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Adoption of Nanoparticle-Based Food Additives — A Review of Theoretical Basis and Hypothetical Limitations for Real - Life Application in Staple Foods in China

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Abstract: Descent algorithms, particularly gradient-based methods are very important in optimization of deep learning models. However, their application is often accompanied by significant mathematical challenges, including convergence guarantees, avoidance of local minima, and the trade-offs between computational efficiency and accuracy. This article begins by establishing the theoretical underpinnings of descent algorithms, linking them to dynamical systems and extending their applicability to broader scenarios. It then delves into the limitations of first-order methods, highlighting the need for advanced techniques to ensure robust optimization.The discussion focuses on the convergence analysis of descent algorithms, emphasizing both asymptotic and finite-time convergence properties. Strategies to prevent convergence to local minima and saddle points, such as leveraging the strict saddle property and perturbation methods, are thoroughly examined. The article also evaluates the performance of descent algorithms through the lens of structural optimization, offering insights into their practical effectiveness. The conclusion reflects on the theoretical advancements and practical implications of these algorithms, while also addressing the ethical considerations in their deployment. By bridging theory and practice, this article aims to provide a deeper understanding of descent algorithms and their role in advancing artificial intelligence.

Keywords: Mathematics, Computer Science, Deep Learning, Descent Algorithms

1. Introduction

The potential applications of nanomaterials in the food and agricultural industries are being explored to improve the food supply's safety/quality ensurance, nutrition supplement and shelf-life lengthening. Many food-grade substances have been converted into nano-food additives (e.g. colouring, fragrances, antimicrobials, vitamins, and nutritional supplements) or advanced packaging materials (such as bright or active coatings/films). Given the wide range of nanomaterials available for the carriage of substances in relevance to the food additive industry, it is worthwhile to dive into the reserve tyre of literature in compiling the scholarly discoveries regarding the choice of nanomaterials, surface modification of the nano-carriage system for food additives, the mode of attachment for the substances, and the multi-functional aspects of the nanomaterials. For this article, I would like to fixate the discussion of utilisation of nanomaterial-based carrier system for the food additives used during the production of Chinese staple foods with Chinese steamed bun (CSB) as the example. Given

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that the most commonly used food additives for the making of CSB, such as salts, vital wheat gluten, hydrocolloids, esters, enzymes, acids, are naturally generated out of reaction process. The natural additives are adopted, generally, for the microbe growth and for their utility in enhancing the texture and chewing quality of the CSBs. With advancement for packaging and treatment of the flour with the assistance of the aforementioned additives stalled recently, this article sets off to discuss the advantages that may be brought about by nanomaterial-based technology in probable bundling with natural food additives with the case of CSB. Limitations arising out of current technical hurdles and generation of injurious byproducts will also be included.

2. Food additves and a general introduction

Toward the middle of the 19th century, food additives were invested for food adulteration purposes. This resulted from the food industry being centralized, the dwindling of personal responsibility, food analysis emerging, and the food safety imperfections being seen at governmental control. Thus, the unrestrained touching of food was tantamount to a serious global concern about food being compromised. Gradually since early 2019, one of the key achievements was the implementation of the availability of data on food analysis combined with regulatory requirements, which reduced the significance of this problem in 1920. Very vital in the 20th century is, of course, the integration of processed food into the human diet and, at the same time, legal chemical additives were largely used, further fragile regulation, which is still in dispute and needs much cognitive effort to settle it properly for the consumers [1]. As of today, to meet the consumers' preferences, from the approximately 2,500 functionally enrich food additives to extend the shelf life, while several are banned for the consumers' benefit, some at a global level and others in certain specific countries [2].

