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Review

Green Food Development in China: Experiences and Challenges

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Received: 17 October 2020; Accepted: 3 December 2020; Published: 9 December 2020



Abstract: China feeds approximately 22% of the global population with only 7% of the global arable land because of its surprising success in intensive agriculture. This outstanding achievement is partially overshadowed by agriculture-related large-scale environmental pollution across the nation. To ensure nutrition security and environmental sustainability, China proposed the Green Food Strategy in the 1990s and set up a specialized management agency, the China Green Food Development Center, with a monitoring network for policy and standard creation, brand authorization, and product inspection. Following these 140 environmental and operational standards, 15,984 green food companies provided 36,345 kinds of products in 2019. The cultivation area and annual domestic sales (CNY 465.7 billion) of green food accounted for 8.2% of the total farmland area and 9.7% of the gross domestic product (GDP) from agriculture in China. Herein, we systemically reviewed the regulation, standards, and authorization system of green food and its current advances in China, and then outlined its environmental benefits, challenges, and probable strategies for future optimization and upscaling. The rapid development of the green food industry in China suggests an applicable triple-win strategy for protecting the environment, promoting agroeconomic development, and improving human nutrition and health in other developing countries or regions.

Keywords: green food; authorization; standard; food quality; environment; sustainable development

1. Introduction

A leading challenge of the 21st century is to ensure global food security on a socioeconomically sustainable basis; annual grain production needs to increase by approximately 580 million tons (MT) by 2030—a 2% increase per year—in order to meet the grain demands of the rapidly growing population [1]. With 22% of the world's population depending on only 7% of the cultivated land [2], the total annual grain production in China has increased from 280 to 617 million tons (~120%), and the average grain yield has increased from 2949 to 6081 kg ha^{-1} (~106%) over the last four decades (1980–2018) [3,4]. Such achievements in grain production rely heavily on high levels of resource inputs. The increase in the application of chemical nitrogen (N) fertilizers, from 9.34 to 20.65 million tons (National Bureau of Statistics of China), has resulted in a lower overall N use efficiency of 0.25, compared with 0.42 in developed countries [5]. If an excessive amount of synthetic N enters the surrounding environment,

it causes soil acidification and the intensification of greenhouse gas emissions, N deposition, and the eutrophication of surface water [5–7]. Soil acidification in southern China significantly stimulates the bioavailability of heavy metals, i.e., Cd and Mn, and certain levels of heavy metals are unintentionally included in composts and phosphate fertilizers [8]. Almost 20% of the farmland in China has been polluted by heavy metals, especially cadmium (Cd), nickel (Ni), and arsenic (As) [9], and the related food contamination has become an increasingly serious agricultural and social issue [10]. The overuse of pesticides is another challenge for improving food quality; the intensity of pesticide use increased from 5.83 kg/ha in 1990 to 13.07 kg/ha in 2018, with an average annual growth of 4.28% [3]. The public policy "zero growth of chemical fertilizer and pesticide use by 2020" was therefore initiated in 2015 in order to sustain agriculture development in China.

Green food was first introduced in China by the Ministry of Agriculture (MOA) in 1990, and it primarily refers to a full range of edible plants, animals, fungal raw materials, value-added processed products, and condiments. According to the principle of sustainable development, standard operational protocols apply to the full industry chain, including the production, processing, packing, storage, and transportation of green foods for farm-to-fork quality control and the efficient utilization of resources, as designed by the China Green Food Development Center (CGFDC). With strict regulations and regular inspection, green food dramatically reduces resource inputs, i.e., chemical fertilizers, pesticides, and related additives; disseminates new technologies; improves environmental and food quality; increases farmers' earnings [11]. Over the past three decades, green food has undergone exponential development in terms of the cultivation area, number of products and companies, and domestic and international markets and sales. Herein, we systematically summarize the regulation and development of the green food industry, as well as its broad significance and challenges.

