Review paper

REFLECTIONS OF VIRTUAL AND AUGMENTED REALITY APPLICATIONS ON CULINARY SCIENCE

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Abstract

Virtual reality (VR) and augmented reality (AR) technologies, successfully applied in various fields such as the game and advertising sector for a long time, have also been reflected in the gastronomy field in recent years. Today, some food and beverage businesses claim that they can provide their customers with extraordinary experiences by integrating VR and AR technologies into the gastronomy field. These experiences not only lead customers to have different eating experiences but also allow the perceived flavour of the food to be manipulated to increase the preferability of healthy foods, which many consider unpalatable. VR and AR technologies may also be used for training chef candidates or food and beverage business personnel. This review aims to examine the current uses of VR and AR in culinary science in an inclusive way and to emphasize their potential to shape the gastronomy sector in the future. For this purpose, in this study, the existing literature on the reflections and potential use of VR and AR on gastronomy was examined in depth. Based on the results of this examination, it was concluded that although it can be said that the use of VR and AR technologies in gastronomy has the potential to provide various benefits, these technologies need to be further adapted to better suit gastronomy.

Keywords: Gastronomy, Virtual reality, Augmented reality, Flavour perception, Multisensory experience

INTRODUCTION

Today, food and beverage businesses are under pressure to maintain their existence and achieve success due to globalization and increasing competition. As a result of this pressure, the reflections of digitalization in the field of gastronomy have become more visible in recent years. In particular, the widespread use of smartphones and social media encouraged manufacturers to establish effective ties with consumers and to highlight their own businesses. In this context, Virtual Reality (VR) and Augmented Reality (AR) technologies stand out in terms of their ease of application and their potential to meet consumer expectations (Penco et al., 2021).

Due to the continuous advances in core enabling technologies and the conflicting meanings of virtual and reality, the term VR is extremely difficult to define and there is no single definition in the literature (Crofton et al., 2019). However, in general, it can be said that VR is

a simulation that enables objects using three-dimensional (3D) virtual environments and different technological equipment and the person using this equipment to interact with the virtual environment (Pan et al., 2006). This interaction also allows the person to intervene and change objects in the virtual environment. According to Lin & Woldegiorgis (2015), a successful VR experience occurs when the user accepts that virtual environments and images can replace real objects and environments. Nevertheless, VR applications also enable the creation of imaginary environments with different futures than the world leading to the success of VR experiences depending on high levels of immersion and the user's sense of presence in the virtual environment (Bowman & McMahon, 2007).

AR encompasses a set of technologies that basically try to integrate digital with reality (Berryman, 2012), and can be defined as changing aspects of the physical environment that can be achieved by adding digitally prepared materials to the real environment. AR describes a person's reality as "augmented" because digital content adds different perspectives and factors to the situation or environment that the person using this device is directly observing (Varnum, 2019). In addition to combining real and virtual information, a true AR system must operate in real-time and seamlessly harmonize the natural world and virtual objects (Crofton et al., 2019). The fact that the environment or object perceived with AR applications is more usable or "augmented" and the use of these applications with AR programs that require touch or interaction makes continuous innovations possible (Yuen et al., 2011; Zhang et al., 2014; Jang et al., 2022). Projecting images of physical and artificial environments where AR applications are used can be achieved in three basic ways: "Head-worn displays" are systems where images can be observed by placing them on the head and are also used in VR applications. "Handheld displays" consist of small panels containing a video-guided camera. In "projection displays", which are based on the direct projection of the desired virtual information on the physical objects to be augmented, a single projector mounted in the room without the need for special glasses is used (Azuma et al., 2001).