Food additives, defined in Oxford English Dictionary (OED) as “substances...added to food for flavour addition, preservative means, colouring, and otherwise supplements”. According to Pressman et al. [3], in referencing the clauses by Federal Food, Drug, and Cosmetic Act (FFDCA) with a focus on the use of food additives for commercial production): any substance expected to become a component of food is classified as a food additive and necessitates premarket approval by the FDA. Regulation in regions otherwise than the United States echoes the general understanding over food additives as supplementary to the food’s original feature both phyically and chemically [4]. Despite the fact that the human diet is of natural source for the most part [5], these naturally occurring substances should be considered in concert with additives, those that are intentionally added, where the latter may include various nutrients, dyes, or flavor-imparting substances. More food additives may be used as part of the food processing and preparation process that may change and convert some of the primary major compounds which farmers market as an end product. They may either be in the form of biogenic or synthetic, and may bring with them new compounds. Food additives are, however, introduced as I said for a certain technical role: stability, colour consistency (e.g., emulsification). Among these, food additives are used for supplementary aim for flavours (sweetening or tartness), smells, and other physical features. Additives are widely used in the food industry to improve food's nutritional status, safety, shelf life, and aesthetics [6].

Food additives can be assembled from natural ingredients or chemical synthetic ingredients [7]. Food additives of certain kinds are only manufactured as follow-up byproducts and often in very small quantities, which are largely coming from agriculture or indirect process. For the latter, they may be traced to harmful substances like pesticides or drugs used in animal care and management. They may also be substances that move from food contact surfaces (FCS) and packaging to the food products. Our diet is prone to exposure to other undesirable toxins from natural sources such as microorganisms and byproducts they create, contaminants that are the inherent metabolites of plants. These aforementioned types of food additives shall be latter clarified in accordance with relevant literatures.

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Integral to modern food production and preservation, food additives are categorised according to their functionality and regulatory guidelines. Within the European Union, food additives are classified into 26 functional classes as specified by Council Regulation (EC) 1333/2008. This classification includes a diverse array of additives ranging from sweeteners and colorants to specialized categories such as anticaking agents and packaging gases. This detailed classification system is designed to ensure that each additive serves its specific purpose, thereby enhancing food quality, safety, and shelf life. In the United States, the classification system for food additives is structured into six main groups, according to the FDA. These groups are preservatives, nutritional additives, coloring agents, flavoring agents, texturizing agents, and miscellaneous agents. Some of these groups are subdivided to delineate specific functions, for example, preservatives are categorized into antimicrobials, antioxidants, and antibrowning agents, while flavoring agents include sweeteners, natural or synthetic flavors, and flavor enhancers. Additionally, food additives can be categorized based on their origin and manufacturing process into four principal groups: natural additives (derived directly from animal or plant sources), similar to natural additives (synthetically produced to emulate natural substances), modified from natural (natural additives that have been chemically altered), and artificial additives (completely synthetic compounds). This regulation of classification is based on the broad genres of food additives and the concerned method of application in meeting the regulatory standards and consumer expectations for taste, texture, appearance, and shelf life in food products.

3. Food additives in Chinese context

In China, the classification and regulation of food additives are managed and overwatched by the National Health Commission of the People's Republic of China. These regulations are erected surrounding standards that are designed in aligning with both national directives and international food safety practices, echoing the detailed means of classifications adopted in EU counterparts and the broader categories typical of U.S. standards. Within this current framework at work, the Chinese one categorise food additives into twenty-three different categories, including antioxidants, bleaching agents, and emulsifiers, natural addictives, etc. Each category is distinctively defined to be limited within specific functional roles, from enhancing the texture and taste of food to extending its shelf life and preserving its nutritional value.

To ensure the safety of these additives, the categorisation system in Chinese context for food additives also specifies permissible uses and maximum allowable levels for each additive. The Chinese authority employs a positive list system, allowing only the listed additives to be used in food products, a practice that aligns with international regulatory standards. This rigorous approach not only demonstrates China's commitment to food safety but also facilitates trade as it combines the stipulated regulations by global standards set by entities like the Codex Alimentarius, managed by the Food and Agriculture Organization and the World Health Organization (WHO). The alignment with globally utilised rules embeds the nature of food additive regulation in China and ensures that products manufacturing process comply with both national safety standards and international expectations.

