vanilla, amber, and musk [2].

The use of aromas in food is regulated (R1334/2008 in the European Union), and all aromas need to be approved by public authorities after following strictly regulated procedures. In the present review, we do not consider food aromas but scents used in food-related environments. Scents should also comply with safety and quality standards that are supervised by independent laboratories leading to safety certificates, such as the International Fragrance Association (IFRA) Conformity Certificate, assessed by a panel of experts from the Research Institute for Fragrance Materials (RFIM). The safety of scents is evaluated according to the intended use (odorant, skin contact, etc.).

Classical data collection on consumer studies are questionnaires to consumers; however, they cannot assess the complex set of factors affecting decision making (emotions, feelings, etc.) [19]. It is in this scenario that neuroscience tools entered the field of consumer marketing studies. Neuromarketing aims to use psychological and neuroscience tools to study subconscious processes during decision making in order to provide scientific explanations of consumer's preferences and behaviours. Main neuroscience tools used in neuromarketing are biometric measurements (body reaction measures: eye movements, facial expressions) and brain measurements. Using such techniques to measure respondents' subconscious reactions in addition to classical feedback collection techniques may provide a comprehensive perspective on consumers' perception [19]. In the present review, we will focus only on scents, even though visual factors (packaging, design, portion size, the gastronomic service used, etc.) also influence consumers' perception and food appeal. Both senses are closely related; however, little is known about their complex interactions [20], and only a few studies combine the evaluation of both factors.

Regarding sensory marketing in the food business, one may differentiate between food stores (food is sold, not consumed) and restaurants (gastronomic facilities where food is consumed). To this second situation applies the concept of neurogastronomy; neuroscientist Gordon M. Shephard [19] first summarised the neuroscientific research on the gastronomic experience in the brain (perception and processing of taste, etc.).

Taking all above mentioned into account, it can be said that there is a strong relationship between sensory marketing, aromachology, and neuroscience as consumers' responses can be measured in two ways, namely, (i) explicit tests: through direct consultation with consumers through surveys/questionnaires and (ii) implicit tests: using biometric parameter measurement equipment, for example, using eye trackers. These three applied sciences (sensory marketing, aromachology, and neuroscience) are closely interrelated.

Scent branding is quite popular in non-food stores, and one may recall certain brand scents, but it is not that common in food stores and restaurants. Most developments in this area have been driven by companies' needs, and carried out by private companies, with little knowledge shared with the public and scientific community [19]. The present work was carried out within the framework of the Erasmus + KA2 project NEUROSMARTOL-OGY GY Strategic partnership Project No. 2018-1-SK01-KA203-046324. Implementation of Consumer Neuroscience and Smart Research Solutions in Aromachology. Very little information is available in the scientific literature regarding aromachology and much less on aromachology related to food. The present review aims to evaluate scientific evidence and knowledge on aromachology related to food. For this purpose, a literature review was conducted, focusing on the use of scents in restaurants, food establishments, and artificial laboratory conditions. A critical evaluation was performed on their aims, tar-

get population, place of the study, scents tested, foods tested, and measured parameters, and main findings were reviewed. Case studies carried out by a scent company are also presented. Results of the review may provide the scientific community with the state of the art on aromachology in food-related environments and a critical evaluation of the applied experimental procedures. The study may also help scientists, scent providers, food businesses, and consumers in understanding and developing solutions to better suit consumer needs and demands (enhanced customer experience related to food purchase or consumption, appetite modulation, etc.).

## 2. Literature Review Methods

### 2.1. Scientific Literature Review

The review is organised as a research paper. A scoping review was used to synthesise the evidence and assess the scope of the 18 studies on the topic. This review was based on the PRISMA Extension (PRISMA-ScR) approach [21] for Scoping Reviews. A comprehensive literature search—Scopus and ScienceDirect—was performed in April 2021 and was limited to articles published in English since 1990 (Figure 1). Text words and controlled vocabulary for several concepts (food, consumer, aroma, behaviour) within the titles, abstracts, and keywords, were used. Scopus, Web of Science, and Google Scholar were used for the literature search. Terms such as sensory marketing, scent marketing, aromachology, behaviour, consumers and food, etc., were used. The main focus was given to studies published in journals included in Journal Citation Reports, as well as sensory and aroma marketing books published by highly relevant publishers and only focused on food and food business. Only research papers including experimental design and data treatment were selected. The structure of the review allows dissection of how published studies have been conducted: population under study, number of participants, tested scents, location of the study (real or artificial laboratory conditions), foods evaluated, measured parameters (customer ballots, biometrics, etc.), aims of the studies, and major findings.