Even though the concepts and applications of VR and AR are often confused, they show various differences due to specific application areas. Although both applications have evolved interface systems to display digital information, there are fundamental differences in the type of computing systems required to experience them. AR is built on physical reality, while VR presents digitally created or simulated environments and objects (Catapan et al., 2023). AR superimposes digital information in a real environment instead of completely replacing it, and considering this aspect, it is possible to distinguish it from VR (Crofton et al., 2019). Due to the various advantages, it provides, Mixed Reality (MR), which has seen increased usage in

recent years and is not always distinctly separated from AR and can be considered synonymous with AR by many researchers, can be said to be a hybrid of AR and VR (Morimoto et al., 2022). Because MR is the result of blending virtual computer graphic objects with a real 3D scene or incorporating physical world elements into a digital environment (Pan et al., 2006; Holz et al., 2011). MR stands out because it alleviates the limitations of VR, such as excluding the physical world environment and the inability of AR to interact with 3D data packets (Sakai et al., 2020).

VR and AR technologies are used effectively in many areas such as the gaming, cinema, marketing, and simulation sciences (Guo et al., 2021; Khosasih & Herumurti, 2021; Kirakosian et al., 2021; Nguyen et al., 2021). One of the most used examples of these applications today is the advertisements of football matches broadcast on television and the rule lines that are not physically visible on the field (Varnum, 2019). However, the fact that these technologies create a world of possibilities for transforming the real world and how people interact with it provides an opportunity for the food industry to gain a competitive advantage by leveraging these digital tools (Crofton et al., 2019). As a matter of fact, examples of this have been encountered in the world of gastronomy in recent years. Based on these examples and the potential of these technologies, it is thought that these technologies can significantly increase the eating experience of consumers (Solmaz & Pekerşen, 2022).

Although there are various reviews in the literature examining the use of VR and AR in tourism (Yung &Khoo-Lattimore, 2017; Wei, 2019; Omran et al., 2024) and food science (Chai et al., 2022; Bhavadharini et al., 2023; Liberty et al., 2024), there are very few review studies examining the use of these technologies in gastronomy (Çöl et al., 2023). It is thought that this study will contribute to the literature by reviewing the use of VR and AR in gastronomy and culinary science, especially in terms of their potential to increase flavour perception. The focus of this study is to examine the current applications of VR and AR technologies in gastronomy and culinary science and to reveal the potential benefits that may arise from the further integration of these technologies into the field of gastronomy.

METHODOLOGY

This review aims to reveal the current reflections of VR and AR technologies on gastronomy and culinary science and their potential future usage areas by examining the literature on VR and AR technologies and the sector applications of these technologies. To achieve this purpose, a literature review was conducted based on the keywords “AR in Gastronomy”, “VR

in Gastronomy" and "MR in Gastronomy". In this context, prominent journal articles, book chapters, and congress/conference proceedings were examined in depth using databases such as Web of Science, Science Direct, Scopus, EBSCO and Google Scholar. In addition, food and beverage businesses that use VR and AR technologies in practice were also examined. In this regard, the areas of use of VR and AR technologies in gastronomy have been evaluated to cover various aspects such as flavour perception modification, training, and marketing activities.

VR AND AR IN GASTRONOMY

VR and AR applications can be examined in different categories in the field of gastronomy. VR needs an artificial environment, individual headsets, and special devices to show the person a pre-built virtual environment (Arnaldi et al., 2018). Therefore, it can be said that it is more difficult to adapt VR applications to eating activities in the food industry. Additionally, developing VR applications is more difficult as it requires technical expertise. AR and MR are expected to be used more widely in the field of gastronomy than VR applications due to reasons such as being relatively cheap and users being able to access these applications even from their own mobile devices (Cevikbas et al., 2023). It's also worth noting that current VR applications restrict social activity while eating. The wide application options of AR allow this technology to be adapted to many techniques in gastronomy and this has caused AR to be used more in the field of gastronomy recently (Chai et al., 2022). In addition, there is a study (Ali, 2022) conducted to create a measurement scale according to the experience development of AR applications in restaurants and to use them in future applications. Nevertheless, the advantages and disadvantages of VR and AR technologies against each other in terms of suitability for use in gastronomy need to be revealed through different experimental studies.

