Application of bioinformatics technology in food processing and food safety assessment

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Abstract: As known, bioinformatics is a rising interdisciplinary field that involves biology, computer science, mathematics and statistics to interpret and analyze biological data with high throughout and efficiency. It is widely applied in the field of genetics and genomics based on DNA sequencing, transcriptomics and proteomics detecting expression and regulation of genes and proteins, and also stimulation modeling to calculate and pattern general processes. Food processing and food safety are extremely close to human lives. Precise handling and high quality are keys in food industry, making it very necessary to introduce advanced and powerful technology into this field. This review is aimed to provide new sights of bioinformatics technology including proteomics and sequence analysis used to benefit food processing and achieve reliable evaluation of food safety. We introduced some examples for sequencing and modeling based bioinformatics contributed to food production and safety assessment in these decades.

1. Introduction

About two decades ago, the term “bioinformatics” has been introduced to science field as we learned that it combines computational and experimental technology applied in molecular and cell biology development. It has made a great contribution to science research as it is a predominantly discipline for handling (i) genome sequencing, annotation and comparison,(ii) sequence analysis, (iii) expression data analysis, (iv) protein structure prediction, (v) modeling biological networks, (vi) protein allergenicity detection[1]. It is traditionally believed that bioinformatics was developed to support scientific programs and researches. however, its function could never be limited like this. Meanwhile, emerging science and computer technologies have provided a lot of chances to improve public health and food production through improving the safety of the food supply and facilitating food process using innovative methods. Many bioinformatic technologies have showed their potential to safeguard public health. “Regulatory bioinformatics” has been proposed to build a standardized and transparent bio-informatic framework to guarantee food and drug safety[2]. For several years, the computational toxicology methods have been used to support the safety evaluation of related products by the United States Food and Drug Administration[3, 4]. It is obvious that bioinformatics has been playing more and more important roles in public health caring, especially food safety, but little attention has been paid.

Food processing includes many forms of processing foods, from primary processing, secondary processing to tertiary processing. Typically it is a mechanical process includes mixing, grinding, extrusion and chopping by equipment or workers. It contains complex procedures and also possesses potential risks for consumers’ health as flaws in every single step could be possible threats[5]. Food can transmit pathogens and also serve as culture medium for them, which can result in illness or death of person or animals. Food poisoning is one hundred percent preventable by scientific methods and approaches. However, it can not be achieved because of the number of persons and procedures involved in production and supply chain. In order to supervise food safety, many issues should be taken into consideration, including handling, preparation, and storage of food in ways of preventing food-borne illness to avoid potential health hazards. However, it is still ambiguous how

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bioinformatics involved in food industry and safety evaluation to achieve high production and quality.

2. Bioinformatics technology applied for food processing

2.1 Food Processing

With the development of society, people think highly of the quality of food, not only its taste also its nutrition. Food processing refers to grain grinding, vegetable oil and sugar processing, slaughtering and meat processing, aquatic product processing, vegetables, fruits and nuts, which are directly processed from agricultural, forestry, animal husbandry and fishery products. Processing activity is a type of general agricultural product processing industry. With the application of bioinformatics in the field of food processing, the quality, taste, and nutrition of food had been guaranteed well. In the bread baking, how to produce high-quality bread is a challenge in the baking process where various physiochemical and biological transformations take place simultaneously. The water content and temperature are keys for physiochemical and biological processes. Anishaparvin A et al. had invented a method which could produce bread with a great quality. By countering the rate of gelatinization, the temperature of baking, the time required, they put forward a counter model, a 3D computational fluid dynamics (CFD) model for pilot-scale electric heating baking oven was developed and validated with experiments testing baking temperatures[6]. In these years, laser has been applied in manufacture as a useful tool for producing a high power density laser beam which could used for welding, cutting, drilling or material processing. A mathematical model has been developed to predict the depth of cutting in potato tuber and also reduces the chances of microbial contamination. Moreover, it could also improve safety and productivity[7]. In addition, baked goods constitute a large part of people's daily life consumer goods, and a large part of baked goods is flour products, so the quality of flour products plays an important role. In Mun S and Shin M’s experiments, three rice varieties are selected to explore the effects of quality factors of flour processing. The molecular structure characteristics of the selected three samples were analyzed by high-performance size-exclusion-chromatography and high-performance anion exchange-chromatography[8]. They found that there are many good or bad factors that determine the quality of flour processing, the most important factors include the molecular weight of starch and the degree of polymerization of amylopectin, which are particularly important when making gluten-free baked products without glutinous rice flour.