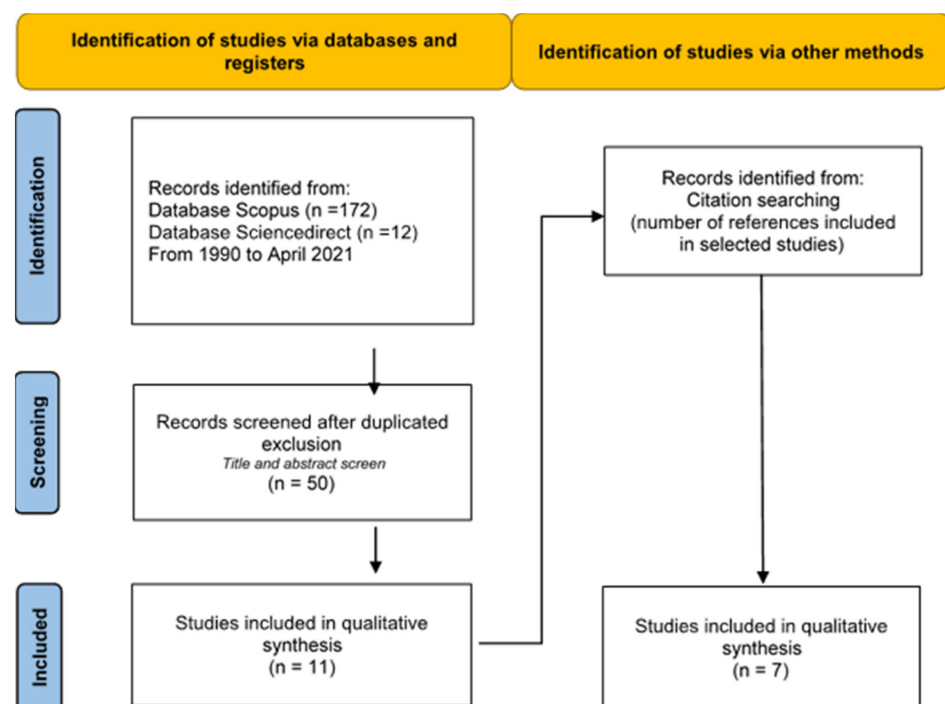


Figure 1. Flow diagram describing study selection process of scientific literature.

Table 1 presents the codification of the studies; the numbers given to each study are used in supplementary tables to cite them. Literature review methodology, objectives, and findings are presented in the table and briefly described to allow further discussion.

**Table 1.** Coding of revised manuscripts found linked to neuromarketing and aromachology in restaurants and food establishments, with its objectives and finding of the revised scientific evidence. Basic data on the experiments on reviewed papers: number of participants, characteristics of participants, and food/non-food used.

Study	Main Objectives	Findings	N	Characteristics of Participants	Material	Data Collected	
<b>OBJECTIVE REAL BEHAVIOUR</b>							
1	Guéguen and Petr [22]	To know the effect of two classical aromas diffused in a restaurant in order to test their effect on consumers' behaviour.	Lavender—but not lemon aroma—increased the length of stay of customers and the amount of purchasing, possibly linked to lavender relaxing effect.	88	Restaurant customers	Lemon and lavender scents in a pizzeria 17 pizzas, 4 types of meat, 3 fishes, and 4 salads.	Length of time and money spent at the pizzeria
2	Wada et al. [23]	To explore whether the ability to bind olfactory and visual information in object recognition is developed in infancy. The study explored the ability of infants to recognise the smell of daily foods, including strawberries and tomatoes.	Infants showed a preference for the strawberry picture when they smelled the congruent odour in strawberry season. This olfactory–visual binding effect disappeared while strawberries were out of season.	Study 1: 37	Babies (6–8 month)	Non food (Digital photos of tomatoes and strawberries were taken for visual stimuli)	Infant looking time as assessed by recording
				Study 2: 26	Females	Pieces of chocolate, cake and stroopwafel, beef croquette, cheese cubes and crisps, slice of melon, an apple and strawberries, piece of cucumber, tomato salad and raw carrot, bread, croissants, and pancake.	Infant looking time as assessed by recording
3	Berčí-k et al. [24]	How aroma influences customer purchasing decision (preferences) in chosen service provider through the tracking of daily sales of baked baguettes (Paninis) with using of aroma equipment; Aroma Dispenser.	The acquired values were baked baguettes sales in a chosen period including aromatic stimulus, as a form of sales promotion, provides only a minimal effect. Nevertheless, an effect of specific odour was noticed on total sale of Paninis but only a small increase, which cannot be considered as economically efficient.	Unknown (real restaurant customers)	Customers of sports bar	Baguettes (Panini) released scents: 'crunchy bread' and 'chicken soup'	Sales and preference for specific baguettes measured in real conditions
4	Leenders et al. [25]	To test the effects of a pleasant and congruent ambient scent at different intensity levels in a real supermarket on shoppers' mood and their evaluations and in-store behaviours. To explore the moderating effects of shopper characteristics such as age and gender.	Shoppers tend to overestimate the amount of time spent shopping at lower intensity levels and underestimate time spent shopping at high scent intensity levels. The nature of the shopping trip is important because shoppers may be more or less aware of the ambiguous scent presence. In this case, grocery shoppers, there was ample variety in time pressure and age.	Unknown (real conditions)	Supermarket customers	Melon scent in a supermarket	Questionnaire: mood, overall evaluation of the store, and store environment. Real time spent in the store. Questionnaire on time pressure and pleasantness of the scent.

Table 1. Cont.

