Chapter- II

Review of literature

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2. Review of Literature

This section includes a review of the developments in scientific interpretations and technological tools concerning food product innovation, role of gastronomy (molecular and computational gastronomy), application of flavour network theory, computational gastronomy for food design and recipe recommendation, analytics in food engineering, common tools for data analytics and visualization, similarity analysis and generative models and innovation for consumer need-based product.

2.1 Food product development vis-a-vis innovation

The process of food product innovation in Agro-food sectors and food value chains has become a necessity for various regional shareholders that are interested in new business opportunities [20]. Food Innovation grants an opportunity for the producers to market their products for better consumer satisfaction and loyalty and earn competitive advantages. [30]. In addition, food innovation is influenced by new food technologies, as well as the interaction between the surrounding environment, the economy, and the political system [34].

Food product innovation is the introduction of novel products and services into a market, and it is often regarded as of greater importance than process innovation considering the consumer utility viewpoint. Food product innovations are crucial in luring customers given the slow growth of the global food markets, the tepid demand, and the constant supply. Often consumers' expectations of innovations are mirrored in the latest consumer market trends. Offering specialised food products that are superior to those already on the market is becoming more and more challenging due to global competition [26].

Siegrist [72] identified that factors such as potential benefit, potential risks and potential naturalness has an impact on the psychological aspects of consumers on innovative food technologies. On the other hand, new food technology should take into account the possibility that it will not only benefit the producers and the industry but provide value-added technology to the consumers and society in general. In a few cases, "food neophobia" can sometimes result in consumers rejecting innovative food products [13]. A scientific investigation that has a qualitative and quantitative approach can give consumers desirable top-quality novel food products [83].

Von Hippel [62] first recognized consumer participation in innovation processes as an effective tool for increasing consumer acceptance of market-oriented techniques for decades. Besides, in the early 1990s, a consumer-driven product development was introduced by Urban and Hauser in response to the transition from a scientific to a systematic market-driven model [84]. Consumer tastes and desires, along with their purchasing behaviour, are the only factors that may reveal and validate an innovation. The consumers' approach to integrated product development provides valuable insight into how the product is being perceived by the consumer. To lower the failure rate of innovations resulting from consumer responses, an excellent understanding of consumers' perceptions, expectations and attitudes is required to attain the successful development of innovative food products [42]. However, to attain a successful innovative product, there is a need for food producers to build open businesses that act as innovation hubs. As a result, the types and nature of innovations in food products should not be determined by marketers, but by consumers and their aspirations. Food producers should accurately track consumer trends to develop successful innovative products to satisfy their demands [26].

2.2 Food service sector vis-a-vis food engineering

Food engineering is commonly considered to be traditionally associated with the process related to the processing/handling of foods at the industrial scale. In the food service sector, the process associated with the preparation of a meal requires similar considerations as that for food manufacturing and may be considered a part of food engineering. Working with gastronomy is expected to help food engineers gaining a better understanding of societal concerns including the value of encouraging home cooking, creating sustainable food chains, and creating or redesigning delicious foods to prevent lifestyle diseases. As a result, food engineering is expected to influence food innovation and entrepreneurship, which are currently led by chefs [2].

Mohanty et al. [53] state that there are two types of innovations in food service sector viz., "hard innovation" and "soft innovation" depending on whether it is a fine dining restaurant, casual dining restaurant, multi-cuisine restaurant, or an Haute cuisine restaurant. Hard innovation involves aspects of food engineering, food microbiology, and food science, and therefore many times, it is referred to as "art and science." On the other hand, soft innovation essentially consists of the skill and creativity used in food

preparation, serving, and equipment design. While complex innovation pertains to the layout, design, and equipment of a kitchen.

There is a great deal of knowledge available in food engineering that should be utilized in the institutional food operations system, professional chefs, as well as amateur cooks. In addition, one of the other specific areas of interaction is understanding transfer phenomena in cooking processes. Others include scaling up gastronomic preparations for institutional use, modelling changes in cooked food quality under real-world conditions, creating appealing and wholesome processed foods, analysing the effects of cooking on the food matrix, and adapting new technologies to the kitchen level. To ensure the long-term sustainability of our food system, scientists, engineers, and chefs should collaborate more closely as chefs become more innovative, credible, and visible [3].

Future food engineering approach would be required to concentrate on and incorporate the most recent and cutting-edge technology and scientific advancements to solve any difficulties in present and future [9]. Accordingly, there is a need to engage future engineers to be more innovative, creative, and who design and enhance present and future sustainable societal lifestyles. Therefore, it is crucial that the next generation of engineers be more creative, and committed to making sure that the systems, processes, and products they develop and utilise will improve both present and future sustainable future. Through integration with gastronomy, food engineering approaches are expected to contribute toward sustainability, safety, improved nutrition and improved food use [3].

