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Role of artificial intelligence in nutrition

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Abstract

Artificial Intelligence (AI) is revolutionizing nutrition science through its multifaceted applications, enhancing precision and efficiency across various domains. AI's fundamental function in personalized nutrition, food composition analysis, dietary assessment, food industry advancements, public health interventions and popular diet-monitoring mobile applications is examined. By analyzing extensive datasets, AI enables personalized nutrition by customizing dietary recommendations to reflect the unique health profiles and genetic predispositions of each individual. AI algorithms rapidly parse intricate nutritional data in food composition analysis, thereby expediting the processes of food labeling and quality control. Furthermore, dietary assessments that are AI-driven provide real-time insights into dietary patterns and nutritional deficiencies, thereby enabling proactive health management. AI enhances the efficiency of production processes in the food industry, thereby minimizing waste and guaranteeing consistency and safety. The guidance of targeted interventions is facilitated by AI-powered predictive models that forecast nutritional trends and identify at-risk populations, thereby benefiting public health interventions. Popular mobile applications that monitor diets employ artificial intelligence (AI) to precisely monitor dietary behaviors, thereby encouraging the adoption of health objectives by means of personalized feedback and suggestions. Data privacy concerns, algorithm bias, and the necessity of comprehensive regulatory frameworks continue to impede the integration of AI into the field of nutrition, despite these advancements. AI's function in nutrition is predicated on ethical considerations, which prioritize transparency, equity, and informed consent in the areas of data utilization and dietary recommendations.

Keywords: Artificial intelligence, nutrition, personalized nutrition, diet and mobile applications

Introduction

Artificial intelligence (AI) was defined by IBM (International Business Machines) as "any human-like intelligence exhibited by a computer, robot, or other machine." AI allows computer programs to acquire knowledge and identify substances by learning from datasets that indicate cases and assistance in decision-making through problem-solving. The application of AI is vast, and it includes the provision of health and nutrition care (Sudersanadas, 2021) [36]. Artificial intelligence (AI) in nutrition is the application of conceptual algorithms, machine learning and deep learning techniques to analyze, interpret and make informed decisions from a variety of datasets that pertain to nutritional data, dietary patterns and other health factors (Oliveira Chaves, 2023) [31]. There are numerous and extensive applications of AI in the field of nutrition, ranging from dietary personalization to preventative models that predict disease. The integration of AI applications in nutrition enables technological advancements to reshape the landscape of dietary interventions (Theodore Armand, 2024) [38]. Artificial intelligence (AI) techniques are revolutionizing the way we comprehend, monitor and optimize nutritional outcomes (Armand *et al.* 2024) [4]. AI's influence on nutrition is multifaceted, encompassing enhanced dietary assessments, personalized nutrition plans and a more comprehensive comprehension of nutritional epidemiology (Chen, *et al.* 2020) [9]. Potential solutions to global health issues, including obesity and malnutrition, are available through the integration of AI in nutrition science (Mata *et al.* 2021) [22].

Applications of Artificial Intelligence in Nutrition

1. Personalized nutrition

By analyzing individual data, such as genetic, metabolic, and lifestyle information, Artificial Intelligence facilitates the creation of personalized nutrition plans (Wang, *et al.* 2018) [43]. The objective of personalized nutrition is to enhance health outcomes and prevent diet-related diseases by providing dietary recommendations that are customized to the specific requirements of an individual (de Roos & Brennan, 2017) [12].

The development of personalized nutrition programs is facilitated by the ability of machine learning algorithms to analyze immense quantities of data in order to identify

patterns and correlations between dietary consumption and health outcomes (Zhou, *et al.* 2019) [48]. Personalized dietary recommendations are provided by the Nutrigenomix platform, which utilizes genetic information to assist individuals in optimizing their nutrition based on their genetic profile (Arkadianos, *et al.* 2007) [3].

By analyzing an individual's genetic composition, AI algorithms provide personalized dietary advice. AI can recommend precise dietary modifications that are customized to the individual by taking into account genetic variations in nutrient metabolism. Genetic data, dietary evaluations, lifestyle factors, and health information are combined to create personalized nutrition programs through the incorporation of bioinformatics and AI. The Nutri-Educ algorithm is intended to encourage dietary modifications, thereby demonstrating the applicability of personalized nutrition databases (Azzimani, *et al.* 2022) [6].