Study	Main objectives	Findings	N	Characteristics of Participants	Material	Data collected	
5	Biswas and Szocs [26]	This research examines the effects of food-related ambient scents (indulgent and non-indulgent) on children’s and adults’ food purchases/choices. It aims to evaluate whether the perception of a food scent may induce reward and so reduce the need to seek rewards from gustatory food consumption.	Extended exposure (of more than two minutes) to an indulgent food-related ambient scent (e.g., cookie scent) leads to lower purchases of unhealthy foods compared with no ambient scent or a non-indulgent food-related ambient scent (e.g., strawberry scent). The effects seem to be driven by cross-modal sensory compensation, whereby prolonged exposure to an indulgent/rewarding food scent induces pleasure in the reward circuitry, which in turn diminishes the desire for actual consumption of indulgent foods. Notably, the effects reverse with brief (<30 s) exposure to the scent.	Study 1: 900	Middle School Students (middle school cafeteria)	Apple scent Pizza scents No scent	Sales of indulgent and non-indulgent foods under the three scenting conditions
				Study 2: 61	Laboratory consumer study	Cookies’ scent Strawberry scent	Questionnaire to choose either cookies or strawberries under both scenting conditions
				Study 3: Unknown	Customers at a supermarket	Chocolate chip cookies scent Strawberry scent	Collecting customer receipts to register items purchased
				Study 4: Unknown (Students from a major University)	University students	Cookies’ scent Strawberry scent	Questionnaire on food choice between indulgent and non-indulgent food
				Study 5: Unknown (Students with parental consent)	Middle School Students (middle school cafeteria)	Cookies’ scent Apple scent	Questionnaire about feelings and reward
				Study 6: Unknown (Students from a major University)	University students	Cookies’ scent Strawberry scent Tested for: high and low exposure time	Questionnaire on food choice between indulgent and non-indulgent food
				Study 7: Unknown (Students from a major University)	University students	Cookies’ scent Strawberry scent No scent	Scent identification capability Food choice scale between pizza and salad
<b>OBJECTIVE PHYSIOLOGICAL DATA</b>							
6	Krishna et al. [27]	Imagined odours can enhance consumer response but only when the consumer creates a vivid visual mental representation of the odour referent. The results demonstrate the interactive effects of olfactory and visual imagery in generating approach behaviours to food cues in advertisements. Scents can enhance consumers’ responses.	Effect of scent, image, and both in consumer response. Consumer response is measured by salivation change (studies 1 and 2), actual food consumption (study 3), and self-reported desire to eat (study 4).	Study 1: 59	Undergraduate students	Non food (Advertised food products: chocolate chip cookies)	Salivation.
				Study 2: 142	Undergraduate students	Non food (Advertised food products: chocolate chip cookies)	Salivation
				Study 3: 226	Undergraduate students	Non food (visual sensory input with a special focus on imagining pictures on food consumption). Cookies provided after the test	Food consumption
				Study 4: 170	Undergraduate students	Scent of chocolate chip cookies with a picture of chocolate chip cookies in the print ad.	Self-reported desire to eat

Table 1. Cont.

Study	Main objectives	Findings	N	Characteristics of Participants	Material	Data collected
7	Lin [28] The focus of this dissertation is to understand the role of olfaction (sense of smell) in consumer behaviour.	Unpleasant odours raised stronger emotions than pleasant ones. Enhanced olfactory sensitivity (Hyperosmics) and normal individuals reacted in different ways to pleasant and unpleasant odours. Odour conditions affected food choices in both groups of individuals. Scenting enhanced preference for healthier food choices.	Study 1: 26	Students	Scents released from manufactured smell kits, Sniffin Sticks (Burghart, Germany), are utilised as odour stimuli. Twenty different odours are included.	Neuroimagery and questionnaire chemical sensitivity scale
			Study 2: 60	Students	15 pleasant odour-associated pictures, 15 unpleasant odour-associated pictures and 10 non-odour-associated pictures.	Neuroimagery and questionnaire chemical sensitivity scale
			Study 3: 19	Students	Non food (images of snacks)	Food choices questionnaire
			Study 4: 80	Students	Non food (images of snacks)	Food choices questionnaire
<b>SUBJECTIVE DATA COLLECTION (EXPLICIT TEST)</b>						
8	Knasko [29] Two hypotheses were proposed: (i) subjects exposed to pleasant odours will spend more time looking at the food slides and give the slides better scores and (ii) when the odour of the room is conceptually congruent with a food slide, the slide will be viewed longer and be given higher ratings.	The thematic relationship between the ambient room-odour and the content of the photographic food slides did not play a role in this study. Rather, the results suggest that pleasant odours may have some general effects on humans due to their hedonic value. Congruency enhances pleasantness.	120	Age between 18–35	Non food (Slides with pictures: 6 chocolate items and 12 control slides of pine trees)	Questionnaires: mood, pleasantness, arousal, health symptoms (hunger and thirst)
9	Mitchell et al. [30] To investigate the effects of pleasant ambient odours within two different decision-making contexts: (i) to examine how the congruency of the effects of ambient odour on the brands chosen and the related decision process and (ii) to investigate the effects of scent on multiple decisions.	Experiments 1 and 2 provided that the congruency of the odour with the target product class influences consumer decision making. When ambient odour was congruent with the product class, subjects spent more time processing the data.	77	Pennsylvania University Students	Chocolate assortments, and non-food test (flowers)	Questionnaires: memory and choice among chocolate assortments
10	Morrin and Ratneshwar [31] To examine the relationship between ambient scent and brand memory in incidental learning task in which subjects were exposed to brand information through digital food photographs on a computer screen. Ambient scent was manipulated and stimulus viewing time was included.	It demonstrates that for studying the effects of ambient scent in marketing and consumer research settings, theory and methodological tools from cognitive psychology can be successfully adapted and applied to brand and product stimuli.	90	Students with good English level	Food spices plus non-food (brand recognition, other scents)	Questionnaire on food spices for pleasantness, liking, and appropriateness for food and beverages

Table 1. Cont.