2. Classification, Standardization, and Development of Green Food in China

China adopted three food categories in order to ensure food safety and quality, namely, organic food, green food and safe food (pollution-free food), officially introduced in 1989, 1990, 2001 respectively. The standards and logos of each category are shown in Figure 1. One of the most obvious features of such a classification system is the limitations regarding the type and amount of chemical inputs for the three levels. Organic food allows only organic fertilizers, encourages biological pathogen control, and minimizes other chemical inputs. However, the high standard and price of organic food makes it available to a small percentage of customers [12]. Rather than eliminating chemical fertilizers, pesticides, and additives, the green food category reduces chemical N fertilizers by 50% compared with local farmers' fertilization levels, and excludes nearly 72% of commercially available pesticides in China, which is more acceptable for Chinese farmers and is better for meeting the quality and safety demands of customers. As a "middle ground" between organic and safe food, green food has the highest consumer awareness [13] and improves the competitiveness of the food industry and farmers' income, as well as protecting the environment and ensuring the sustainability of agricultural development [14]. Certification of safe food was stopped in 2018 because its standard had been adopted by most farmers and producers.

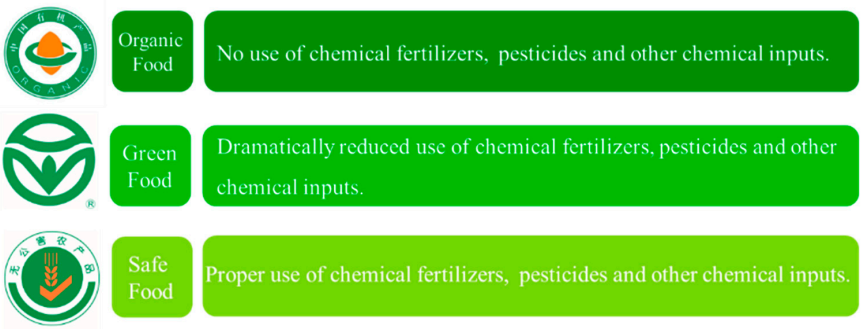


Figure 1. The three levels of food classification in China.

2.1. Administration, Standards, and Authorization of Green Food

CGFDC, founded by the Ministry of Agriculture in 1992, is a specialized agency in charge of national green food regulation and development. It has a general office and six divisions of trademark management, namely, authentication, science–technology and standards, quality inspection, planning and finance, market, and information. Since its establishment, CGFDC has functioned extremely successfully and efficiently in policy formulation, standard upgrading, authentication, accreditation, and quality control. A nationwide monitoring network led by CGFDC ensures policy and standard implementation, including 36 local green good management departments, as well as 96 monitoring organizations.

Green food regulations and standards were developed and established following the Codex Alimentarius programmed by the Codex Alimentarius Commission (CAC) which is the central managing body of the Food and Agriculture Organization (FAO)/World Health Organization (WHO) Food Standards Program to ensure food safety, promote consumer health, and facilitate global food trade. As shown in Figure 2, CGFDC has put 140 standards into effect for food quality control, from the farmland to the dining table. The standard system covers essential requirements for the environment, production technology, product quality, packaging, storage and transportation along the industry chain, and other production material standards, such as fertilizer standards, pesticide standards, food additive standards, and feed additives.