This approach to food additive regulation is further elaborated by Ma (2014), contrasting the previous enacting codes GB2760-2011 with the latest standard, GB2760-2014. According to Ma [8], the new set of regulations incorporates several critical amendments that enhance the management and use of food additives in China. Notable among these is the inclusion of new food additives approved by the NHFPC, the modification of the "Carry-Over" principles which address the residual presence of additives, and the streamlining of components such as gum-based substances in chewing gum. GB2760-2014 revises the provisions for the use of food processing aids and modifies the Food Category System to ensure that additives are categorized more clearly based on their application and functionality. These changes are pivotal to China's strategy to keep its regulations in line with

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international practices, enhancing the safety and transparency of food manufacturing and consumption.

4. What are nanomaterials

Materials at nano-meter scale, usually referred to as nanomaterials, typically ranging from 1 to 100 nanometers in at least one dimension, exhibit unique functional attributes due to their diminutive size. Such attributes are invaluable in various applications such as improving the performance of food products as additives, in treatment protocols, or as novel packaging materials [9]. These nanoscale materials offer enhanced properties, including superior optical transparency at 50 nm, increased resistance to coagulation or sedimentation, greater stability in polymerized forms, altered textural characteristics, and optimized bioavailability and controlled release capabilities. Origins of nanomaterials vary, with some occurring naturally, others being harvested from natural substances (e.g., nitrocellulose or nanochitin), and yet others being synthetically produced through various processes (e.g., nanoemulsions). Classification of nanomaterials by shape ranges from zero to three-dimensional structures on a scale from 0 to 3 — with particles being zero-dimensional, fibers one-dimensional, flakes two-dimensional, and bulk nanocomposites three-dimensional. Within the food industry, the prevalent nanomaterials are nanoparticles (NPs), segregated into organic and inorganic categories based on composition. Organic NPs largely consist of protein-based particles (such as zein nanoparticles and casein micelles), carbohydrate-based structures (like nanomarcitrins and nanocellulose gels), and lipid-based forms (such as liposomes). In contrast, inorganic NPs typically include elements or metallic compounds like gold, copper, titanium dioxide, silicon dioxide, and zinc oxide [10,11].

At the intersection of various scientific disciplines such as chemical engineering, material science, pharmaceuticals, and cosmetic and medical industries, nanotechnology plays a crucial role, particularly with Engineered nanoparticles (NPs). Among its applications, NPs significantly improve the quality and safety of food by serving as additives, fortifying nutritional content, and acting as antimicrobial agents in food preservation and controlled release systems. An increase in the commercial presence of NPS-infused products in the food and beverage sector has been noted, with materials like gold, titanium dioxide, zinc oxide, and silicon dioxide (SiO2) being predominantly utilized, as documented in the List of nanotechnology consumer products updated in October 2013 [12]. SiO2 NPs, identified as the food additive E551 within the EU market, are utilized as an anti-caking agent to enhance the quality and shelf life of various food products [12,13]. Human exposure to NPs is possible through ingestion, accounting for a significant proportion—16%—of overall contact, ranked behind dermal (58%) and inhalation (25%) pathways [13,14]. The safety and regulatory aspects in the context of NPs within the food industry demand rigorous scrutiny and assessment.

Concerning the novel area of food-grade SiO2 nanoparticle toxicological studies in the biological systems, the research community lacksneeds the matching experience compared to the already established commercialized groups [1,14]. In general, research has fixed its aspiration to look at the biological effects of the SiO2 nanoparticles instead of the intervening role of the nanoparticles or the quality or quantity of the final product. This means that the individual nanoparticles are widely distributed among this food group's embedded carbohydrates, proteins, fats, minerals, and many other micro-nutrients. The interaction of the nanoparticles with these components directly influences their adsorption rate, distribution throughout the body, bio availability, and efficacy. The possible moderation of nutrient biomarker absorption by interacting food starches with protein nanoparticles (NPs) has been shown [2]. However, the multitude of interactions that food could have with various food-grade nanostructures remains largely uncharted. Additionally, the degradation of the food or food matrix itself plays a role in both the absorption of nanoparticles and the prevalence of toxic

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elements in the tissue, depending on the matrix [3]. It has been improved in terms of our causation studies that the oral pathway of food grade Si O2 nanoparticles may be seriously affected by the sorts of the food rung, showing 2.4 and 2.5 times rise in the rate of absorption when assisted with albumin and glucose, in sequentially [13].