Study	Main objectives	Findings	N	Characteristics of Participants	Material	Data collected
11	Bosmans [32]	Ambient scents strongly influenced customer evaluations. As long as ambient scents are congruent with the product, scents continue to affect consumers' evaluations, even when their influence becomes salient or when consumers are sufficiently motivated to correct for extraneous influences.	Study 1: 80	Undergraduate students	Orange	Questionnaire on product evaluation
			Study 2: 118	Undergraduate Students	Orange	Questionnaire on product evaluation
			Study 3: 75	Undergraduate students	Banana, apple, or tomato	Questionnaire on product evaluation
12	Yamada et al. [33]	The authors employed morphed images of strawberries and tomatoes combined with their corresponding odorants as stimuli. Visual preference for novel fruits was based on both conscious and unconscious olfactory processing regarding edibility. There is an interaction between visual and olfactory information: odours did not affect categorisation but preference.	56	Students	Non food (pictures of tomato and strawberry) and scent release from subliminal to supraliminal	Questionnaire on evaluation and odour detection
13	Firmin et al. [34]	Inhaling a fresh scent reduced females' craving levels; similarly, when a sweet scent was inhaled, the participants' craving levels for chocolate food increased. These findings are potentially beneficial for women seeking weight loss.	92	Student age 18–22	Non food (12 digital, coloured photographs of chocolate foods in the categories of chocolate cake, chocolate muffin, chocolate ice cream, and chocolate brownie). Fresh and sweet scents released for the evaluation	Place a ballot indicating craving level for chocolate
14	Zoon et al. [35]	Exposure to food odours increases appetite for congruent products, in terms of both taste and energy density, irrespective of hunger state. Food odours steer towards the intake of products with a congruent macronutrient composition.	29	Females	Pieces of chocolate, cake and stroopwafel, beef croquette, cheese cubes and crisps, slice of melon, an apple and strawberries, piece of cucumber, tomato salad and raw carrot, bread, croissants, and pancake.	Study conducted both under hunger and satiety conditions. Rating odour intensity, general appetite, and specific appetite for 15 foods
15	Ramaekers et al. [36]	The appetite for the smelled food remained elevated during odour exposure, known as sensory-specific appetite, whereas the pleasantness of the odour decreased over time, previously termed olfactory sensory-specific satiety. The first minute of odour exposure may be of vital relevance for determining food preference.	30	Women	Cups with banana, meat, or water (no smell). Combinations (odourless/banana, odourless/meat, meat/banana, and banana/meat.)	Sequential exposure to two aromas, followed by appetite questionnaire and food preference



Table 1. Cont.

REVIEWS							
Study		Main objectives	Findings	N	Characteristics of Participants	Material	Data collected
16	Krishna [5]	This review article presents an overview of research on sensory perception. The review also points out areas where little research has been conducted; therefore, each additional paper has a greater chance of making a bigger difference and sparking further research.	Still remains a tremendous need for research within the domain of sensory marketing, and such research can be very impactful.				
17	Paluchová [2]	This chapter is a summary of how the smell sense works through odour perception and its impact on consumer emotions and purchase decisions. Smell and memory are close terms, and their relationship is explained.	Either in a laboratory or in real conditions, air quality has to be respected and adapted for research and for spending time in each store.				
18	Spence and Carvalho [37]	Review: To summarise the evidence documenting the impact of the environment on the coffee-drinking experience. To demonstrate how many different aspects of the environment influence people's choice of what coffee to order/buy as well as what they think about the tasting experience.	The coffee-drinking experience (what we choose to drink and what we think about the experience) are influenced by product-extrinsic factors. There is a need to examine cross-cultural differences in consumers' choices of coffee to determine motivations for coffee consumption in different cultures.				

## 2.2. Case Studies from Scent Company

In addition to the scientific literature, case studies provided by REIMA Airconcept Company, which is a partner of the above-mentioned project are presented. On a regular basis, they develop scents and conduct studies in real conditions with their customers in order to provide solutions for customer needs, most of them protected by confidentiality agreements. Providing two case studies was the only contribution of the company; they did not take part in the manuscript. After reviewing the scientific literature and case studies provided by REIMA, a critical discussion is presented, aiming to point to future research needs on this field and detect fields that may benefit from an in-depth research on aromachology related to food.

## 3. Results and Discussion

### 3.1. Revision of Scientific Literature

Regarding aromachology focused on food, Table 1 shows the scientific manuscripts (reviews and articles) linked with the topic of this review, their main objectives, and findings. Only 18 studies related to aromachology on food were available, most of them on marketing or consumer studies journals, and most of them published within the last 10 years. Therefore, this a new field of scientific studies, with scarce background on the procedures, methodology, and an absence of standardised procedures, as we will discuss below.

*What were the main aims of such studies?* Some published studies reported results from more than one experiment. If we focus on real experiments, a total of 30 were reported. Twelve of the experiments explored food preferences or choices [26,28,30,32,33,36]; seven evaluated appetite modulation/effect [27,34–36]; three evaluated food sales ([24,26]; five evaluated odour–emotion mechanisms [26,28,29,31], and one the shopping experience (Table 1). The interest in aromachology comes from different fields, aroma marketing is probably the main field; however, scents as factors affecting appetite are an especially interesting field given that it can be useful to prevent obesity epidemics [26].

*What were the methodologies used in the studies?* Table 1 shows the main characteristics of the methodologies used in the reviewed studies: number of participants, characteristics of participants, food/non-food used, and type of collected data. ‘Non food’ means that pictures and slides were used to present food. Uneven details on participants have been provided in different studies; as an example, the number of participants is not given in several studies (unknown), mainly in studies performed in real conditions, when it is difficult to assess real numbers of customers. The number of participants ranged from 19 [28] to up to 900 [26]. Most available studies have been conducted with university students as participants, whereas just three on real restaurant or store customers [22,26,35,38]. Among the experiments reported in the selected papers, only eight were conducted in which real foods were present, i.e., real food choices could be made. In the others, only the scents or some pictures were used to recall the idea of food. Both types of studies are probably useful given that there are two types of scenarios: stores and gastronomic facilities. In some of the experiments, more than one type of data was collected (Table 1). Seventeen experiments collected subjective assessments in questionnaires. Nine of the experiments measured objective real behaviour: time measurement in five studies [22,23,25], sales in three studies [24,26], and food consumption in one study [27]). Finally, five studies measured objective physiological data: salivation in three experiments [27] and neuroimaging in two [28].