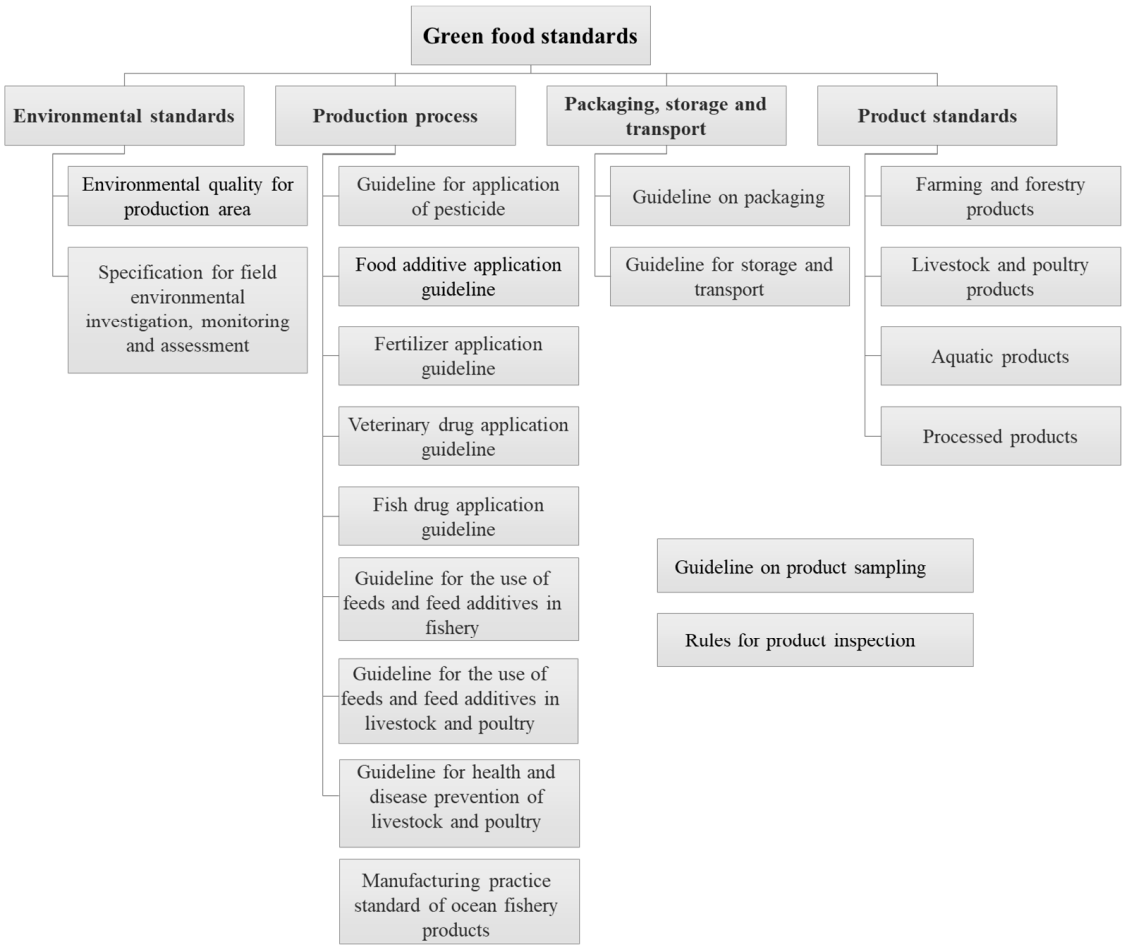


Figure 2. The well-established standard system of green food for food quality control in China.

Unlike safe food, green food places special emphasis on environmental control by specifying the field investigation, monitoring, and assessment. The soil, water, and air quality indexes in

the production area are that of the highest national level, and are free of heavy metals or other contaminants. To maintain a superior environment, chemical inputs, including fertilizers and pesticides, are dramatically reduced, therefore, as listed in Table 1, the threshold level of heavy metals, biohazards, and pesticide residues in rice grains of green food is comparable or lower than that of CAC standards. Green food encourages the increased application of organic fertilizer, including animal manure, compost, crop straw fertilizer, and some other commercial fertilizers. The green food fertilizer standards require the use of a fertilizer that meets the crop nutrient requirement of returning a sufficient amount of organic matter to the soil in order to maintain or increase soil fertility and soil biological activity. In China, 527 kinds of pesticides are available for general agricultural producers according to the national food safety standard; however, only 131 kinds of much safer pesticides are listed in the green food guide. Green food has successfully registered in more than 10 foreign countries including USA, UK, France and Japan, and a series of products have been certified. Lastly, green food follows a "from farm to fork" control principle similar to the Hazard Analysis Critical Control Point (HACCP) system.