Manipulation of flavour perception with VR and AR

Today, while people are looking for different experiences, some restaurants are trying to maximize the perceived flavour and differentiate from other classic restaurants (Natrah-Jamaludin & Nik-Hashim, 2024).

The human oral cavity contains nearly 5,000 taste buds that allow the perception of the tastes of foods. However, each person has a different number of taste buds, making it difficult to generalize the tasting activity evaluated (Briand & Salles, 2016). In addition, psychophysical measurements show the difference in taste sensitivity in taste buds, which also varies with people's suprathreshold gustatory stimuli (Spence, 2022). Although some

researchers suggest that the taste perception of foods originates only from the tongue, results have been obtained in recent years that reveal that there are different stimuli that can change taste perception (Spence, 2015). When multisensory taste is examined, taste usually consists of visual, auditory, olfactory, and textural cues. These cues can be replaced with different technological developments to enhance the gastronomic experience (Velasco et al., 2018).

It has been widely shown that visual difference in food affects perceived taste, and not only the appearance of a food ingredient or the food itself but also the environment is another determinant of perceived taste and experience for consumers (Hoegg & Alba, 2007; Okajima & Spence, 2011). Taste perception can also be increased by changing the lighting conditions of the environment where the food is eaten. Although it is generally thought that dim lighting is more successful than bright light in terms of food intake and taste perception, more research is needed on this phenomenon (Bschaden et al., 2020). Based on this, it can be said that the colour and degree of illumination of the VR and AR environment can change the perceived taste (Cornelio et al., 2022).

Emotions are another important variable related to perceived taste. For example, positive emotions can increase the perception of sweet taste and decrease the sour taste intensity. However, negative emotions can cause sourness to become more pronounced. Additionally, positive emotions can increase a person's hedonic ratings, so taste perception can be altered by the manipulation of emotions (Noel & Dando, 2015). A person's posture can also change their sense of taste. When sitting and standing postures were compared, it was found that sitting posture was more appreciated than standing in the person's sense of taste (Biswas et al., 2019). According to Itoh et al. (2022), observing different environments, watching videos, and/or smelling aromas not only affects the person's perception of taste but also can change the stress level. While stress can result in a decrease in sweet taste perception and a heightened perception of sour taste, low stress enhances the perception of saltiness and sweetness while diminishing the intensity of sour taste (Noel & Dando, 2015). However, the response of stressed individuals to taste stimuli, including different ethnic and sociocultural groups, needs to be elucidated with neuroimaging (such as functional magnetic resonance imaging, fMRI) studies. But still, with the help of various simulations developed with VR and AR technologies, it can be said that the taste perception of a person who orders food can be improved by aiming to reduce the stress level by having a fun time during the waiting period until the service. Moreover, by reducing the level of stress, the perception of sweet taste, which is often closely associated with high-calorie foods (Harnischfeger & Dando, 2021), can be enhanced and thus less consumption of these foods can be achieved.