The role of nanomaterials in boosting the capability of adding-on materials has become a trend. The additives can include colourants, taste-enhancing flavours, antioxidants, vitamins, preservatives, and enriched nutrition supplements [14]. The many nano additives available in many food fields are composed of Aleu-consuming and Andinos-selling. Such nano additives are used in food as ingredients themselves, processed or applied to the equipment used for processing, and finally, it is also used in packing materials to extend their functionality [9]. They could also be used to develop new functional attributes for food samples [8]. They can range from having a sustain of the active agents, boosting the release or deliberately discharging them. The functional aspects of nanoparticles are mainly based on their composition, dimensions, configuration and galvanic power [14].

5. Interaction between nanomaterials and food additives

The safety of nanomaterials application in food and food additives depends on their interactions with other components that may be present, as these interactions can alter the aggregation state, interfacial chemistry, and surface charge of the nanoparticles. As a result, their ability to alter food quality, shelf life, or safety is altered. Therefore, it is crucial to understand how nanoparticle-based food additives interact with food components such as carbohydrates, proteins, lipids, minerals, and phytochemicals. Therefore, this article aims to provide an overview of these interactions and their potential consequences.

This paper aims at unveiling the frontier research interest by the concerned scholarly field in correlating the technology of nanomaterials with the urgent needs of food industry -- safe dosage control of food additives. In reviewing the reserve of literatures,

The food nano-particles open up new applications with many end products such as nano-materials, antimicrobial agents and enzymes in food packaging industry. For the nano-particles used to add to food and do related applications, their composition, physical properties and actions with biological systems are three important factors. Organic nanoparticles, including liposomes, polymersomes, and micelles, hold promise as successful carriers of both drug and genetic material in delivery systems. This is due to their cell compatibility and ability to conjugate. Contrary to organic NPs as the nano-materials of organic substances, inorganic NPs as nano-materials have attracted the attention in food additives because of their unique and variability in physicochemical properties which are only inorganic nano-molecules, for instance optical and magnetic behaviors, chemical inertness, toploading, and stability. Proteins that are coated with inorganic NPs have unique combination of properties. So, these inorganic NPs are good candidates for food summary so by enhancing the functional properties, better

Technologically, nano-hybrid organic-inorganic materials stand out distinctly due to the incorporation of the best features of both inorganic and organic parts in the form of novel functions such as improved catalytic and optical properties [10]. Besides improving the composite, polymer matrix is considered to help spare the dispersal of the NP filler at the interface which is somewhat this proper distribution that brings forth consistency in the application of food additives. The introduction of Metal-Containing Organic Dendrimers as an exemplary example of the delicate balance between organic and inorganic chemistry where dendron l The result is absolutely fine control over the NP surface aspects which in turn facilitates the design of the target-specific food grade materials, that might invite release of molecules during the food stability and thus also minimize the interference under the matrix. Whereas, inorganic magnetic nanoparticles can provide practical properties to serve the desired functions like the controlled processing of the over production of iron

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as one of the main considerations which is there because of the importance of this element in nutrition and also because of the potential side effects [12]. Normally, the consideration of biological interpersonal relationships, such as variations of cellular uptake threshold, is crucial for designing nanoparticles that can be safeguarded against external factors like pH values, temperature, physical interactions, and other components which are inherent in the food environment. This shows that NPs for food additives should be chosen only after clear and deep insight into molecule properties based on their physical, chemical, and biological nature so the expected safety, efficacy and compatibility of them can be ensured with food matrices, as well [5]. The the small molecule Nanoscale chemicals are advancing food technology by providing a playground for the resources tradeoff and molecular design, leading to the development of targeted additions such as improvement in safer, tasty and nutritional foods [7].