Table 1. Comparative safety standards of "green food", "safety food" and "CAC" in terms of heavy metals, biohazards and pesticide residues (mg/kg) in rice grains.

	Green Food [1]	Safety Food [2]	CAC [3]
Pb	≤0.2	≤0.2	≤0.2
Cd	≤0.2	≤0.2	≤0.4
Aflatoxin B1	≤0.005	≤0.01	≤0.005
Fenitrothion	≤0.01	≤1.0	≤0.01
Triazoophos	≤0.01	≤0.05	≤0.02
Dimethoate	≤0.01	≤0.05	≤0.01
Bisultap	≤0.01	≤0.2	-
Butachlor	≤0.01	≤0.5	≤0.5
Buprofezin	≤0.3	≤0.3	-

[1] Green Food Standard for Rice, NY/T419-2014; [2] Agricultural Trade Standard of Safe Food for Rice of China, NY 5115-2008; [3] CAC: Codex Alimentarius Commission for rice.

The applicant initially submits their application to the Provincial Green Food Office for primary screening and for examination of the environment and products. Suitable candidates are then transferred to the CGFDC and the Green Food Authentication Review Committee for systematic evaluation. Certified applicants are then authorized to use the "Green food" logo from the CGFDC for production and marketing (Figure 3). Authorization takes effect immediately, is applicable for the following three years, and requires renewal before expiration. Monitoring staff annually inspect the operational procedures and product quality of the green food logo-users. The permit of "Green food" logo users is canceled under following conditions: (1) production environment fails to reach the green food level; (2) products are not up to the quality standard of green food; (3) industries fail to fulfil the contract of green food logo; (4) industries use unregulated raw materials; (5) industries refuse sampling inspection. Accordingly, for example, 52 products out of 8896 were screened out and ceased when 28.8% randomly selected green food products were sampled in 2018.

2.2. Rapid and Steady Growth of the Green Food Industry

Certified products and companies have undergone historic increases since the 1990s (Figure 4 and Table 2). In 2019, a total of 15,984 green food companies provided 36,345 (127 in 1990s) products. The cultivation area expanded from 0.82 million ha in the 1990s to 11.1 million ha in 2019, accounting for 8.20% of the total farmland area in China. In recent years, small-holder farmers have been encouraged to shift from conventional agriculture to the green food mode, resulting in the growing number of companies without obvious expansion of the cultivated area. Additionally, more newly certified companies prefer food processing for higher added value rather than primary products, which contributes more to industry upgrading than area expansion. The annual domestic

sales in 2019 reached CNY 465.7 billion, and approximately 9.7% of the GDP was from agriculture (National Bureau of Statistics of China). A huge leap in international sales, from USD 0.04 to 4.13 billion, over the period of 2001–2019, suggests robust growth in the green food market outside of China. The steady development of the green food industry has attracted many farmers and has promoted industrial standardization.