2.3 Gastronomy in food innovation

The art of choosing, preparing, serving, and relishing great food is known as gastronomy. As early as 1835, the *Academie Francaise* approved the term "gastronomy", and it soon began to be used interchangeably with "cuisine," or the manners in which food is traditionally prepared and enjoyed in an area or region [24]. In the late 20th century, a new concept for culinary arts emerged known as molecular gastronomy as a way to unravel secrets and learn about new culinary possibilities [12]. Molecular gastronomy plays an important role in providing scientific investigation for development in the technical application of new product development. In order to maximize the consumer's culinary and gastronomic experience, molecular gastronomy provides valuable insights into manipulating and optimizing food products. At the molecular level, designing food begins with investigating the interactions between the constituents of the food, as well as

between the food and the customers. Molecular gastronomy is focused on scientifically identifying the qualitative and quantitative approach to distinctive human perception of food by incorporating research and proving precisions to include analysis to perfect the art of gastronomy [83].

Recently, innovation has gained prominence in a variety of fields, including the service industry [53]. Accordingly, the concept of food innovation is considered to be the interpretation by elite chefs of a “material or symbolic artefact that is superior to the present” [35]. Rodgers [65] states that there are two distinct aspects of food innovation in restaurants: “Front of the House” and “Back of the House”. Taking a five-point perspective, one can examine the front-of-house operations: the space, the meeting, the environment, the product, and the system for monitoring them. While the back of the house operation is focused on food, it focuses on the development and innovation of food-related products. Biological, microbiological, and chemical processes and operations management heavily influenced by natural science is often ignored in the back of the house.

2.4 Computational aspects in gastronomy

The advancement of information technology has led to the accumulation of huge culinary data and the ease with which it can be analysed using computational approaches has altered the artistic outlook toward gastronomy [29]. Computational creativity is a developing area of artificial intelligence, where computers are a key component. It demonstrates a computational system that uses big data approaches to generate innovative, flavorful, and possibly nutritious culinary meals [61].

In recent years, data mining and network analysis methods have been applied to characterise and analysed the publicly available large-scale data on food usage and food chemistry. The application of this high-throughput technology has transformed the biological sciences which in most cases rely on experimental data. Additionally, a new field of study such as "computational gastronomy" is likely to be established due to the increasing data available in food chemistry, sensory biology and food use [6]. The development of data-driven systems has paved a way for food companies and skilled chefs to create new recipes considering the diversity in regional cuisine styles and personal food preferences. However, to create new recipes it is important to (i) identify the degree of ingredient mixture of any recipe considering the regional cuisine style and

(ii) the algorithm developed should be able to replicate the selected regional cuisine style [42]. This system of using machine-generated information in creating of completely new flavour combination which has not been used before is considered to be a culinary application of computational gastronomy [86].

Computational gastronomy is closely related to data mining, which is the search for patterns and trends in large amounts of data beyond simple analysis. A human's sense of taste and smell determines most of the flavour they experience. But how important is each sense to the overall culinary experience? Based on the available body of research, food pairing helps to determine the ideal ingredient combination. It can be used as a key component in the field of culinary science by exploring scientifically the chemical flavour compounds that are components of food ingredients [85]. To justify the flavour pairing theory, whether or not we combine ingredients that have a strong link in the flavour network we require data on ingredient combinations that are widely accepted and preferred by humans, and information that is available in the form of food recipes [5].

2.5 Computational gastronomy with digital data

The application of computers in the field of culinary art has significantly contributed to creating new ingredient pairings which may lie beyond the chef's mental repositories. This capability of machine-generated information for creating a completely new flavour combination, which has not been used before, is expected to intensify the application of digital data [86]. Goel and Bagler [29] assert that the analysis of culinary data using techniques from statistics, data science, complex networks and machine learning could fundamentally change the food industry by enabling data-driven food innovations to improve health and nutrition.

Kinouchi et al. [44] conducted a study on four different cookery books to examine the relationship between the recipes and their ingredients. The frequency rank plots of ingredients were not different across the four different cuisines, which demonstrates the importance of evolutionary dynamics.

Ahn et al. [5] used the idea of flavour pairing as a fundamental algorithm to look for unique ingredient pairings considering 56,478 recipe data from five different regional cuisines viz, *North American, Latin American, Southern European, Western European, and East Asian*. The study reported a positive pairing in the *Southern European* and

Western European cuisines, referring to the ingredients being used recipes were more likely to share flavour compounds. In contrast, *East Asian* cuisines showed quite the opposite, ingredients with a greater number of shared compounds were less likely to be combined in a single recipe.

Jain et al. [37] studied on the food pairing patterns of India's eight regional cuisines. The study considered 2,543 recipe data to validate the culinary pattern that have been cited in several Western cuisines. According to the study, Indian food has a distinct characteristic of negative food pairings and spice as an ingredient and category contributes to culinary pattern in the Indian cuisines.

Al - Razgan et al. [8] validated the food pairing theory in Saudi cuisine. A genetic algorithm was used to create a quantitative model of ingredients and their compounds found in the recipes of Saudi cuisine. It was reported that Saudi cuisine follow a positive food pairing as they contain more ingredient-sharing flavour compounds which are similar to Western cuisines. The study also demonstrated the potential application of the genetic algorithm as a powerful mathematical model for the research in the field of food science and computational gastronomy.