As mentioned above, taste perception is quite complex and depends on different stimuli. These stimuli can be modified for different purposes such as reducing expenditure, improving taste perception, and eating experience, reducing food intake, or managing diet. Currently, the food industry aims to develop or use new applications for different purposes such as improving the perceived experience (Spence & Piqueras-Fiszman, 2013) and reducing ecological concerns (Shin et al., 2017) and costs (Mun & Jang, 2018). In this context, with the use of VR and AR technologies by businesses, the taste perceptions of foods and thus the eating experiences of consumers can surprisingly increase with very low energy consumption. Currently, restaurants like Le Petit Chef are using AR to enhance their dining experience, increasing customer satisfaction, and creating a point of differentiation. This restaurant, for example, uses a 3D video mapping technology that allows one to watch a "little chef" (le petit chef) cook the ordered food while customers wait for their orders to be prepared. While table mapping is not a new idea, Skullmapping's diverse storytelling ideas and concepts have allowed Le Petit Chef to serve in nearly 42 restaurants. At Le Petit Chef, using different technologies such as holograms, motion capture, 3D video mapping, and AR, the time until the service is transformed into a pleasant interim period (Batat, 2021). MoonFlower Sagaya Ginza, Art by teamLab, is another example where projection mapping is used to enhance customer satisfaction. The effects of projection mapping on flavour perception have been tested in different studies, for example, Ohyori et al. (2022) reported that colour differentiation with projection mapping can affect the taste of shaved ice perceived by consumers. In this study, red was the colour most associated with sweetness. According to the researchers, this is because the red colour is associated with strawberry flavour. It is thought that the reason why shaved ice reflected yellow colour is perceived as less sweet than other shaved ice colours is due to the association of yellow colour with lemon flavour. Probably for similar reasons, the colours yellow and green (associated with muscat flavour) were associated with more acidity than shaved ice, which reflected red and light blue (associated with soda flavour). The researchers also suggest that adding textural expressions to projected images can further alter perceived taste. At present, projection mapping technology used in restaurants can be improved with electrical muscle stimulation proposed by Niijima & Ogawa (2016), which can mimic the act of chewing through a photo-reflector to detect biting, food tissue database, and electrical stimulation segment. In addition, sound is an important indicator of the freshness/staleness and textural properties of some foods. This also can affect the perceived flavour of the food. Therefore, it seems possible to enhance customer

satisfaction with systems based on increasing the chewing sounds of foods (Endo et al., 2016; Endo et al., 2017).

Multisensory technologies in gastronomy

People's perception of food and the multisensory interaction of food is so wide that it can be affected by many factors, from the chemical, biological, and physical properties of the food, to the serving utensils in which the food is served, the packaging of the food and the characteristics of the environment in which the food is consumed (Spence, 2016). When multisensory experience in gastronomy is examined, it is possible to find different initiatives of chefs. However, it can be said that the first multisensory food perception was brought to life by the Italian Futurist Filippo Tommaso Marinetti, who tried to increase the senses of the eaters with textural, olfactory, auditory, and observational interactions (Spence et al., 2013). Marinetti worked with futurist painters (Caviglioni & Alberti) at the Futurist Air Banquet in Bologna, which prompted him to write the Futurist Cookbook in 1932 (Berghaus, 2001). Later, Mattia Caselegno created Aerobanquets RMX, the first MR restaurant intended to serve as part dining, part art experience.

Today, researchers are trying to use many different AR and VR applications for different purposes in gastronomy. Although these applications and studies were created to improve the multisensory aspects of food, diet monitoring, and different eating experiences, it should be considered that future AR applications can also mimic the taste of food. Galvanic taste stimulation is a fundamental technique discovered by Sulzer in the 18th century as an aid in finding gustatory diseases among patients (Krarup, 1958). Nakamura & Miyashita (2011) used cutlery and straw that was modified with an electrical current to observe the perceived taste of the food. It has been seen that five basic taste (salty, sweet, umami, bitter, and sour) sensations can be simulated through electrical pulses and thermal modification (Ranasinghe et al., 2011; Aoyama et al., 2017).

A Virtual Cocktail system named Vocktail, designed by Ranasinghe et al. (2017), takes advantage of taste, odor, and colour to both create a virtual flavour or augmented the existing flavour of a beverage. A couple more years later, the thermally enhanced model was tested to measure the perceived virtual taste liking of plain water through the virtual taste sensation enjoyed by participants (Ranasinghe et al., 2020). Currently, new studies ensure taste recording via five different gels and taste sensors that can be reproduced through calibration. Moreover, prototypes can be adapted to different tastes according to consumer preferences (Miyashita, 2020). While studies and experiments were concerned with the position of the

electrodes and the effect on the mouth, Nakamura et al. (2021) developed a galvanic taste stimulation system that could be placed outside the mouth that could minimize the negative impact on the eating and drinking experience. When the aforementioned studies are examined, it is seen that sugar-free and salt-free foods with high nutritional value can be consumed with a flavour similar to other foods. It is also possible to enhance the perceived taste of the duplicated flavour with other AR applications (such as olfactory, textural, visual, and audio).