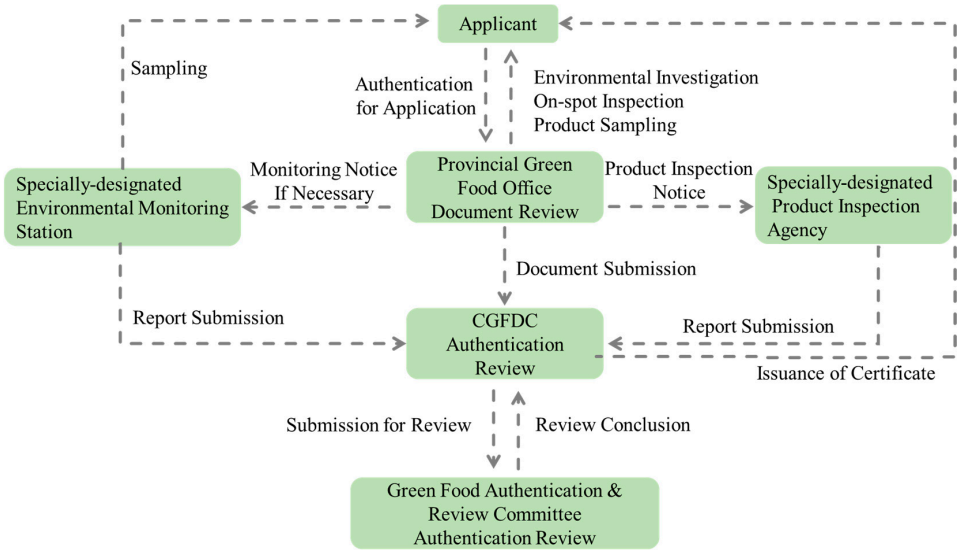


Figure 3. Schematic illustration of green food authorization in China. CGFDC, China Green Food Development Center.

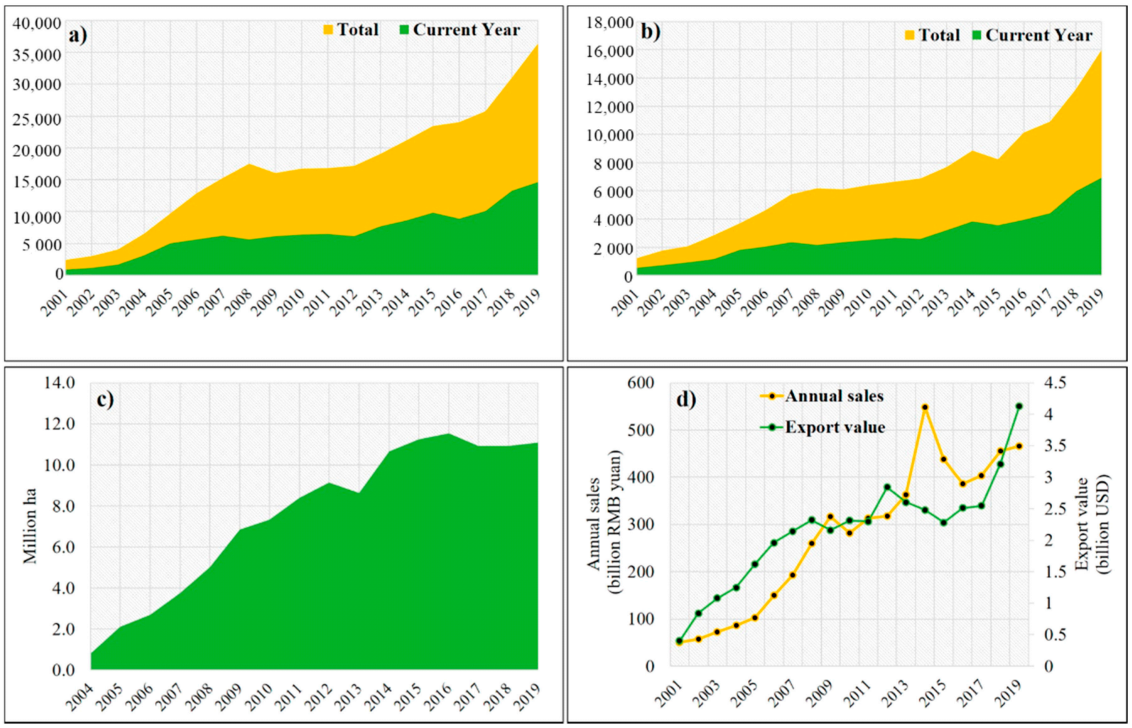


Figure 4. Green food development in China over the last two decades (2001–2019): (**a**) Number of certified products, (**b**) number of certified companies, (**c**) cultivated area, and (**d**) annual sales and export value. "Total" in (**a**,**b**) indicates cumulative number to date, and "Current year" refers to the number of newly certified products or companies in a particular year.

Table 2. Current status of the green food industry in China in 2019 (Source: CGFDC).