2.2 Food supply and consumption

Agricultural crops are basis of almost all of the world’s food and feed. Bioinformatics based modeling is not only useful for long-term food processing, but also helps to predict food production and consumption somehow. Integrating plant science and crop modeling has been used to assess the impact of climate change on soybean and maize production[9]. And also, the cocoa product consumption could be predicted primarily by a metabolomics-driven approach[10]. Much more importantly, many important nutritional and medicinal species are difficult to cultivate and supply sufficiently, while attempts have been made with unsatisfactory results. Recently, proteomic analysis has been used to study edible mushrooms focusing on the molecular mechanisms and effective proteins for their anticancer, antidiabetic, antioxidant, and antibiotic value, also environmental habits[11]. Beyond that, the studies highlighted the contribution of advanced techniques and different proteomics methods in species breeding and culture and crop protection[12, 13]. It is quite clear that proteomic analysis of valuable food materials would improve the productivity and consumption basically. Moreover, the food storage stability and safety directly affects the production and supply, and biological knowledge by genomics and proteomics could effectively optimize the food quality and inhibit food corruption.

3. Bioinformatics technology applied for food safety assessment

3.1 Evaluating safety of food additives

Food additives are very common in people's daily life, and their definitions vary from country to country, with the increasing use of processed foods. The Food and Drug Administration of the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO) define food additives as: food additives are consciously added in small amounts to foods to improve food non-nutritive substances in appearance, flavor and texture or storage properties. Generally, a lot of people have been misunderstand the use of food additives, thinking that food with food additives are harmful to people after some events had happened like "Melamine event", or "Sudan III event". Though the benefits and risks of food additives are significantly controversial during these years, obviously excess additives brings harm or cause allergenic reactions to certain persons. For an example, using sugar as an additive could endanger diabetics. In this case, to quantify the concentration of food additives is necessary. Law WS et al. had used both conventional capillary electrophoresis (CE) and microchip electrophoresis to successfully separate and detect the commonly used preservatives and edible vitamin C[14], and they concluded that the methods developed are very helpful to determine and quantify the food additives in real commercial products such as soft drinks and vitamin C tablets. Coelho AG and de Jesus DP improved this methods to determine the additives in sugar-free chocolate, named as CE-C4 D method[15]. What is more, high-performance liquid chromatography-electrospray ionization tandem mass spectrometry also is used for determining food additives in pickle. Pickle is referring to vegetables that have been fermented for long-term storage. After pickling and seasoning, there is a special flavor that many people use as a common side dish. Among an experiment of Kin HJ et al[16], they found seven elements of food additives could be estimated well simultaneously, which shows it is so convenient for people to detect food additives when they need at any time. In order to attract more consumers, manufacturers will try to change the color of the food in order to make them look more attractive, colorants can achieve this purpose. Food colorants are additives whose main purpose is to color foods, also known as food coloring. Food coloring agents make foods have a pleasing color, which is important for increasing the taste of foods and stimulating appetite. The amount of colorant added requires strict standards for uniform management, and the detection of colorants requires a better method. Nowadays, the use of biometric methods to detect the content of food colorants has been widely used[17]. These methods would encourage and support the establishment of systematic allergens database including allergens similarities and variations which could provide more evidences and references for clinical treatments.