Park et al. [58] introduced a detailed food compound network graph derived from food databases, known as flavorGraph. A dense vector representation of food was generated based on a chemical and statistical analysis of the flavorGraph. Using food representations in flavorGraph, food pairing can be made more accurate than in previous studies, and predictions of compounds and foods can also be made based on these suggestions. Food pairing techniques as well as food science were explored freshly and innovatively.

2.6 Utility of non-digital data in computational gastronomy

Food flavour research on sensory and assessment is a process of obtaining data to analyse, evaluate, and interpret consumer behaviour toward food products while considering the five fundamental senses of taste, smell, touch, sight, and hearing. An important aspect of flavour analysis is determining the odour and taste profiles of food products using volatile and non-volatile compounds as indicators. As a result, food sensory science and flavour analysis are vital to the development of new products because they bridge the gap between the attributes of a product and consumer perceptions and acceptance [92]. Moreover, the

understanding of our food choices and habits has changed as a result of large-scale data analysis, including machine learning and network analysis. This change will likely have an impact on our future food choices and habits [54].

The use of an integrated data-driven approach is expected to give a better insight into the ingredient preferences, which can be used to facilitate the possible modification of ingredient combination formulations. The principle of flavour pairing can be applied to computational systems to create recipes by identifying new ingredient combinations in recipes, designing recipe recommender systems, and generating new recipes, all of which contribute to the creative domain of cooking [5]. In addition to revealing ideas about cooking fundamentals and yielding intriguing insights into both culinary foundations and user preferences, the existing data on user preferences for food allows data mining and information retrieval to take on a new perspective [66].

Due to text parsing errors in cookbooks and other sources, data collected from these sources is considered dirty. In general, there will be more ingredients in more sophisticated recipes than in cookbooks with everyday recipes, and an individual cookbook alone cannot represent an entire cuisine [5]. In contrast to physical cookbooks, where content must be carefully chosen, using an online database has the advantage of not requiring such restrictions. However, statistics about cuisines can be obtained from culinary books by examining the methods and combinations of food preparation in a particular cuisine [44].

Varshney et al. [87] conducted a study investigating the role of the flavour pairing hypothesis in different data sets of recipes from Medieval Europe to understand the effect of dirty data. The study involves the usage of two different chemical compound data. The study reported that a greater number of ingredients was used in the modern world than before the Columbian exchange, which led to the different pairing behaviour between the two-recipe datasets.

Tao et al. [81] presented a review to examine text data in the food industry along with their sources, computational methods, and applications. The study reported that food-related studies have been analysed using a variety of text analysis methods. In terms of dietary pattern characterization, word-level analysis is most popular, followed by joint text and non-text analysis. In the context of food products or food brands, sentiment analysis has proven useful in understanding consumer preferences.

Wang et al. [90] presented a cross-modal retrieval of food images and cooking instructions. A common feature space is used to embed images and recipes, so that the embeddings of the images and recipes lay close to each other. The study concluded by proposing SCAN, as an effective method for cross-modal food retrieval training.

2.7 Flavour network theory in the development of computational gastronomy

Over the years, the availability of a huge amount of data on social, biological, and communication networks that have been systematically collected and documented has made it possible to conduct scientific analyses and investigations. The concept of network science has been used to analyse and produce new knowledge from qualitative data.

Kinouchi et al. [44] conducted a study on statistical and complex network approaches to model culinary diversity and evolution with the help of data collected from various traditional cookery books to model culinary diversity evolution by examining the relationship between the recipes and their ingredients. This model shows that individual ingredients diffuse very slowly within a cuisine, explaining why some ingredients have remained popular for so long.

Ahn et al. [5] in his study presented the idea of a flavour network to determine whether the flavour compounds affect the choice of ingredients in a recipe. A bipartite network with two kinds of nodes was constructed which consists of (i) ingredients present in the recipes and (ii) ingredient flavour compound of each ingredient known to contribute to the flavour. The projection of this bipartite network forms the flavour network. It has been reported that whereas East Asian cuisine does not combine ingredients that share similar flavour compounds, cuisine from North America and western Europe do.

Teng et al. [82] conducted a study for the purpose of analyzing regional preferences and ingredient modifiability. A network analysis was constructed based on ingredient complements and ingredient substitutes. The study reported that data from recipes can reveal the regional preferences of ingredients in recipe and the variability of specific ingredients.

In certain cases, there has been a challenge in the analysis of large-scale networks is the extraction of the relevant backbone or the identification of the statistically relevant structures/signals. However, weighted networks with the heavy disorder can be filtered

out by identifying the quantitatively significant weight variations locally, preserving structural properties and hierarchies across the network [67]. Towards this, data mining approaches with various network analysis methods were applied to the widely available information on the chemical composition and consumption of food [6].

Ahnert [6] converted the flavour network of food ingredients and chemical flavour compounds into a bipartite network's single mode projection. The study reported the emergence of new academic field such as “computational gastronomy”. The term “computational gastronomy” refers to emerging academic fields that use network theory to analyse food. Additionally, a wider applicability for the field of study is anticipated as data on food usage, sensory biology, and food chemistry become more readily available.