Item	Number
Product	36,345
Company	15,984
Farm	721
Farmer (million)	21.7
Cultivation area (million ha)	11.1
Domestic sales (billion CNY)	465.7
Export value (billion USD)	4.1
Technical standards	15
Product standards	125

2.3. Categories and Proportions of Green Food Products

Green food is generally classified into five categories, namely, primary and processed products of agriculture/forestry, beverage, livestock and poultry, aquaculture, and others (Figure 5 and Table S1). There are 23,986 agricultural and forest products (73.5 million tons), accounting for 77.5% of the overall green food. Subgroups of vegetables, fruits, and rice amount to 60.6% of the total amount of green food. The other agricultural and forest subgroups include soybean, maize, coarse cereals, wheat flour, edible forestry products, and vegetable oil, among others.

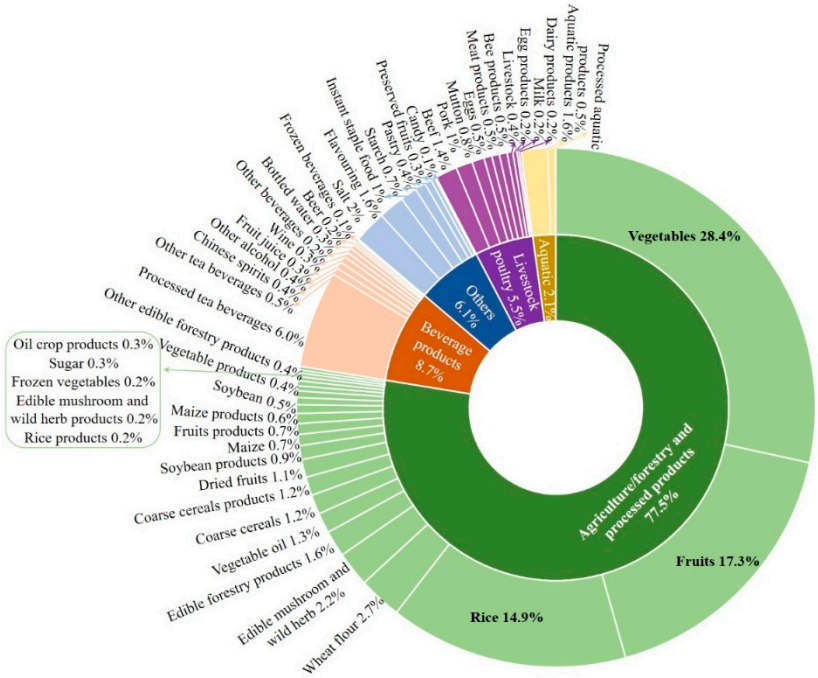


Figure 5. Green food categories and their corresponding proportions on the basis of the amount of product in China.

The second largest category (8.7%) is beverages, with a lower cost and higher profit; processed tea (nearly 6%) dominates this category. The third category (5.5%) is livestock and poultry products, including beef (1.4%), pork (1%), mutton (0.8%), and eggs (0.5%), as well as their products. Aquatic products rank fourth (2.1%). Notably, compared with agricultural/forestry or livestock products, the proportion of poultry and aquatic products is fairly low because of the strict prohibition of genetically modified (GM) ingredients according to the standard of "Green Food: Guideline for the Use of Feeds and Feed Additives in Animals." Most Chinese customers dislike GM food [15,16], and therefore, green food excludes direct GM feed or additives, which considerably hinders the application and authorization for livestock, poultry, and aquatic producers.

2.4. Distribution Patterns of Green Food Production

By the end of 2019, green food had spread across all province-level administrative regions in the mainland (Figure 6), with the highest density in the eastern coastal area and Heilongjiang. More than 40% of green food companies are concentrated in five provinces—Shandong, Anhui, Jiangsu, Heilongjiang, and Zhejiang—with Shandong being the province with the greatest number of green food companies (1625; 10.2%) and products (3898; 10.7%). By contrast, 5.9% of the green food companies are scattered in Xinjiang, Tibet, Qinghai, Shanxi, Shaanxi, and Ningxia. Tibet has the least companies (17) and products (42). Such an asymmetric distribution suggests good development of green food in eastern and northeastern China and underdevelopment in Western China. Given the high-grade environmental conditions in the west, western China possesses a great advantage for accelerating green food growth for local rural and economic development.