3.2 Evaluating genetically modified food

Genetically modification refers to genetically transfer some exogenous genes into a specific organism and effectively express the related product, generally polypeptides or proteins. This biological process is termed as transgene which have vigorously prompted the production and development of food and drugs. Foods produced by this process are called genetically modified foods(GMFs). This technique brought human benefits but also concerns. In the past years, risk assessment of GMFs has been performed to test the safety and nutritions. Studies including different aspects of GMFs safety evaluation were carried out, from acute to chronic, from generation to generation, and even carcinogenicity[18]. The analysis are technically based on polymerase chain reaction(PCR), such as quantitative PCR, real time PCR and some immunoasssays. The assessment of plant is a main concern of people as it is the main source of food, which means the methods to evaluate transgenic plants are very important. The food products derived from soy and maize are main targets of evaluation. To date, 2D-gel electrophoresis combined with mass spectrometry (MS) remains the most widely used qualitative approach for comparing plant proteomes to identify differentially expressed proteins[19]. Batista R had performed 2 dimensional (2D)-gel electrophoresis of protein extractions of transgenic maize(MON810) and non-transgenic lines[20]. Batista R et al. assessed the safety of non-transgenic and transgenic soya food through proteomic analysis[21]. In recent years, a number of papers describing transcriptome analysis of genetically modified plants have showed up[22].

Transcriptomics has been used to analyze genetically modified and conventional wheat varieties and tomatoes[23-25]. Above all, the development of techniques allowed the assessment of food safety vary from accurate and fast system to high through-put screening.

3.3 Microorganism detection

As we have mentioned, food safety is closely related to storage which is mainly determined by interaction of microorganism. Food microorganism could cause spoilage and contamination, and pathogens of them may cause diseases although some probiotic bacteria are used to produce fermented foods. Identification of microbial groups and potential pathogens including toxin proteins is particularly important. As some viruses and most bacteria could be eliminated by proper heating or cooking, while toxin proteins left in or produced during food processing could also be safety threats. To ensure food safety, it is required to perform microbiological tests to prevent food poisoning outbreaks. Generally, PCR is a quick assay to detect the targeted viruses and pathogens based on their unique DNA sequences. Mass spectrometry (MS) is a suitable technology for microorganism identification and characterization. High-performance liquid chromatography combined with mass spectrometry has already become one of the major methods to identify toxin proteins. According to research of Yang Q et al[26], fifteen toxins were identified which included seven firstly detected crystal proteins by the strategy of 2 Dimensional-Liquid Chromatograph-Mass Spectrometer (2D-LC–MS/MS), which gives a quick and solid result. Furthermore, gas chromatography-mass spectrometry (GC-MS) also have been reported to establish metabonomics[27]. MS coupled with affinity-based techniques can be used to concentrate targeted proteins collected from sample solutions so that it can highly improve the detection limits. Many data analysis methods and bioinformatics approaches with high efficiency and fidelity have been developed for microbial identification. Completed microorganism databases and essential protein or DNA sequence information are keys to clinical microbiology and personal medial care.

3.4 Allergen detection

The levels of allergen both in fresh and processed foods can vary dynamically. As different sources of foods can cause different types of allergic reactions, reliable detection and absolute quantitation methods are urgently required to effectively protect the food-allergic population. Proteins are ubiquitous and contribute to nutritional materials people need. Some of them regarded as allergens mostly responsible for food allergic reactions, resulting in mild to severe systemic reactions to body. Allergen varies to different people, different places, even different periods to same person. Allergenic foods derived from plants and animals, they include peanuts, soy, milk, eggs, and some seafood and even some fruits. In the developed countries, about 4%-8% people suffers at least one food allergy according to the reports. And it is much more common in children than adults. More importantly, concerns about potential food allergens would account for that GMFs have not been world widely accepted. PCR and antibody based immunoassay are classic methods for food allergens identification and detection[28]. Recently, proteomics have increasingly been used in the allergy field to (i) identify allergens in crops, (ii) obtain well-characterized allergens, (iii) detect and quantify allergens[29]. McClain S used a statistical method to identify a threshold specific to identifying cross-reactivity potential[30]. Absolute quantification of proteins can be achieved by triple quadrupole mass spectrometers, which is a high-throughput and accurate quantitative approach to quantify hundreds of proteins in a single 30 min acquisition[31-33]. Overall, reliable and solid analysis result is required to be provided to allow greater control of the food allergens to safeguard certain consumers.