Jain and Bagler [37] applied the concept of flavour network theory and copied mutate model to eight regional cuisines of India to probe for mechanisms of culinary evolution. The study suggests that ingredient frequency in recipes render the characteristics of food pairing pattern in Indian recipes.

2.8 Tools for analytics and visualization

There are many sectors in the food industry where advanced data mining techniques have been applied [81]. Cloud computing is a powerful tool for providing decision support system services to the manufacturing sector. It allows businesses to reduce unit service costs as a result of increasing operational size, provision of new services, and increased supply/demand chain services [49]. In addition, big data analysis and artificial intelligence (AI) have enabled food industry innovators to experiment with the most advanced technologies, despite the fact that many new technologies have emerged to address the sector's challenges. This novel method used workflow modification and data pattern observation to provide an output that is reliable, consistent, requires limited resources, and benefits the customer by predicting future situations. Since big data analytics can turn large amounts of data into insights for business decisions, it has found its application in many industries [81]. It's anticipated that drone technology will progressively advance to another milestone in the logistics and food supply chain. The use of sensors in food preservation is also viewed as an essential tool. Consequently, AI and big data have made it possible for the food industry to improve, optimize, and achieve results in real-time [69].

AI may significantly contribute to the innovation process by making a variety of innovation analytics possible, including problem and problem exploration. Additionally, big data has significant value for AI because it allows innovation teams to use huge amounts of information to conduct innovative studies that are incredibly scalable and repeatable. In order to delegate tasks of greater complexity to machines, data scientists and innovation managers need to work together. For instance, AI can be used to validate creative insights and minimize blind spots in creative thinking. As part of the innovation process, artificial intelligence can be used to improve results for existing questions and ask insightful questions as well. It is also possible to inductively derive new hypotheses about innovation context using AI models that account for a range of complex interactions between variables. As an additional resource for innovation managers, these models can be further utilized to derive empirical observations [41].

Additionally, with the application of network science, patterns can be presented through visual representation. Considering that complex networks summarize thousands of data points, they are inherently more difficult to visualize than pie charts. As a result, a large dataset can only be understandable through visualization. Typically, lines linking dots that represent data points and the interactions between them are used to represent complex networks. Another benefit of complex network visualisation is how effectively it communicates research findings to laypeople [56].

Ahn et al. [5] have presented a strategy based on network science to determine whether a recipe's ingredient selection is influenced by flavour compounds. The study considered 56,498 recipe datasets with a bipartite network of 381 ingredients and a total of 1,021 flavour compounds. For visualization, a flavour network was created with the use of *Cytoscape* [59]. The ingredients present in the recipes and the ingredient flavour compounds of each ingredient known to contribute to flavour were created as nodes in a bipartite network. Each node in a flavour network, an interactive data visualisation, represents an ingredient, while the width of the edge or link denotes the number of shared flavour components.

2.9 Food analytics for innovation

In various economic sectors and industries, data analytics plays an increasingly important role in driving innovation and growth. The growing amount of digital data, both structured and unstructured, may be examined in real-time utilizing digital technologies, cloud

computing, and machine learning algorithms, leading to improved business decisions and increased customer and shareholder satisfaction [45]. An innovation analytics approach involves computer-assisted, data-driven insights, models, and visualizations created as a process for innovation [41].

Bianchi-Aguiar et al. [17] conducted a study to solve the issue of product allocation to shop floor shelves with regards to shelf-space planning in leading Portuguese food retailers. They successfully created a scalable operational research methodology that systematically employs algorithms and mathematical programming models to choose the optimal product placement on shelves.

Singh et al. [74] conducted research on challenges with supply chains in the food industry. A big data analytics approach was implemented taking into account data from Twitter. Tweets on 'beef' and 'steak' were collected to identify consumer sentiments with the application of a support vector machine and hierarchical clustering. It was found that consumers were most concerned about the colour, taste, fragrance, and safety of their food when it came to beef products, as well as the possibility of extraneous objects being present in them. The suggested study might be applied to other food supply systems, including lamb or pork.

Kosior [45] provided information on the applications of social media analytics, stressing the advantages, potential risks, and restrictions of food innovation and its manufacturing. The study found that the food industry and the food service sector can obtain considerable business value from social media database. Whereas, a higher level of focus is needed when using data from social media for food innovation and production, as digital technologies and advanced data analytics are still lagging in the food industry. Social media platforms significantly boost knowledge about consumers and their tastes by making data readily available previously only accessible through pricey surveys and public opinion polls available. This has a significant impact on how food is viewed and consumed around the world.

Liu et al. [49] investigated the "small and medium-sized businesses" (SMEs) in certain regions of the UK to determine their awareness of and potential motivations for employing big data-based analytics. The findings from the exploratory survey from two focus groups suggest the need for various technological and managerial constraints SMEs must take into account. Finally, this study urges SMEs to engage large customer data and

asserts that the best way to provide access to big data analytics methods is through a cloud-based strategy.