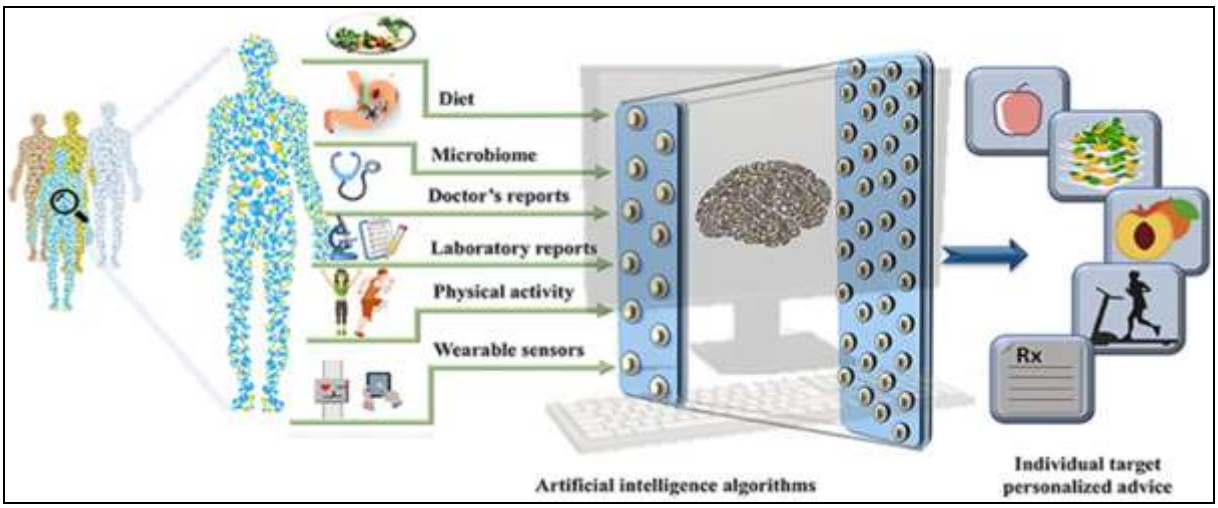


Fig 1: A system for personalized nutrition and health

The diagram shows how different types of information, like diet, gut bacteria, health records, physical activity, and data from wearable devices, can be combined to teach smart computer programs. These programs can then give personalized diet advice.
https://www.frontiersin.org/articles/10.3389/fnut.2018.00117/full

2. Food composition Analysis

The precise prediction of food components is essential for the development of products, the preservation of food safety, and an overall understanding of nutrition. Time-consuming, costly, and extensive laboratory analysis are frequently necessary for traditional methods of determining food composition. Recent advancements in artificial intelligence have unveiled a promising opportunity to surmount these constraints and offer reliable and efficient predictions of dietary components. As an illustration, Artificial Neural Networks (ANN) accurately predicted the chemical composition of peach fruit, suggesting that the integration of AI in the food industry is both feasible and efficient (Abdel-Sattar, *et al.* 2021) [1].

The function of AI in food composition analysis is multifaceted, providing novel methods for analyzing and improving the nutritional quality of food products (Bader, *et al.* 2020) [7]. Researchers and food scientists can acquire a more profound understanding of the nutritional profiles of foods, identify critical components, and refine food formulations to achieve superior health outcomes by utilizing AI technologies (Cunha, *et al.* 2020) [11].

Artificial intelligence (AI) technologies, particularly machine learning (ML) and deep learning (DL), have revolutionized nutritional analysis by offering precise and efficient methods for determining the composition of a variety of food items (Nesvadba, *et al.* 2021) [28]. Chemical assays, which are conventional nutritional analysis methods, necessitate specialized apparatus and necessitate a significant amount of time (Ozcan & Mohsenin, 2015) [32]. AI-driven tools have the capacity to analyze extensive datasets of dietary composition, thereby identifying patterns and correlations that may be overlooked by conventional methods (Wibowo, *et al.* 2019) [47].

3. Dietary Assessment

The accuracy of dietary assessment methods has been substantially enhanced by AI, which has also reduced the burden on individuals (Wang, *et al.* 2022) [46]. Self-reporting biases and recall errors frequently occur in conventional dietary assessment methods, including food diaries and recall surveys (Illner, *et al.* 2012) [16]. AI-driven tools, including mobile applications and image recognition software, can automatically identify and quantify food items from images, thereby delivering more precise and dependable dietary data (Zhu, *et al.* 2015) [49].