As previously commented, most studies relied on students as participants, and although valuable information was obtained from students, it is not clear to which extent a more complex population (diversity of ages, educational level, income level, etc.) will perceive or react to the tested scents in the same way, and therefore, if the results may be translated to market conditions. There are no standardised procedures to set target populations of consumer groups to conduct scent marketing studies, and some studies

have been carried out only in women, mainly those regarding effects on appetite and food choices [23,35,36].

It is important to highlight that one of the aspects related to the aroma of an establishment is the number of people in it at any given time. In this, some studies in real conditions included air quality assessment [24] which is somehow related to the influx of visitors, among other factors; however, store influx has not been taken into consideration in the reviewed studies, where only three had been performed in real conditions [24–26]. In future studies in real conditions, air quality assessment should be considered. Chebat and Michon [39], in the context of a field experiment, varied the aroma along with the retail density (how crowded the mall was) and examined the perceptions of the buyers about the quality of the product, mall environment, and positive effect. They found a positive effect of ambient scent on shoppers' perceptions of the mall's atmosphere only at the medium retail density level. In addition, a favourable perception of the retail environment influenced the perception of product quality. Buyers' moods did not have a significant direct effect on perceptions of product quality.

*What data were collected in the experiments?* At present, almost 50 per cent of aroma-chology studies on food are based on subjective assessments collected under controlled conditions (questionnaires), and there is little evidence on the real effect of aromatisation on physiological responses and behaviour. Very little use of neuroscience tools has been reported so far in the scientific literature [28], and the measurement of physiological data is very limited [27]. Studies reviewed are a collection of individual contributions with scarce coincidences on methodology, and therefore, collected results are quite difficult to compare. Given the diversity of methods employed and parameters evaluated such studies cannot be compared or discussed as a whole. Another relevant point is that most studies are directed to evaluate food choices or appetite. The aims of scent use are not always directed only to enhance customer satisfaction, as in non-food stores, but mainly to modulate food consumption or to provide knowledge on understanding the effect of odour on consumer mood or behaviour. Given that the scent can modulate consumer behaviour, many types of studies with different purposes may be planned and may need different methodology and measured parameters.

*Where did the studies take place?* Most of the studies were conducted under artificial laboratory conditions (79%) mainly collecting data by computer-based assessments, and only three were conducted in real conditions with real customers (restaurant, store) (details in Table S1).

*What were the most tested scents?* Fruit scents were the most popular in the reviewed studies. The scents used in the scientific studies were grouped as follows into five distinct groups: sweets, fruits, salty, floral, and spices. Among the aroma groups used, the most commonly used were 'fruits' (31.4%), and 'floral' (29.4%), followed by 'salty' (17.6%), 'sweet' (15.7%), and 'spices' (5.9%) (details in Table S2). Flowers were tested in studies evaluating congruent aromas [30].

*What were the main findings of the reviewed studies?* Table 1 presents findings from individual studies that are summarised in this section. The use of pleasant scents enhanced pleasantness, and unpleasant odours raised stronger emotions than pleasant ones [28]. The use of ambient scents modified behaviour (time spent at stores or viewing food images) [22,23,25]. The presence of scent in general stores can slow the flow of customers in the store and therefore increase the time spent in the store [2]. Scenting affected consumer choices, and the effect of scents was enhanced by the congruency of the odour with the images, products, or even seasons [23,29,30,32,35]. Scents, hence olfactory perceptions, interact with visual perceptions or imagery [27,33]. Appetite was affected by odour exposure; however, nonconclusive results can be obtained from the reviewed studies. Knasko [29] reported that exposure to chocolate scent reduced the perceived hunger, and other pleasant scents (baby powder) also reduced hunger perception. Some authors reported that exposure to food odours increases the appetite for congruent foods, including sweets, [34,35] and that fresh scents reduced the craving for sweets. Some authors even concluded that

exposure to food odours may promote overeating and therefore contribute to obesity [35]. Mechanisms explaining the appetite for congruent foods have not been elucidated; a theory has been proposed that cephalic phase responses mediated by the vagal nerve that prepare the body for intake and digestion may be involved [36,40]. It has been reported that the pleasantness of food odours (banana and savoury meat) was reduced during odour exposure, whereas the specific appetite for the congruent food remained unchanged, and hunger/general appetite was unaffected [36]. This decreased odour pleasantness may be related to olfactory sensory-specific satiety (SSS), defined by Rolls et al. [41] as the decrease in the pleasantness of, or desire to, eat recently consumed foods, relative to uneaten foods, which suggest a lack of appetite for the smelled food; this does not match results obtained by previously cited studies. In this sense, Ramaeckers et al. [36,40] have coined the opposite term: sensory-specific-appetite (SSA), pointing to an enhanced appetite for the congruent food that is possibly explained by the fact that smelling the food anticipates food intake; these authors hypothesise that the extended exposure to the odour stimulates chemical senses and reduces the appeal for the odour but not for the taste, and therefore, different mechanisms would underlie both processed SSS and SSA. It is also hypothesised that the largest changes in food preferences may occur within the first minute to odour exposure; thus, it is of main relevance to study behaviour changes during that first minute. Several authors report that such effect depends on the exposure time to the scent: short times of exposure to sweet scents may enhance appetite for the food, whereas long times decreases the appeal for sweet foods and enhances the appeal for healthy or other choices [26,36,41,42]. This may be caused by cross modal sensory compensation; the scent provides enough reward and reduces the desire for consumption of indulgent foods, such as an olfactory sensory-specific satiety. Another factor to be considered is that the intensity of the scent is either subthreshold or recognisable, as different effects can be reported [20,43]. Fresh scents are thought to be associated with health care, good hygiene, and cleanliness, rather than being associated with sweets consumption [29,34]. Most of the published studies only collected and reported craving sensation or appeal, which are not truly food consumption; it needs to be clearly differentiated whether the studies report subjective measurements anticipating food intake (appetite, food choice) or actual food consumption (intake satiety), given that they cannot be directly extrapolated [20]; therefore, more studies are needed in real situations that measure actual consumed food to determine how to use scents to either prevent obesity or ameliorate malnutrition.