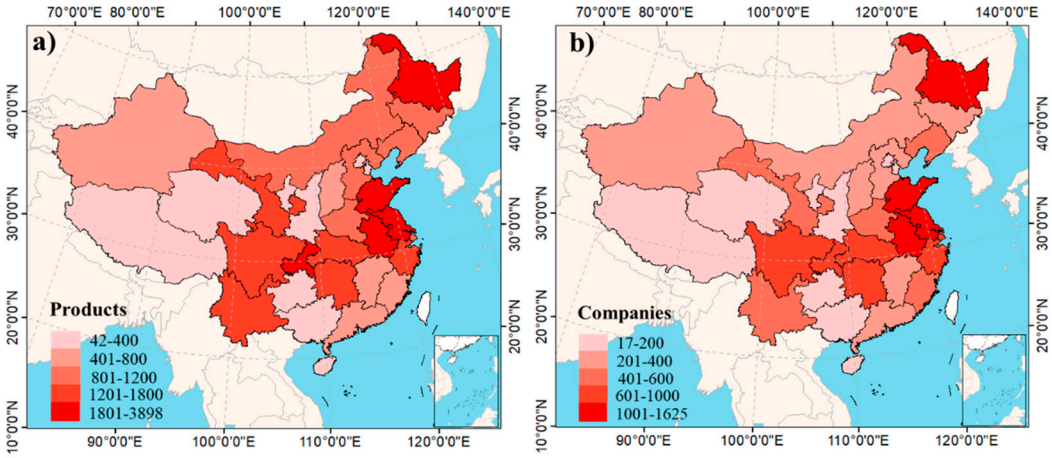


Figure 6. (**a**) Product- and (**b**) company-based distribution of green food in China in 2019.

Green food is a quite unique system well developed in China to ensure food quality on a sustainable basis. However, in order to ensure sustainable farming, environmental protection, and human health, other approaches are also adopted across the world with different principles from those of green food. In particular, organic farming and integrated farm management practices can be observed in USA, Germany, France, Canada, UK, Italy, etc. For example, a UK-based leading organization namely LEAF (Linking Environment And Farming) is actively working to deliver more sustainable and resilient food and farming chain [17,18].

3. Agricultural and Environmental Advantages of Green Food

Green food has brought about far-reaching environmental, economic, and social impacts with its rapid development across the mainland over the past three decades. Here, we consider how a 50% cut of chemical nitrogen fertilizers and the supplementation of organic fertilizers (N fertilization guide for green food) affect crop production and environmental protection (Table S2).

3.1. Crop Yield and Quality

Numerous studies have suggested that less than 50% of the N fertilizers that are applied are absorbed by crops, and a large percentage of the remaining active N goes into the soil, water, or air, causing severe environmental damage [19]. In the North China Plain and the Taihu Region, a 30–60% decrease in chemical N fertilizers does not affect the yields of rice, wheat, or maize [20]. A more recent meta-analysis has revealed that the substitution of 50–75% of chemical N fertilizers with livestock manure improves the crop yield by 12.7% [21]. In a 19-year long-term field experiment in China, using a similar 50% replacement strategy, the crop yield was improved and yield variability was reduced; these results are also supported by experiments with other crops [22]. Beyond annual crops,

apple yields can increase from 31.5 to 42.1 t/ha when supplied with mixed N (50% chemical N and 50% swine manure); more importantly, a combinatorial N supply significantly improves the fruit quality, as indicated by the higher values for the sugar/acid ratio, concentrations of vitamin C and soluble solids, and firmness [23]. Green cucumber grown in this manner is free from environmental contamination and is safer for human consumption compared with local farmers' cucumber [24].