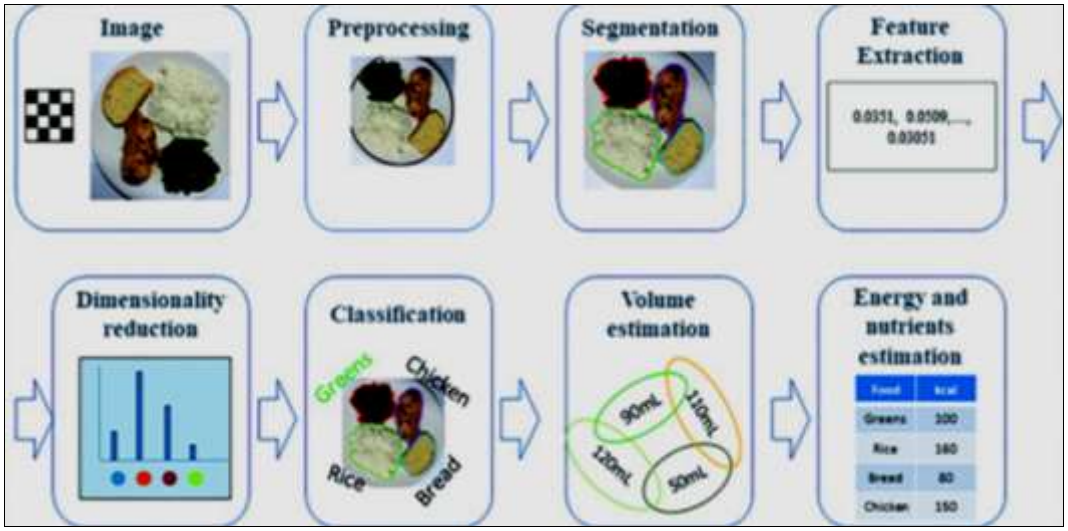
For example, the AI-based application "Food-Log" employs convolutional neural networks (CNNs) to analyze food images and estimate calorie intake, thereby demonstrating superior accuracy in comparison to conventional methods (Okamoto & Yanai, 2016) [30]. In the same vein, the "Bite Counter" device employs ubiquitous sensors to monitor eating behaviors, thereby enabling users to maintain precise food intake records (Scisco *et al.*, 2014) [35].

Dietary assessment with food images recognition techniques

Detopoulou *et al.* (2022) [13] have developed numerous analysis techniques, such as principal component analysis,

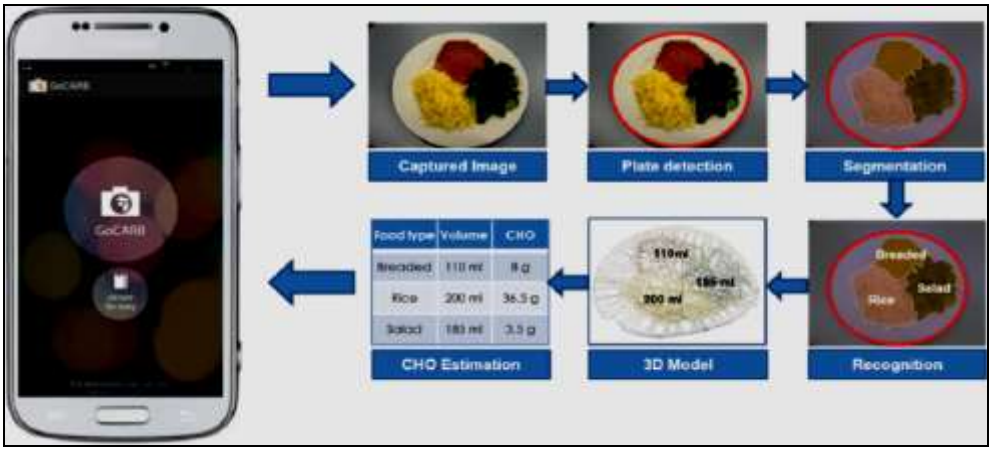
to identify dietary and meal patterns. However, these techniques continue to depend on self-reported data.

Food image recognition is a novel approach that is facilitated by deep learning methodologies (Matusheski, 2021) [23]. Its capacity is expected to increase as food databases continue to expand (Cai, *et al.* 2019) [8].