6. Nano system through which cellular vesicles/cells are delivered

The suites of nanoparticles with their diverse physical and chemical characteristics act as the smart vehicles for such type of simulation in area of cell adhesion and the molecular interactions. First definitive indications of cadherin functionality compliance in cellular aggregation were obtained by taking cumbersome methods that mainly can be characterized by the fact that mainly what came out as the results was irregular information mainly due to difficulties in quantifying cadherin molecules and their multimolecular structure formation. The researchers have tackled the challenge of athymic mice myeloma model in the analysis of biological activity of cadherin recombinant fragments in standard assays using nanoparticles such as functionalized glass and polymeric systems. As an example, fluorescent proteins A-coated polystyrene beads are useful in analyzing the functions of ectodomain sections depicted at the junction of C and E-cadherins in bead aggregation experiments conducted. The reaction which leads to self-aggregation is Ca2+ concentration associated and the binding capability is to the cadherin-expressing cells [13]. On the other hand, the modifications facilitate cell-matrix-related signaling by promoting the formation of normal contacts and tolerance of exposure to the media. Notably, the bead-cell binding assay to assess the signaling mechanism has been conducted using nanoparticle systems by where the wear-degraded cells have revealed hassle-free integrin signaling, facilitating exploration therapeutics to aid osteochondral repair. Furthermore, these strategies tested for cell-matrix binding in the constitutive secretory control have been demonstrated as having a significant role of activation in the chondrocytic and aromatization of the ingredients within the closed environment of the culture program. In addition to that, PCa strictures can be isolating by using this method as well. They harbor natural cell-adhesing interactions as well as the ability to draw the assembly of important membrane components including N-cadherin, catenins, and F-actin. Besides, they are involved in remodeling at the cell interface with such coated beads. Furthermore, the use of porous material enhanced the specificity streptavidin spherical polystyrene beads, which has further obtained the formation and processing of cells and then engulfed [12]. This internalization process, precise and mutation-sensitive, underscores the utility of nanoparticles in yielding insights into the finer details of cell membrane dynamics [6].

As we turn our attention to the realm of food science, specifically the composition of Chinese steamed buns, an intriguing application of this technology emerges. Common food additives used in these buns—such as preservatives, flavor enhancers, and nutritional supplements—can benefit significantly from the encapsulation and controlled release properties offered by nanoparticles. This integration could revolutionize traditional food processing by improving the stability, bioavailability, and efficiency of additives, thereby ensuring longer shelf life, enhanced taste, and augmented nutritional value. Thus, the exploration of nanoparticle systems in the previous section sets the stage for a detailed discussion on their potential roles in food industries, using Chinese steamed buns as a case study to illustrate broader implications and opportunities.

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7. Conclusion

This paper has sought to make clear of the interplay of the common additives and ingredients for the making of Chinese Steamed Buns (CSB). The author has elucidated their critical roles in enhancing the physical texture and sensory attributes of these staple foods. My exploration into the adoption of nanomaterial technology and its combination with CSB has entailed the components including: salt, alkaline substances, phosphates, vital wheat gluten, and esters. The main body discussion, in reference with literatures in coverage of material selection, carriage mode and surface modification of nanomaterial carrier system has revealed their probably meaningful contributions to improving texture, shelf life, and overall consumer acceptance of CSB if applied with the common food additives.

Given that the role of vital wheat gluten has been recognized as crucial in providing structural integrity and enhancing the textural appearance of CSB in the existing literatures. My discussion unveil that the inclusion of gluten as a means to improve the overall quality and processing/aging of the dough cater to the diverse tastes by the users. The use of esters and the innovative combination with nanomaterial carrier systems represents a forward-thinking approach to food additive integration, offer new ways to enhance the functioning and efficiency of ingredients in CSB production. These systems not only improve the distribution and effectiveness of common food additives applied during the making of CSB but show the possible way for the development of cleaner-label products by minimizing the total amount of additives needed. The findings from this study highlight the significance of each additive in the production of CSB and point towards a likely approach that marries traditional practices with frontier technical advances. As the demand for high-quality, clean-label food products continues to grow, the insights gained here provide a valuable framework for future innovations in food technology, ensuring that the cultural heritage and nutritional value of CSB are preserved while enhancing its appeal to a global audience. I think my future research, in following of this EPQ, should continue to look into the relationships, particularly in the context of emerging food technologies, in refining and optimisation of the production of CSB and possibly other staple foods.

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