Taste perception and hedonic responses are affected by the environment in which food is consumed. It is possible to bring the environment where the food is consumed to a more comfortable level by changing it with different VR environments according to the customer's preference. In a study (Torrico et al., 2021) in which two different chocolate samples were sensorially tested in two VR environments and in a traditional tasting cabinet, it was determined that the created VR environments affected the participants' perception of sweetness and emotional responses. In another study (Stelick et al., 2018), in which panellists were asked to evaluate cheese samples in three different virtual environments, it was observed that the environment in which the food was eaten affected the perceived flavour of the food. According to the researchers, every meal can be eaten in the same place but in different virtual environments created to maximize the dining experience. Crowded conditions in restaurants can affect customer satisfaction and stress customers when it comes to personal privacy. VR applications can also help customers reduce crowd-induced stress (Hwang et al., 2012).

Ultraviolet is a multisensory restaurant developed by Chef Paul Pairet in 2012 with support from the VOL group. The restaurant consists of a VR setup, dry scent projectors (diffusion system of dry odor capsule that control intensity and dissipation of scent), UV lighting, 360-degree wall projections, table mapping projections, speakers, and a multi-channel speaker system to create different virtual environments for each meal. The restaurant's design consists of ten seats that all guests sit together, also a dining room of high technology. The restaurant's aim is to achieve a fully immersive dining experience to optimize the perceived taste for its consumers which Chef Pairet defines as "psychotaste" and can be associated with the gastrophysics concept (Yemsi-Paillissé, 2020). Sublimotion is another example of using technology and multisensory cuisine, Chef Paco Roncero works with different partners to achieve a high-end adventure for the customers. While the restaurant experience takes place in a place called a "capsule", VR headsets are used to immerse the consumers in the world of

dreams, and the project consists of famous film directors, composers, and famous chefs (Bertran et al., 2021).

Marketing and training via VR and AR in gastronomy

Over time and with the development of technology, food advertisements, food blogs, and food preparations have changed significantly. As a result, these developments have affected people's nutrition, health, and food preparation and presentation. According to Kulcsár et al. (2018), VR and AR in gastronomy is one of the important and emerging aspects when viewed from a marketing perspective. Even though the real restaurant's food service can be highly personalized and may be in advance of the VR experience, consumers also tend to try more intellectual services such as different physical environments. The use of VR and AR not only enhances consumers' experiences with physical environments but can also bridge the interaction gap between staff and consumers with the advancement of technology (Kulcsár et al., 2018).

Currently, VR applications are used in the training programs of universities and in the training of employees in companies, especially to improve their theoretical learning (Syamimi et al., 2020). At the same time, virtual environments can be created according to train the employees for their practical experiences. There are various VR and AR applications for restaurants to train their employees efficiently. These applications can help increase employees' knowledge of their duties, such as food safety, food preservation, cost estimation, customer relations, and marketing, while also reducing the time and effort wasted by managers by providing a standard training program (Georgakopoulos, 2010). It is thought that the use of these applications, especially in theoretical training, as mentioned above, will be supportive in increasing work efficiency. However, currently, practical training with VR can be presumed as more difficult than literature-based training due to the cost, labour, and calibration-level of the virtual environment. Nevertheless, the use of VR in some educational programs such as medicine, military, and engineering is quite convenient. Due to the importance of practical training in these areas and the necessity of different scenarios, VR training can provide practical experiences without the need for a real case (Mathur, 2015; Tang et al., 2021). Similarly, practical skills are essential for chefs and gastronomy students (Marinakou & Giousmpasaoglou, 2022). The culinary needs different equipment, materials, and food while training the chef and chef candidates, VR may ensure the training field to gain those practical skills. The experience and practical skills that a chef must gain over time can be gained in a shorter time with VR, which promises greater efficiency in training areas