The flow of the dietary assessment systems combining a camera of the user's mobile device with computer vision methods is as follows: 1) the user takes a photograph of the upcoming meal with a camera of his/her mobile device, 2) the image is preprocessed, 3) the different types of food are divided from each other through segmentation techniques, 4) robust and discriminative features are then extracted, 5) the most important features are selected and are given as input to the next phase of the system, 6) classification of food items in food categories takes place, 7) the volume of each food item is calculated, and 8) the calories and nutrients of the depicted meal are estimated using appropriate nutritional databases. (Dalakleidi *et al.* 2022) [12]

For example: The GoCARB application was equally efficient in carbohydrate estimation compared to dietitians (Vasiloglou *et al.* 2018) [40].



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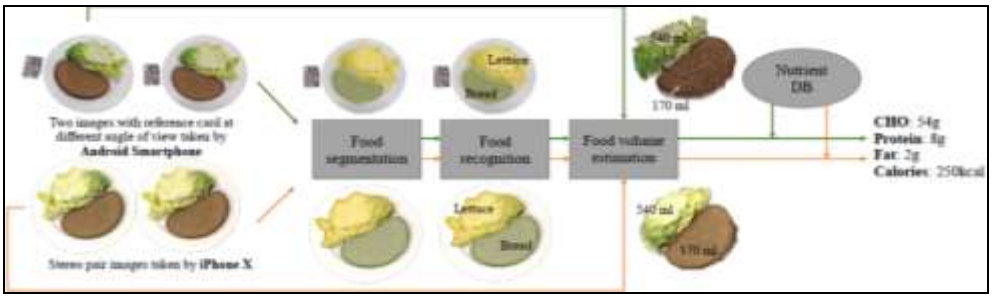
The goFOOD™ application was able to estimate the calorie and macronutrient content of a meal, based on smartphone photos (Lu *et al.* 2020) [2].



(Lu *et al.* 2020) [20]

4. Food Industry

Trend Analysis

In the food industry, the initial application of AI is to assist companies in the analysis of common consumer requirements and desires. On the basis of machine learning models and big data analytics, AI can produce valuable insights regarding user requirements and desires that facilitate product development. This stage is crucial, as it necessitates the company to identify the products that are most likely to be successful in the consumer market. Artificial intelligence (AI) is the catalyst for innovation that empowers organizations to introduce distinctive products with distinct attributes. Trend analysis techniques enable food companies to effectively address consumer requirements and target the appropriate market segments.

Quality control

The assessment of food quality is a complex endeavor that necessitates precision. Nevertheless, quality is rarely compromised or disregarded when food and other items are manufactured in large quantities. Nevertheless, this is not a disadvantage if the production process is overseen by AI-supported machines. Nevertheless, it is possible to instruct and modify AI tools and algorithms to evaluate a variety of criteria in order to ensure quality. This particular task can also be completed with reduced error due to the fact that machines only accept specific characteristics (Choudhary, *et al*. 2023) [10].

Improvement of food products

Many food brands are improving their product offerings by using artificial intelligence and deep learning technologies to create flavor combinations that will be popular with consumers (Nikolola-Alexieva, 2024) [29].

Sensors

Intelligent sensors continuously monitor the manufacturing and packaging of the finished product from the beginning to the end, notifying the user of any deviations or inconsistencies. This could range from a lack of product quality to power outages. The implementation of AI in smart sensors will significantly benefit all food businesses, as it has the potential to eliminate the need for quality inspectors throughout the entire production chain and detect aberrant activity (Choudhary, *et al*. 2023) [10].

Track of Supply Chain

Custom AI applications and portals enable food manufacturers to monitor the entire food supply chain, from packaging materials to production constituents. The efficient and transparent traceability of produce from the farm to the end consumer is also facilitated by artificial intelligence, which in turn increases consumer trust (Hammerkopf, 2019) [14].

5. Public Health Interventions

The objective of public health nutrition interventions is to improve the nutritional status and dietary habits of the general population (Mozaffarian, *et al.* 2018) [27]. Artificial intelligence (AI) technologies, such as computer vision, natural language processing, and machine learning, provide novel opportunities to address nutritional challenges with increased precision and efficiency (Topol, 2019) [39].

Dietary Assessment

Dietary assessment methods are substantially enhanced by AI, which automates the collection and analysis of dietary consumption data (Illner, *et al.* 2012) [16]. Zhu *et al.* (2015) [49] have demonstrated that the accuracy and efficacy of dietary recalls can be improved by the use of machine learning algorithms to process food images and identify food items and portion sizes. For instance, the AI-based application "Snap-N-Eat" employs image recognition to evaluate users' food intake from photographs they have taken.