Kakatkar et al. [41] conducted a study on the role of artificial intelligence (AI) in the process of innovation by enabling many areas of innovation analytics. Based on previous research in the area, the study provided four distinct case studies of AI in action. The paper concludes with three strategic implications highlighting the advantages and drawbacks of employing AI in innovation.

Sharma et al. [69] discussed on various AI enabled algorithms such as machine learning, artificial neural networks (ANNs), and big data analytics in the food business. Furthermore, this study discusses logistic, supply - chain management, marketing, and production patterns, as well as artificial intelligence applications in food subsectors. The study reported that process and production management can be significantly improved through the use of AI techniques and intelligent optimization algorithms. As a result, digital technologies have transformed the food business, with AI and big data enabling us to obtain optimal results in real time.

2.10 Generative models for food innovation

The availability of high-quality food data poses difficulties for health app developers. There are several major differences between commercial and open data sources. While public data sources are frequently inaccurate, duplicated, and insufficient, commercial data sources are costly and cannot be retained for years [55].

Bhattarcharjee et al. [16] analysed user sentiment in the telecom industry. This study proposes a new method of classifying user comments on a positive-to-negative scale using the Cosine Similarity measure. Further, the proposed algorithm was compared with other commonly used machine learning algorithms. The proposed Cosine Similarity-based classifier has an accuracy rate of 82.09%.

Prakhash et al. [63] presented an approach to address the issue related to customer requirements for selecting food in a dine-in restaurant. The study presented two methods for food name categorization with the use of similarity measurements, food name categorization using tf-idf and single pass partitioning method. The study reported 89% accuracy in categorizing food names.

Achananuparp and Weber [1] explored a data-driven strategy as the first step in making better meal recommendations to extracting food alternatives from personal food consumption. The public food diary entries on MyFitnessPal were used to create a real-world food intake dataset for the study, and a similar crowdsourcing tool was used to collect human evaluations of meal substitutes. They used the vector space models of semantics, a popular natural language processing (NLP) technique under the presumption that items eaten in similar situations are more likely to be good replacements for one another. The experiments produced encouraging findings.

Song et al. [78] conducted a case study on an incident related to food poisoning in China. Based on the former information, the indicator system was built using descriptive information about food safety incidents. A case database was created based on 295 food safety incidents since 2000 that fit the characteristic attributes. Utilizing MATLAB, the study was able to compare historical cases with target cases based on information entropy and cosine similarity algorithms. Both food safety emergencies and the prevention of additional safety accidents can be handled using the root cause analysis and the framework of the food safety emergency plan developed.

Using computers as the centre of the creative process, computational creativity is an emerging branch of artificial intelligence. Generally, the creative process involves both generating ideas and selecting those that are most valuable. Computational creativity can be validated through data-driven approaches [87].

Varshney et al. [87] developed a computational creativity system for discovering culinary recipes that are flavourful, novel, and maybe even healthy. The study proposes a structural computational creativity system which includes three main components: a designer, a processor, and an algorithm. Additionally, the study included how domain knowledge databases set boundaries for cognitive processing structuring it. According to chefs at hotels, restaurants, and culinary schools the system helped professional chefs explore new horizons in the field of culinary arts.

Calmon et al. [21] introduces a data driven analytics framework to assist flavour developers in the process of new product development. The solutions suggested are new formulations and algorithms that solve difficulties in the creative processes of many flavour and fragrance enterprises. Additionally, the study outlines some common and core

algorithmic difficulties in recipe creation which may serve as inspiration for a wider computational creativity approach employed in industry.

Khan [43] conducted a study using various Machine Learning methods to rate recipes. The algorithm evaluates the performance of various classifiers in grading a recipe based on various performance criteria. This can benefit restaurants financially by assisting them in improving their recipes and gaining more customers. It may also be used on a more personal level to enhance domestic recipes and to help restaurant customers determine which restaurant is best for a given meal by considering how satisfactory their recipe is.

Jagtap et al. [36] conducted research to comprehend the application of big data in the development of novel food products. The study helps in the discovery of important information and the incorporation of sustainability into the early stages of the new product development process in the food business. The usage of big data approach helps minimize time and cost of the new product while maintaining taste and product competitiveness.

Chavan et al. [22] conducted a study to design, implement, and evaluate three recommender systems using collaborative filtering, content-based recommendations, and hybrid recommendations. The objective of this study is to evaluate the recommender systems within the personal health and nutrition domains. Among the models, the hybrid recommender system performed the best because it combined content from individual recipes, individual preference ratings, and group-rated content.

2.11 Lifestyle disease, dietary restriction and need for alternate recipe

Dietary management is the idea of altering one's eating patterns in terms of meal preparation, selection of food, preparation of food, dining out, quantity control, and rational reactions to eating disorders. All lifestyle aspects must be affected by continuous dietary adjustments. To improve the effectiveness of nutrition interventions, health professionals should take into account the various concerns related to diet and nutrition when they work with patients. In most cases, patients commonly exhibit binge eating, restriction, and body image dissatisfaction [89].