compared to real-time training (Mendivil-Gonzalez et al., 2020). For example, cutting techniques, which consist of lessons that cover almost half of a semester in traditional education, provide students with the opportunity to practice in very different environments such as home and metro, with simulations that can be prepared in VR environments, causing this period to be both very short and enjoyable. Indeed, Papachristos et al. (2018) created a VR experience consisting of 50 different recipes that allow participants to collect ingredients/equipment and use cooking/cutting techniques for training. Although it can be said that VR should be developed for the physical activities of the participants to be close to the real world, it can be ensured that the participants develop their practical skills through the created environment. Given this situation, studies such as the validation of a food feature perception in VR comparing the real cookie sample with the virtualized version and evaluated similarly by the participants are important developments for future hands-on training with VR (Gouton et al., 2021).

Undoubtedly, in addition to the need for a chef or chef candidate to cook the food directly, they also need to interact directly with the ingredients to gain the ability to predict properties such as the hardness of tomatoes and the ripeness of zucchinis. Therefore, it can be said that VR and AR technologies will only be effective if they are used to support the traditional training of chefs and chef candidates. Furthermore, for VR and AR technologies to be actively used in gastronomy education, besides effective design tailored to cuisine needs, employees or students must have basic computer skills and be willing to use these applications (Georgakopoulos, 2010).

Efficiency and support

Simple enhancements such as QR menus, which became commonplace to address health concerns (and to modify menus easily and efficiently) during the COVID-19 era, are now being developed to improve customers' dining experience in restaurants in certain situations. The idea of using QR-based menus has developed over time due to their easy use, and some applications have been created to provide a one-to-one image of each food on the menus in the restaurant. Thus, there is no language barrier and users can choose the food items they want more freely. Additionally, the application's database can be expanded with various restaurants, allowing users to explore different restaurant menus simultaneously. The Chatbot and Frequently Asked Questions sections can also be utilized for users to obtain other consumers' opinions about the food and restaurants (Molejon & Comendador, 2020; Rane & Usmani, 2021). Moreover, more complex, and time-intensive applications are planned for

different purposes, such as BOTTARI, a special AR application for food and beverage business recommendation systems to its users for more specific and local elections with interests-based opinions from the social media community (Balduini et al., 2012). Huang et al. (2022) claim that basic AR applications in restaurants can enhance customer satisfaction due to their direct relationship with consumers. On the other hand, hololamp menus in some hotels and restaurants are another appealing application for AR. The exact image of the menu items can be demonstrated by means of a holographic 3D design, which can engage consumers because it is portable and easy to access (Shivekar & Padave, 2019). However, it should be emphasized that these developments may be acceptable and beneficial for young people or individuals who are open to or familiar with technological developments, but it is necessary to emphasize that older and conservative individuals may have difficulties accepting and using these innovations.

FoodAR is one of the applications that has been studied to help its users efficiently work and find recipes with the products which already exist in their fridges. The application was introduced to help people to decide what to eat in a short time while also it can help the consumer choose which recipe they should use according to the instructions. This application is planned with a device that has a camera to scan all the products in the fridge or in storage to be able to classify the ingredients and find recipes from the web data by means of the recipe assistant. Then, it is planned to open the recipes from the application and show the instructions as to how to prepare the selected dish (Chitaniuc et al., 2018). The other application which is planned to help its users when cooking is AREasyCooking. This application aims to scan the ingredients that users have and search for well-known recipes from cooks as well as traditional recipes. It also intends for its users to try different recipes rather than cook the same dishes because of the insufficient time and giving the choice of a healthier diet. AREasyCooking application consists of three stages, recognizing ingredients, searching/selecting recipes, and preparing food. This application is modified with different applications to help to identify the ingredients with a camera and with a barcode reader which also helps to modify your storage easily. In the second stage, the application ensures a wide variety of English recipes (almost 1.5 million) that can be categorized according to famous cooks or traditional recipes. And, in the last stage, the user can choose the cook, the recipe while examining in the textual format or with a movie play. In the movie play, the recipe's instructions can be controlled via audio commands or eye control (Iftene et al., 2020). Recently, recipes and cooking lessons such as ChefSteps and Gronda have been developed where AR applications can provide more efficient ways to improve online cooking lessons,

and these types of applications are gaining more and more popularity with each passing day. Although it is said that such applications can be used at home and have potential benefits, they need to be developed for use in professional cuisines such as hotels and catering services, as well as large warehouses.