Reported results have similarities with those reported in non-food stores. Numerous studies have been carried out evaluating the effect of applying scents in non-food store environments [1,8,14,39,44–46]. Those studies reported that product sales increased between 14.8% and 15.9%, the time that customers spent in the store also increased by 18.8%, and interest on the purchased products and the request for information also increased [45]. Therefore, scents are used in stores to create a positive shopping environment with the aim of increasing purchase intention or increasing the time spent in the establishment [24]. All these factors are expected to lead to an increase in sales and in the degree of customer satisfaction [6]. Stores that use scents have been reported to give their customers the feeling that they spend less time looking at products and trying them [7,8,47]. Spangenberg et al. [47] exhaustively tested 26 individual essences and separated them into the affective dimension and the exciting or activating dimension. They found that the affective dimension explained most of the effects that scent produced in people. In parallel, they combined the effect of aroma (neutral versus pleasant) and its intensity (low, medium, high) and studied it with an additional control group. The authors found that whether the aroma was neutral or pleasant did not matter how intense the aroma was, as compared to the control group that had no aroma. Furthermore, they observed that subjects in the scented group reported noticing that they had spent less time in the store, compared to the unscented control group. On the other hand, subjects in the unscented group reported spending much more time in the store than they actually had. Subjects in the scent group did not show this discrepancy. Evaluations of the store, in general, and the store environment were

more positive when the store was scented than if it was not. Most results obtained in the reviewed studies have been positive, presenting a clear correlation between the aroma used and the sensation produced in consumers, which is beneficial, because it leads to an increase in stay in supermarkets or restaurants, in addition to an increase in consumption or purchase of food as already found [45].

*What are the reasons or mechanisms behind this positive response?* The two most commonly used explanations can be separated by whether odour primarily influences unconscious effects, such as mood, or whether an odour primarily influences cognition. In the area of the commercial atmosphere, Mehrabian and Russell [48] discussed mood as a mediating factor between environmental cues and behaviour. Environmental psychologists claim that shoppers react to environmental cues with focus (desire to stay in the environment, explore, etc.) or avoidance behaviours (desire to leave) and that mood mediates this relationship. However, in the marketing literature, this explanation has not received strong support. Bone and Ellen [44] found that only a small percentage of the studies (16.1%) showed any influence of smell on mood. Another explanation for the process is that smell influences cognitive processes. Morrin and Ratneshwar [31] found no effect of scent on mood, but they found that scent increased attention to brands, as measured by display times for various brands [31,49]. Mitchell, Kahn, and Knasko [30] found that smell influenced the extent of information processing and cognitive elaborations. Chebat and Michon [39] tested various process theories and concluded that cognitions related to product quality and the shopping environment are influenced by smell, which in turn influenced the buyer's mood. As mentioned before, Herz [3] concluded that the most comprehensive theory was based on psychological mechanisms mediating the effect of odours on mood, physiology, and behaviour.

Another relevant factor is the congruence between the products offered by an establishment and its aroma. In this sense, Mitchell, Kahn, and Knasko [30] studied the effect of an ambient aroma congruent with a product category: a chocolate aroma was combined with an assortment of sweets and a floral aroma with a flower arrangement. If the aroma was congruent with the product, the subjects spent more time processing the data, generated more self-references, and were more likely to make additional inferences and exhibit a search behaviour for other purchase options. In general, cognitive elaboration was higher in congruent conditions. According to Berčík, Palúchová, Vietoris, and Horská [24], a pleasant aroma can affect the perception of the passage of time. It can also affect visual and taste perceptions [7,45] or create a generally pleasant environment for clients [46,50]. Another example is that the results of Guéguen and Petr [22] confirmed the hypothesis that scents have an influence on restaurant customers' behaviour. The study found that both the length of time and amount of money spent were positively affected by lavender in pizzeria restaurants (small choice of dishes: 17 pizzas, 4 types of meat, 3 fishes, and 4 salads). However, the lemon aroma was found to have no effect on either of the above two variables.

### 3.2. Case Studies

In addition to data from the scientific literature, we had access to real data from customer applications from a scent company, thus in the specific application of sensory marketing.

One of the studies was conducted in a small cafe with a patisserie serving and selling both chocolates and cakes located at Gottingen (Germany). In this café, the scent Coffee & Cake (REIMA Airconcept) was used. Due to the existing outdoor area in front of the cafe, the fragrance device was placed in the entrance area. This allowed the scent to waft outside a little bit as well. During the test period (7 weeks: half of the period scented and the other half without scent), customers had handy questionnaires requesting their age, sex, date of visit, time spent, and opinion on the atmosphere. In total, 30 people took part in the survey. One of the participants was not considered because the survey was not completed, in addition to another three who did not indicate the date of the cafe visit.