For people to remain physically fit over time, it's crucial to establish and maintain healthy eating habits. Although there are many dietary recommendations available, as shown by the development of chronic conditions like type 2 diabetes and obesity, only a few people

can follow them. The reason for this failure is that these recommendations are generic, making it impossible for people to embrace them regularly. Contrary to dietary recommendations, recommendations made to specific people by recommender systems may be more effective at promoting gradual behaviour change. More specifically, by discovering users' food habits from available data sources at hand and suggesting food alternatives tailored to the users' current dietary needs and tastes, the systems can guide the users toward similar but healthier options [1].

Yannakoulia [89] surveyed the dietary behaviour of patients with diabetes. The study reported that diabetes patients acquire a lot of information and develop a strong concern for their diet as one of the key tools for controlling their disease status. As a result, they display restrictive eating habits, express emotions of food deprivation, and believe that stringent dietary restriction is the sole strategy for losing weight. The foods that are chosen to eat determine whether nutrition therapy is successful.

Guida et al. [31] conducted a study, the study's objective was to assess the eating behaviours and nutritional knowledge of a homogeneous population of IBD patients from southern Italy. The study considered 167 patients who had reported having IBD disease. A semi-structured questionnaire that assessed participants' demographic characteristics, disease features, dietary practises, and food intolerance was part of the survey's methodology. Most of the patients did not think that diet was the cause of their illness. However, less intake of seasoned food and spices in addition to dairy products was observed. Most dietary changes were driven by personal experience rather than professional advice. This affects how psychosocially people behave and may result in nutritional inadequacies.

The dietary limitations as consequences of the disease have a significant impact on one's way of life and social interactions. Regarding nutritional approaches, research has shown that the traditional exchange-based dietary regime and nutrition counselling provided in the form of a simple meal plan with an emphasis on tips for making healthy food selections are both equally beneficial [89].

2.12 Innovation towards developing foods based on consumer’s needs

There are huge variations in what people eat around the world as well as in how they prepare and consume it. Among the major influences on staple foods are soil and climate,

as well as the past domestication of plants and animals [7]. We must understand human dietary trends and food preferences in order to make better-informed decisions about our food choices as culture and nutrition are closely related. Not just from a sociological and anthropological standpoint, but also from a medical standpoint, it is possible to observe the significance of dietary preferences and choices. It is possible to be healthy even in the presence of disease if one can adapt to their environment. Additionally, in supplying nutrients, food culture plays a significant role in helping the elderly adapt successfully to their new environment [89].

In today's consumer-driven food market, customers' role as food decision-makers affects whether food products are successful or unsuccessful [77]. One of these concerns is related to food safety, which is a significant component of food quality and the foundation of any high-quality food. Over the years food safety problems are gaining more attention from consumers worldwide due to an increase in food safety accidents. However, providing nutritious and healthy food to an ever-growing population is quite a complex and demanding task for the food industry [76]. To address such issues, it is believed that artificial intelligence (AI) will affect scientists and governments soon, including conventional approaches to economic and political challenges [62]. There is a great deal of potential for growth in the agri-food sector, but a lot of smart and innovative technologies are needed to ensure high-standard production, such as AI and big data [69].

Asp [10] discusses some of the elements that affect consumers' meal choices which include the social, psychological, behavioral, and dietary trend aspects. The study identified the barriers to following the Food Guide Pyramid recommendations for healthy diets. The study suggests the importance of continuous monitoring and regular updates on the Food guide pyramid.

Aizhen & MacLennan [7] conducted a study on the dietary pattern of older women in Zhejiang province, China to determine the implication of cuisine and its health impact. The research reveals that Zhejiang province's older women's diet adheres to the most recent WHO recommendations for the chronic disease prevention, which fits with the province's history of having long life. However, given the abundance of Western-style fast-food restaurants in urban areas, it is inevitable that many younger generations are not meeting their dietary goals, which has already been demonstrated and is expected to

become more pronounced in the future. These negative effects include obesity and diabetes.

Aguilera [4] states that around the turn of the 20th century, as far as consumers are concerned, ample food availability, convenience, and low prices did not satisfy their needs. As passive participants several questions plagued them including how food is produced, why there should contain food additives, and how healthy and secure processed foods are.

Aguilera [3] summarizes the contributions of modelling of food processing which reveals the events going on in cooking pots, baking ovens, and food manufacturing systems; and the possible integration of different perspectives of health and food for personalized food design for coming years. The study highlights the role of food engineers in food innovation and entrepreneurship, integrated into cooking and gastronomy, addressing concerns related to sustainability, safety, nutrition and better food use.

Singh and Bagler [75] conducted a data-driven investigation on 45772 regional traditional recipes from 22 countries. The study identifies popular ingredients and non-random recipe compositions using "similar" or "contrasting" flavour combinations as a major contributing element. Applications in areas including food design, creating novel flavour combinations, and modifying recipes for better nutrition and wellness were made possible by data-driven investigations.