In addition to their current uses, estimating the properties of food and food components such as calorie values, nutritional compositions, and their potential to cause allergies or intolerances through these technologies may allow individuals to prepare meals in different combinations in line with their needs. There are some compounds in foods that have synergistic or antagonistic effects on each other. For example, if ayran (a traditional Turkish yogurt drink) and meatballs are consumed together, the calcium ions contained in the ayran reduce the bioavailability of the iron ions contained in the meatballs (Lönnerdal, 2010). On the contrary, when orange juice and meatballs are consumed together, the ascorbic acid (vitamin C) in orange juice increases the bioavailability of iron (Piskin et al., 2022). Based on this example, the information that will be included in VR and AR applications that will be developed in the future may cause individuals to prefer much more conscious and nutritious recipes.

CONCLUSION

The growing interest in gastronomy and increasing worldwide interaction between people through such as social media, and advertisements has increased the global reach and hence rivalry between different food brands/establishments. Furthermore, advancements in technology changed most industries and business areas in different ways. Technological developments are also used for different purposes in the field of gastronomy. Some restaurants have used technological developments to offer different experiences to their customers, some businesses have used them to increase the productivity of their businesses, and some chefs and entrepreneurs have used them to create different gastronomic trends (such as molecular gastronomy and gastrophysics).

Recently, advances in VR and AR technologies have impacted many industries, including food, from a tool used to differentiate business with experience development to a way to make it possible to change neutral food to different flavours with galvanic flavour simulation. Advances in galvanic taste simulation technology could help usher in a new era for gastronomy. While thermal modification and electrical pulses can mimic the five basic tastes, they can potentially be used for different purposes, such as promoting healthier food consumption, easy calibration of perceived taste for each consumer, and reducing costs for

businesses. In addition, these technologies are designed as “recipe assistants” and can provide different recipes of world cuisines suitable for the materials in the kitchen, which allows chefs or non-professional home cooks to prepare dishes that they have not tried before from existing materials. Moreover, this situation can be enjoyable with the use of simulations designed in game format. The use of these technologies in this direction also indirectly contributes to reducing waste in the kitchen by providing waste management.

VR and AR technologies can also be used to support/improve traditional gastronomy education in schools or food and beverage businesses. Although it can be said that VR and AR technologies are more suitable for theoretical gastronomy education, these technologies also have the potential to be used to support practical training. Although the introduction of QR menus was undoubtedly facilitated by the COVID-19 pandemic and related personal hygiene concerns, some organizations took the opportunity to offer different AR apps to outshine their competitors. Menus designed using VR and AR technologies according to the concept of the business can even turn customers’ food preferences into fun ones. However, it would be appropriate to test the functionality of these menus in food and beverage businesses preferred by elderly and conservative guests and to make plans accordingly.

In this review, the latest AR and VR applications and studies are reviewed, and the complexity of the perceived experience behind gastronomy is highlighted. Although it can be said that VR and AR technologies can be adapted to the gastronomy sector in various aspects and have the potential to provide benefits in different ways, the effects of the use of these technologies on consumers need to be examined in long-term studies. The fact that these technologies are costly for businesses and that some applications have the potential to restrict customers’ socialization are important factors that limit the use of these technologies in gastronomy. Some of these technologies are currently more suitable for home use rather than large-scale professional cuisines such as hotels and catering services. Comprehensive studies are required to make these technologies more suitable for large-scale professional cuisines in a way that will increase consumer welfare.

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