Nutritional Epidemiology

AI facilitates the identification of dietary patterns and their correlations with health outcomes through the advanced analysis of large-scale epidemiological data (Luo, *et al.* 2020) [21]. Targeted public health interventions can be facilitated by predictive models, which can reveal relationships between diet and diseases, including obesity, diabetes, and cardiovascular diseases (Afshin, *et al.* 2019) [2]. For instance, the National Health and Nutrition Examination Survey (NHANES) data has been analyzed using machine learning techniques to predict dietary risk factors for chronic diseases (Luo, *et al*, 2020) [21].

Personalized Nutrition Recommendations

AI enables the creation of personalized nutrition recommendations that are tailored to the unique health conditions, genetic profiles, and dietary preferences of each individual. For example, the AI-powered platform "Nutrino" provides personalized nutrition advice and meal plans that are tailored to the health data and objectives of users (Wang, *et al*. 2019) [45].

Behavior Change Interventions

Artificial intelligence-driven tools facilitate behavior change interventions by offering real-time feedback, monitoring progress, and increasing user engagement. Mobile health applications that are equipped with AI can monitor dietary intake, provide motivational support, and recommend strategies to surmount obstacles to healthy eating. For instance, the "Noom" application employs AI to provide personalized coaching and support for weight loss and healthy eating (Teasdale, *et al.* 2018) [37].

Policy Development and Evaluation

AI aids in the formulation of policies by evaluating the prospective effects of nutrition policies and interventions on public health outcomes (Mozaffarian, *et al.* 2018) [27]. The impact of policy changes, such as sugar tariffs or nutrition labeling, on the dietary patterns and health metrics of the population can be simulated by predictive models (Afshin, *et al.* 2019) [2]. AI can also assess the efficacy of current policies and recommend enhancements to enhance public health outcomes (Mozaffarian, *et al.* 2018) [27].

Mobile Applications

Kao and Liebovitz (2017) [17] assert that mobile health applications offer the potential to enhance patient engagement, data collection, and remote monitoring of

outcomes beyond the healthcare facility. The utilization of mobile applications to monitor health data is a rapidly expanding field, and surveys of mobile phone users in the United States suggest that 58% of them have downloaded a health-related application to their device (Krebs & Duncan, 2015) [18].

Nearly 83% of registered dietitians report employing mobile applications in their practice (Sauceda, 2016) [34]. Apps continue to be the subject of ongoing research for their potential applications in healthcare management, despite their ubiquitous use among individuals. Azar, *et al.* (2013) [5] estimate that there are presently over 10,000 diet and weight loss applications available, and they are extensively used. Apps may also distribute health information, such as guidance on weight management or diet, regardless of whether it has been verified or validated by healthcare professionals and specialists. Other applications may include a social engagement feature that enables users to engage in group forums or establish connections with other users. The features of nutrition apps are highly variable; however, they all share a commonality in the ability to monitor the user's daily dietary intake and physical activity (Limketkai, *et al.* 2021) [19]. MyFitnessPal is one of the mobile applications that is commonly used for weight loss management. This application is equipped with a large database, barcode scanner, recipe importer, restaurant recorder, and food insights. It also records food and calorie intake. Noom provides a team of virtual coaches, weekly challenges, and customized meal plans. It offers educational resources, tools for monitoring your progress, and training programs to integrate additional activities into your daily routine (Theodore Armand, *et al.* 2024) [38].

For instance, diabetes applications may offer users a more comprehensive comprehension of the correlation between their diet and behavior and their blood sugar management (Veazie, *et al.* 2018) [42]. Day Two, Glucose Buddy, and Dario Health are among the applications that may be implemented by patients with diabetes. Day Two - Employs the Algorithm Diet, which necessitates that patients submit a stool sample to establish a profile of their gastrointestinal microbial ecosystem. This profile is then combined with laboratory values, such as HgbA1c, to determine individualized dietary plans for patients. Utilizes the food as medication approach to manage type 2 diabetes by offering insights into the unique metabolization of nutrients by the body.

Blood sugar, medication, hemoglobin A1c, weight, and blood pressure are all monitored by Glucose Buddy, a glucose surveillance system. Dietary intake-capacity to monitor intake through the scanning of product barcodes or photo recognition Data export-download reports to distribute to healthcare providers. Education and coaching-a 12-week diabetes education plan that includes five-minute lectures, as well as the opportunity to meet with certified diabetes coaches individually. Integrate data from FitBit, Apple Watch, and other wearable devices (Limketkai, *et al.* 2021) [19].