Therefore, 26 participants were left. The range of ages of the participants was 33–46 years (17 females and 9 males). Nine of them (30%) were in the range between 30–40 years. The average length of stay at the café was 1 h and 8 min. During the fragrance phase, 16 people participated in the survey, while in the non-perfumed phase, 10 people participated. The rating was performed according to the German school grading system (GPA): from 1—very good/completely to 6—insufficient/not at all right. The perfumed phase was rated at 1.65 and the non-perfumed one at 1.95. Looking at the sexes, there was a small difference between the grading of the two phases among women. However, men rated the two periods much more clearly. Here, the rating during scenting was 1.61. Subsequently, men rated the atmosphere only with a grade of 2.78. This is a clear divergence and could be an indication of the influence of the fragrance. Another peculiarity can be seen by dividing the whole group by age. Odour perception was most pronounced between the ages of 30 and 40. This can be justified based on the fact that the participants between 30 and 40 years assessed the atmosphere during the scented phase with 1.72 and the unscented with 2.83. This clear difference cannot be determined in the other age groups, with a tiny difference of only 0.11 points. As another aspect observed in this age range, male participants gave much better marks than female ones. In conclusion, the most positive evaluation of the café atmosphere was obtained during the fragrance phase and especially by men.

A second food establishment was an eatery, which was part of a larger chain, offering Tex-Mex dishes, burgers, and snacks, as well as cocktails and desserts. In addition to a large guest room inside the restaurant, which extended over two floors, there was also a large outdoor area with lounge character. The interior was rustic style. The restaurant had an open kitchen, through which odours from the kitchen can waft in the guest room (fatty and roasted aromas). Two devices of the type AromaStreamer 750 with the intensity level 3 (REIMA Airconcept) were placed in the guest room (interior about 250 m<sup>2</sup>). The scent curry-pepper marinade was used to match the kitchen flavours (REIMA Airconcept). During the test period (7 weeks: first half scented, second non-scented) a questionnaire was provided to consumers asking: date, age, sex, residence time, rate the atmosphere if (pleasant, cozy, stimulating, unpleasant) and the question: how well do you feel today? In total, 54 people participated in the survey (36 females and 18 males). The range of ages 29–68 years (34 (63%) 20–30 years; 10 (18.5%) 30–40 years; 5 (9.3%) 40–50 years; 2 (3.7%) 50–60 years; 3 (5.6%) not specified). The high participation, as compared to the experience at the café, was probably due to the fact that there was a coupon worth EUR 30 to win. Four participants were excluded: three because their survey was not completely finished and one that specified a residence time of 20 h. Overall, this resulted in the usable participation of 50 people. The rating was performed according to the German school grading system, as in the previous study. In the evaluation of the data of this restaurant, there were sometimes clear differences in the rating but sometimes very marginal. The overall average of the criteria ‘pleasant’, ‘cozy’, and ‘stimulating’ showed that the participants rated these criteria better (average 2.33), during the scenting phase than afterwards (2.42). There were only small differences between sexes, both before and after scenting experiment, although there was a tendency for women to rate the atmosphere slightly better than men. The criterion ‘unpleasant’ showed only a difference of 0.08 points: during the scenting experiment, this criterion was rated at 5.42, followed by 5.50 during the non-scent phase, meaning that on both phases customers disagreed or strongly disagreed with the description of the restaurant as ‘unpleasant’. A relatively large difference was seen in the question ‘How well do you feel?’: during the perfumed phase, the restaurant reached a mark of 1.96, while after the perfumed phase, the average rate was 2.50. The difference became clearer when splitting the ratings between women and men. Men averaged 2.07 during and 3.00 after the fragrance phase. For women, the difference with the grade 1.91 to 2.00 was only 0.09 points. This shows a markedly differentiated rating between the two periods, which is an indication of the actual effect of the scenting. The average length of stay in the restaurant was 2 h and 13 min during, and 2 h and 15 min after the scent period. Again, the difference was very marginal. Thus, it could not be proven whether the scenting had an effect on the

length of stay of the guests; the only clear trend is that men felt better during the scenting phase.

Those are two real examples provided by a company in which data were collected through questionnaires for consumers. The company carries out many more types of studies to develop real applications, but the effectiveness of the scents is directly evaluated by their clients through real sales of food products, with no need of contacting customers. Such case studies are confidential and cannot be shared to be published. We can still analyse the two case studies presented and the main difficulties of studies performed in real conditions. The present cases are evaluations of applications for a small business. Gathering 30 to 50 surveys within 7 weeks is considered quite low numbers for conducting reliable research. From the results, one may guess that the youth and men are more influenced and better discriminate whether the atmosphere is scented or not, but still, total numbers are low. In addition, it cannot be proven to what extent those participants represent regular customers of the establishment, which is probably the reason why in real conditions, total sales are the best indicators for food business, and, if possible, implicit measurements of neuroscience-related and physiologically based sensations should be considered. Small businesses need to measure whether the investment in aromatisation unit plus scents is worthwhile in the short term.

### 3.3. Improvements, Trends, and Future Research on Aromachology Related to Food

Aromachology related to foods may have different applications; the most active fields are sensory marketing and appetite modulation. Although extensively used in non-food businesses, scent marketing would be also of great interest to food businesses, and purposes such as brand identity or specific developments to suit needs and enhance consumer satisfaction would be of interest. Much more interesting would be the use of scents for modulating appetite, which will be an interesting tool to be included in anti-obesity strategies.