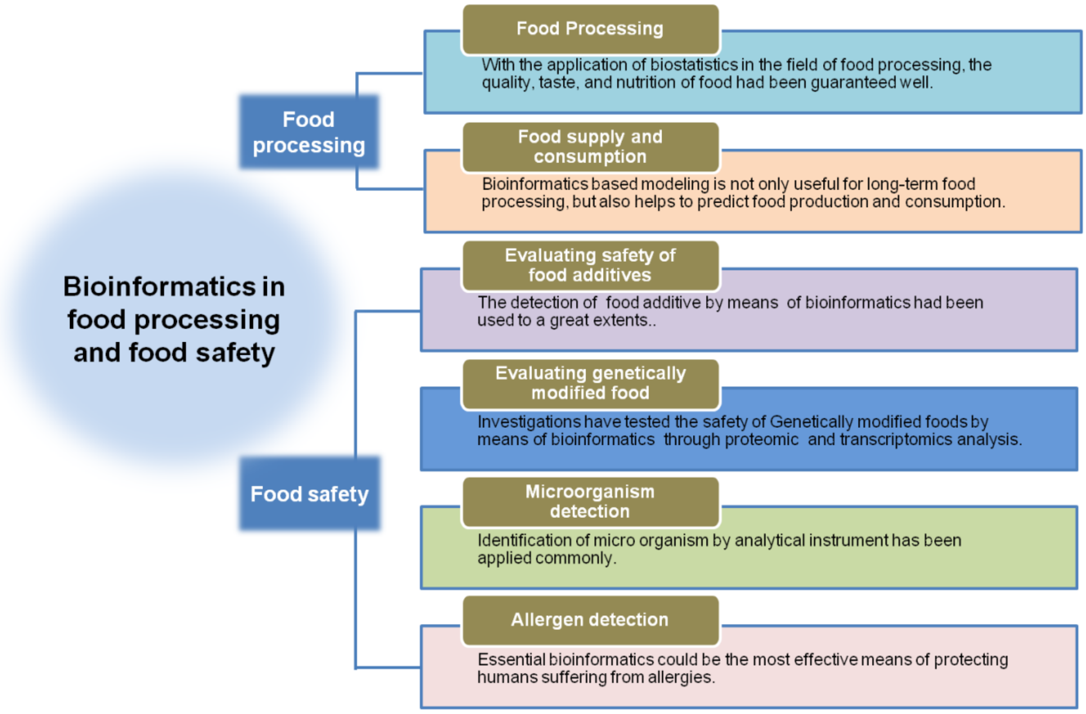

Figure.1 Application of bioinformatics in food processing and food safety

4. Conclusion

With emerging new techniques, applications and potential treatments, bioinformatics will deliver much more solutions to unimagined problems, providing food security, health and well-being to human lives[34]. A summary of bioinformatics applications which have been described in this review are illustrated in Figure 1. One hand, it seems that most of the bioinformatics technologies used to control food quality are sequence analysis based data dealing. Still little is known about how to improve the application of bioinformatics in mechanical processing. It will liberate food handlers and make processing under precise control. More and more attention should be paid to modeling investigation in the future. On the other hand, for most crops are genetically complex and some are not available for research, current knowledge is not enough to explore the mechanisms involved in plant diseases, which directly limits food supply and processing. Moreover, newly developed technology in this century also brings the other side of coin-variable underlying pathogens and antigens, one of the main challenges of food safety in the future. Bioinformatics greatly facilitate data management so that it is doomed to be an essential and useful tool to collect, integrate and translate data and information in food science. Besides food safety assessment, the preferences, needs and feedback of consumers could also be analyzed and modeled to adjust food flavor and food production.

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