Some popular diet-monitoring mobile apps

Healthify Me: The application offers a comprehensive collection of meal plans and recipes. Lifesum provides a barcode scanner and macro monitoring feature to enable users to monitor their daily calorie intake and meals.

My Net Diary: Is a mobile application and online platform that are intended to assist individuals in the monitoring of their diet, weight management, and the attainment of their health and fitness objectives. The application includes a user-friendly calorie counter that enables digital diet support for weight loss.

Fastic: The application is intended to assist users in the practice of intermittent fasting. It provides a variety of features, including the ability to monitor fasting times, meal plans, and educational content regarding healthy living and intermittent fasting (Theodore Armand, *et al.* 2024) [38].

Challenges in AI Integration in Nutrition

Data Privacy and Security

AI applications frequently necessitate substantial quantities of data, which may encompass confidential information regarding individuals' health status, genetic information, and dietary routines (Topol, 2019) [39]. It is imperative to safeguard this data from unauthorized access and intrusions in order to uphold user trust and adhere to regulations like the General Data Protection Regulation (GDPR) (Morley, *et al.* 2020) [36].

Algorithmic Bias

AI systems have the potential to exacerbate and perpetuate biases that are already present in the data they are trained on. In the field of nutrition, this can result in biased dietary recommendations and interventions that may be ineffective or even detrimental to specific populations (Huang, *et al.* 2022) [15]. In order to mitigate bias and enhance the accuracy and impartiality of AI-driven nutritional advice, it is imperative that AI algorithms are trained on diverse and representative datasets (Vayena, *et al.* 2018) [41].

Transparency and Explainability

However, the absence of transparency and explainability in AI systems is an additional substantial obstacle (Mittelstadt, *et al.* 2016) [25]. Many AI models, particularly those that are based on deep learning, operate as "black boxes," which makes it challenging to comprehend how they arrive at specific recommendations or predictions (Samek, *et al.* 2017) [33]. This lack of transparency can impede the trust and adoption of AI in nutrition among the public and healthcare professionals (Vayena, *et al.* 2018) [41].

Ethical Considerations in AI Integration in Nutrition

Equitable Access

A significant ethical concern is the guarantee of equitable access to AI technologies in the field of nutrition (Vayena, *et al.* 2018) [41]. If AI-driven nutritional tools are exclusively accessible to specific populations, such as those with higher socioeconomic status, there is a risk that they could exacerbate existing health disparities (Wang & Hu, 2018). It is imperative to make these technologies accessible and affordable to all, with a particular emphasis on marginalized and vulnerable communities (Morley, *et al.* 2020) [36].

Autonomy and Informed Consent

The utilization of AI in the field of nutrition poses

significant inquiries regarding individual autonomy and informed consent (Mittelstadt, *et al*. 2016) [25]. Users must be completely apprised about the implications of AI-driven recommendations and the manner in which their data will be utilized (Vayena, *et al*. 2018) [41]. Furthermore, individuals should be able to make decisions about their health and nourishment without feeling coerced or excessively influenced by AI systems (Topol, 2019) [39].

Accountability and Governance

Addressing the ethical challenges of AI in nutrition necessitates the establishment of transparent governance and accountability frameworks (Morley, *et al*. 2020) [36]. This encompasses the establishment of accountability for the consequences of AI-driven decisions and the establishment of mechanisms to mitigate any adverse effects or injury that may arise from AI applications (Vayena, *et al*. 2018) [41]. Trust can be fostered and AI technologies can be employed ethically and responsibly through the implementation of robust governance frameworks (Mittelstadt, *et al*. 2016) [25].

Conclusion

The precision and efficacy of Artificial Intelligence (AI) are revolutionizing the field of nutrition science. It revolutionizes personalized nutrition by customizing recommendations based on a comprehensive data analysis, which includes genetic and health profiles. AI expedites the analysis of food composition, thereby guaranteeing the precision of food labeling and quality control. It facilitates proactive health management by providing real-time insights into dietary patterns and deficiencies through advanced dietary assessments. AI improves the efficacy and safety of production in the food industry, while simultaneously reducing waste. AI's predictive models that effectively target interventions and foretell trends are beneficial to public health. Nevertheless, the incorporation of AI in the field of nutrition continues to be hampered by obstacles such as data privacy, algorithm bias, and the necessity of robust regulatory frameworks. Transparency and equity in data utilization and recommendations are essential ethical considerations. Embracing these ethical imperatives and challenges will be crucial for the effective and responsible optimization of nutrition science by AI.

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