*Scents in sensory marketing: Copyright of a scent as food establishment identity.* Transferring laboratory findings into products is neither an easy nor a quick process, and it is now starting to see the development of products and marketing campaigns that are properly incorporating scents into food establishments and/or experiences. Should it be possible to copyright or trademark a scent? From the perspective of marketers, an affirmative response will increase the scent marketing industry. Currently, only scents that are non-functional can be trademarked, and it is still not easy to obtain a scent trademark. As a clear example, an orange juice company could not trademark the scent of oranges, but if the same scent were adopted by an automobile or electronics company, that company might be able to prevent its competitors from copying that aroma [51]. One relevant factor to consider in scent marketing is the opinion and well-being of employees. They are exposed to the scent during their entire working session, and they should be able to feel comfortable under such conditions. Air turnover also needs to be considered, as well as air quality and airflow. Scents need to be congruent with the store location and not interfere with the scent of fresh food to avoid masking, confusing, or generating off-flavours. All those considerations are taken into account by scent companies when developing applications for their customers.

*Research effect of scents to suit specific needs: the example of food consumed in aeroplanes.* Scent branding is a well-established practice in airports and planes [52], but it requires careful consideration. While some may find aromas soothing, others find them intrusive, and some passengers may have an unpleasant flight experience. A Spanish aircraft company has introduced an aroma called 'Mediterráneo', which mainly has notes of lemon, bergamot, and citrus blossoms. Heathrow Airport (London) applied this concept at Terminal 2, giving passengers a whiff of exotic destinations within reach of the airport [52]. There is an issue regarding airlines' food service: Food consumed on airplanes does not taste as that consumed on land. Recent studies suggested that various factors such as low pressures, the decrease of the level of humidity, and the noise perceived inside the plane may be responsible for the decreased perception. The degree of decreased perception has

been determined for sweet and salty tastes: salty taste is reduced up to 30% and sweet up to 20% when foods are consumed during flights [53]. However, real causes are currently unknown, and more studies are needed under real conditions for a better knowledge of the condition. Aromachology may be explored to provide solutions to overcome such a decrease in taste perception.

*Generating general accurate scales for scent in restaurants/food establishments: data collection procedures.* Regarding methodology, the collection of data through questionnaires shows clear limitations under real conditions. Wrzesniewski et al. [54] developed a scale measuring individual differences in the affective impact of odours on places, objects, and people. Among others, one promising direction for future research would be to develop a general scale measuring the susceptibility of an individual to using scent as an input for decisions and evaluations. Efforts can be made to enhance the reliability of questionnaires; however, collecting objective data (implicit tests) would be much more helpful and reliable. In this sense, the use of neuroscience tools and physiological measurements needs to gain a place in the methodology applied to aromachology on food.

*Future needs.* Most relevant future needs include in-depth research on scents use as appetite modulators (either to tackle malnutrition or obesity), which is not the main topic of this review but a matter of high interest for consumers, and the use of neuroscience tools and physiological measurements to gather human responses trying to avoid subjective data. Regarding marketing studies in the scientific literature, they may benefit from the development of standard methodology and recommended experimental designs (number of participants, place, time, etc.), and there is a clear need of conducting studies in real conditions (stores, restaurants, food business) with real food, as most of the available studies were conducted in artificial conditions. It has been pointed out that very few studies have been carried out in real store environments, and those studies had limitations: reduced number of participants, uneven participation during different phases, and the fact that explicit measurements have also limitations (are they given by the most representative customers? are they influenced by other factors such as noise?). Such observations point to the need of using implicit measurements (assessed by tools measuring body responses neuroscience and physiological-related parameters) and other measurements such as sales of different goods (either related or unrelated to the scent). Additionally, data collected from the stores should be compared between scented and unscented periods, as well as with data collected from the same period from the previous years or similar establishments during the same period. Air quality assessment during the studies will provide valuable information on the level of occupation of the establishment and proper ventilation conditions and health conditions for employees and customers (CO<sub>2</sub> concentration, particles in suspension, and volatiles in the air). Other points in need of attention are ethical issues, whether consumers agree with the use of food scents in food environments, and if they had to be regulated to avoid the use of scents that may mask unwanted flavours or enhance the scent of low-quality products.

#### 4. Conclusions

A small number of scientific studies on aromachology related to food are available, and most of them are conducted in artificial laboratory conditions. The most common aim is food preference and choice, followed by the study of the effects of odour on appetite; other interests are sales, shopping experience, and the study on mechanisms connecting odour and emotions. Participants through questionnaires provide most of the data collected, with a scarce number of studies using neuroscience and physiological tools and measurements. Methodological procedures largely diverge among studies, making them very difficult to compare and extrapolate results. The reviewed literature points to a greater effect of scents when they are congruent with the food, to the fact that unpleasant scents raise stronger emotions than pleasant ones, to a clear effect of scents on food preference and appetite mediated by the scent and the exposure time, as well as other effects on human behaviour. There is a clear need for research on aromachology related to food in the



fields of both sensory marketing and appetite modulation. At present, the effect of odours on appetite/food intake is not clear and consistent among studies and may depend on exposure time to scents. This field is in need of studies evaluating the effect of scent exposure during the first minute on real food intake, not just on appetite or preferences. Only when the real effect of scent on food intake is determined may scents be potentially used in anti-obesity strategies. The methodology for scent studies is in clear need of improvement by working in real conditions and introducing neuroscience tools and real physiological measurements.

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/article/10.3390/app11136095/s1>. Table S1: Type of place in which the study was carried on each reviewed study, Table S2: Scents used in the reviewed studies.

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