2.13. Computational gastronomy-based food design and recipe recommendation

A hypothesis that has been widely accepted among chefs and food scientists for over a decade state that “ingredients sharing flavour compounds are more likely to taste well together than ingredients that do not” [18]. This theory has sparked the development of numerous novel and unique ingredient combinations for dishes and has helped researchers in the quest for unique ingredient combinations such as the combination of caviar and white chocolate or blue cheese and chocolate based on the number of flavour compounds they share (73 flavour compounds).

Cooking styles vary significantly between the cuisines of the world due to the ingredients used and the methods adopted in preparing the food [80]. Regional cuisines vary from one region to another, and variations in flavour preferences lead to variations in the foods that people choose to eat. However, regional cuisines that are geographically close to one

another have some flavour characteristics. Numerous factors, including genetics, environment (geographic and cultural), current health demands, diet balance, and others, have an impact on users' food preferences [94]. With the variety of regional cuisines illustrating the diverse culinary culture and practices, one might wonder if the ingredient combinations are affected by any general patterns in contemporary meals that go beyond personal tastes [5].

A variety of external sensory and internal states are involved in the perception of flavour in humans. In general, compared to the original items, the taste and texture of the majority of commercial "healthy meals" with less salt, sugar, and fat, along with gluten-free and high-fibre products, tend to be compromised. Additionally, dietary limitations and a decrease in the amount of food ingested by the patient as part of their treatment are frequently required for the treatment of several diseases. On the basis of the permitted foods list, the components used to create alternatives or supplements must therefore maintain a balance between flavour, taste, and nutritional characteristics [51]. Thus, to improve the functional and sensory qualities of foodstuffs, experts like chefs and food material scientists must create a workable technological solution by modifying formulations and technological variables [3].

Big Data analytics and machine learning advancements have provided intangible benefits in a various aspects of one's health. Recommender systems employ strategies to filter and refine information depending on consumer tastes or needs, and to assist users in determining which information is most relevant. A healthy diet is one of such areas [22].

Zhu et al. [94] worked on a specific analysis of various Chinese regional cuisines, where they investigated the regional cuisine similarity based on climate and geographical terms. According to their research, geographic distance promotes the use of similar substances whereas climatic changes have no noticeable effect.

Song et al. [78] suggested a system for recommending substitute ingredients in recipes based on the co-occurring substances' frequency and cooking ontology. The alternative ingredients complement well with those ingredients that co-occur in the recipe and it was more preferable to use items from the same category as the substitute ingredient in place of it.

Pinel and Varshney [61] illustrate how to create healthy culinary recipes using big data in a flavourful, novel way that incorporates flavourful, and novel techniques. The

outcomes consist of an ingredient list, ingredient quantities, and a directed graph displaying a relative order of culinary dish procedures.

Jain et al. [38] conducted a study on Indian regional cuisine food pairing pattern. The study was assessed by comparing the compounds shared between two ingredients in a recipe. It was reported that Indian cuisines follow a consistent trend of negative food pairing. Additionally, the study emphasizes the statistical importance of creating a recipe recommender system and in the creation of a new recipe.

Shino et al. [70] suggested a recipe recommender system based on the recipe database that takes into account the recipe ingredient categories and co-occurrence frequency of ingredients. The study showed 88% acceptance of the alternative ingredients suggested through the recommender system.

Mitra and Mitra [51] developed a novel approach based on specific food items for a person with restricted health conditions. In general, compared to the original items, the taste and texture of the majority of commercial "healthy meals" with less salt, sugar, and fat, along with gluten-free and high-fibre products, tend to be compromised. The novel approach developed could predict near-identical flavour profiles as per the requirement of the patient with a significantly lower value of sugars, fat, calories, or carbohydrates.

Guo et al. [32] created a recipe recommender system based on the similarities of regional flavours, allowing users to select their preferred regional cuisines. To gather ingredients for dishes featuring regional preferences and determine ratings for all of the regional cuisine's recipes, they employed the algorithm "term frequency-inverse document frequency" (TF-IDF) method. Further, the similarity between the regional cuisines was calculated using the cosine similarity algorithm.

Kazama et al. [42] introduced an innovative method that uses a barycentric Newton diagram and word2vec to recommend ingredient substitutions to change a chosen recipe style into a particular regional cuisine style. The proposed system was able to identify and transform a cuisine into a specific regional cuisine style. The system effectively suggested ingredient substitutions to obtain an authentic regional cuisine style.

Sanjo and Katsurai [66] presented a preliminary study on using data for the recommendation of seasonal recipes. The study proposed diverse recipes with various ingredients however, there was an overlap of certain ingredients.

Perez [59] presented the relationship between cooking, science and technology. The study highlighted the new development of innovative cooking devices, new ingredient usage and techniques. The scientific basis of cooking brought improvement in the empirical culinary techniques.

2.14 Chapter summary

Geographic proximities are perceived to promote the use of similar ingredients-based food habits [94]. The work of Jain et al. [38] analyses the food pairing pattern in selected Indian regional cuisine, however does not have much information on cuisines/ food habits of the Northeast region. Van Schendel [85] has commented the region to be 'not only the Northeast borderland of South Asia but also the north-western borderland of Southeast Asia'. An analysis of the food culture of the region based on the principles of flavor pairing is expected to highlight the cultural proximity to both the Indian sub-continent (South Asia) as well as South-East Asia and to garner benefits for regional development. Since such information is rare as of now, therefore the characteristics of the cuisines of the region are aimed to be studies under the first objective.

Works reviewed under sections 2.1, 2.2 and 2.3 signify the role of a collaboration between gastronomy and food engineering in innovative product development. How the public data and organized data are being utilized for deriving computation-based approaches for analysis of food preferences described under sections 2.4, 2.5 and 2.6. Works cited under sections 2.7 and 2.8 has helps to develop flavour networks and computational framework for the cuisines under consideration. These has contributed towards attainment of objective 2.

Works reviewed under sections 2.9, 2.10, 2.12, 2.13 and 2.14 containing few examples of food recipe generation and the application of computational creativity, has provided the input for developing models for implementation for recipe completion and recipe generation. Also, they are referred to for validating some of the observed trends. Many a times the necessary modifications may arise out of lifestyle issues as highlighted in the reviews under section 2.11.

Overall, the reviews strengthen the argument of the thesis, wherein an attempt is made to use a-prior knowledge on food combinations to generate newer combinations, which would have a potential to diffuse in to the food formulation in future.

Table 2.1: Summary from major reported studies based on chronological development in computational gastronomy and customized food recommendation.

Sl no.	Author (s)	Work done	Major findings/ Outcome	Year
1.	Kinouchi et al. [44]	Conducted study on statistical and complex networks approaches to model culinary diversity and evolution with the help of data collected from various traditional cookery books.	Culinary history has a glassy dynamic very far from equilibrium. The diffusion of new ingredients within a cuisine is very slow.	2008
2.	Ahn et al. [5]	A network-based investigation was applied to identify the significant characteristics as to how humans choose to combine ingredients in their food.	It has been reported that North Americans and western European dishes combine ingredients that have similar flavour compounds while East Asian cuisine avoids them.	2011
3.	Teng et al. [82]	Network analysis based on ingredient complements, and ingredient substitutes were constructed to gather insights about regional preferences and modifiability of individual ingredients.	Recipe data could give an insight into regional preferences and modifiability of individual ingredients.	2012
4.	Ahnert [6]	Using one mode projection the bipartite network of chemical flavour compounds and food ingredients is converted flavour network. Prevalent ingredients were estimated based on the frequency of occurrence and number of shared flavour compounds.	Computational Gastronomy, a term for new research disciplines with the study of gastronomy by application of network theory. The increase in the availability of data on food usage, sensory biology and food chemistry has projected a wider application for the field of study.	2013
5.	Zhu et al. [94]	Investigation on the similarity of regional cuisines based on differences in geography and climate.	Geographical proximity rather than climate proximity is identified as a crucial factor that determines the similarity of regional cuisines.	2013
6.	Song et al. [78]	A recipe recommendation system was proposed for alternative-ingredients based on the frequency of ingredient that co-occurs and cooking ontology.	The alternative-ingredients compliment well with those ingredients that co-occur in the recipe and ingredients from the same category of the exchanged-ingredient were more suitable as an alternative ingredient.	2013

7.	Jain et al. [39]	A negative food pairing pattern in Indian cuisines was studied to assess whether al regional cuisines follow a consistent trend.	Indian cuisines follow a consistent trend of negative food pairing.	2015
8.	Jain et al. [38]	Food pairing in recipes of Indian cuisine to show that in contrast to positive food pairing reported in some western cuisines.	Indian cuisine has a strong signature of negative food pairing. Spice as an ingredient and category contribute to the negative food pairing in Indian Cuisines.	2015
9.	Mitra and Mitra [51]	Developed a novel approach based on specific food items for a person with restricted health conditions.	The novel approach developed could predict near-identical flavour profiles as per the requirement of the patient with a significantly lower value of sugars, fat, calories or carbohydrates.	2017
10.	Guo et al. [32]	Developed a recipe recommender system for the various Chinese regional cuisines to recommends a set of dishes in terms of flavour similarity. Two algorithms are used to calculate and measure the similarities among regional cuisines.	A system has been implemented through which a user can specify cuisine according to their preferences, and find other cuisines similar to the cuisines they have specified to satisfy their taste bud requirements.	2017
11.	Aguilera [3]	The review summarizes the contributions of modelling of food processing which reveals the events going on in cooking pots, baking ovens, and in food manufacturing systems; and possible integration of different perspectives of health and food for personalized food design for coming years.	Highlighted the role of food engineers in food innovation and entrepreneurship, integrated into cooking and gastronomy, addressing concerns related to sustainability, safety, nutrition and better food use.	2018
12	Kazama et al. [42]	Proposed a novel system to transform a selected recipe style into a specific regional cuisine style using barycentric Newton diagram and suggested ingredient substitution using word2vec.	The proposed system was able to identify and transform a cuisine into a specific regional cuisine style. The system effectively suggested ingredient substitutions to obtain an authentic regional cuisine style.	2018