3.2. Environmental Consequences

The application of organic fertilizers improves the organic matter content, soil microbial activities, and water and nutrient holding capacities, while reducing water contamination [25–28]. Green food favors organic fertilizers because of its greater nutrient-use efficiency, less nutrient leaching and volatilization, and lower environmental costs in different agroecosystems, as supported by numerous studies with a comparable N regime [28–33]. The mixed and balanced organic and inorganic N supply promotes soil carbon sequestration in the rice–wheat rotation system [34], and considerably reduces N_2O emissions compared with inorganic N dominant treatment [35]. Therefore, the green food model may serve as a win–win strategy for sustainable environmental and economic development.

4. Major Challenges of the Green Food Industry

In spite of the considerable progress and environmental benefits, the cultivation area of green food has maintained a relatively low level (8.20% of the total arable land in China). More livestock, poultry, aquatic, and processed products are needed in order to meet the market demand. Making green food a stronger public brand is another challenge in the long run.

4.1. Unbalanced Development of Green Food

The green food industry needs to be well-structured in terms of food processing, food categories, and regional distribution. (i) As described in Section 2.3, primary agricultural products dominate green food production, and primarily processed and further-processed products account for only 25.5% of the overall green food products, which makes green food less value-added and favorable for producers. (ii) Crop products make up a particularly large proportion of green food, while products of an animal origin hold a proportion of only 7.6%, which weakens the competitiveness and profitability of the industry. Such a product structure cannot meet the food consumption pattern or nutrient requirements. (iii) Green food is more preferentially distributed in eastern China, although western China, rich in natural resources and ideal for green food production, is still relatively less developed. For instance, Xinjiang and Ningxia are major grape production regions in China both for fresh and wine-brewing grape under favorable environmental conditions. If production is properly upscaled with sequential processing and optimized logistic organization, green food boosts local economic development, improves employment and farmers' earnings.

4.2. Insufficient Technological Innovations

Technology plays a critical role in improving production efficiency and product values, reducing food waste, and promoting industry upgradation. Green food calls for new techniques for nutrient management, crop and animal management, disease control, food processing, cold storage, and waste recycling along the industry chain. Technological innovation also ensures food quality, helps nurture leading companies, and enables better marketing and advertising strategies, and also improves export competitiveness. To date, more than 60% of green food companies are small-sized producers with limited capabilities in terms of scientific and technical innovations. Underdevelopment of farmer training programs and a lack of awareness regarding the essence of green food production technology is one of the reasons for its low popularity among local growers.

4.3. Weak International Competitiveness

The overall competitiveness of the green food industry is still very weak and the trade levels are relatively low. The green food industry in China has achieved remarkable development; however, the total output of green food is still relatively low compared to the demand for safe agricultural products in both the international and domestic markets. The global consumption expenses for organic food in 2017 exceeded USD 69.8 billion [36], so it has a big sale potential in the international market. However, the export value of Chinese green food was only approximately USD 2.5 billion in 2017. Green food allows the use of chemical compositions in production and does not meet certain international standards. Insufficient product diversification and lack of processed products also are significant barriers facing green food exportation.

4.4. Consumer Mistrust, Awareness, and Higher Prices of Green Food Products

The demand for green food or organically produced food plays a central role in the successful proliferation of these industries. Apart from the abovementioned strict certification and quality maintenance standards (see Section 2.1. Administration, Standards, and Authorization of Green Food), Chinese and international consumers are very much concerned about food safety. There is a lot of consumer mistrust about the quality of labeled food and there is not enough awareness about the quality standards of the current green food; therefore, there are not many consumers who demand green food. The second, and one of the most important reasons, for the limited demand for green good is the price difference, as the price of green food-labeled products is comparatively higher than conventionally produced food. Therefore, developing domestic market and awareness programs regarding product quality standards is needed in order to build solid trust among consumers.

4.5. Inadequate Policy Support

Proper policies accelerate industry development, and the challenges facing green food indicate inadequate policies for further expansion of the industry. Less support from government and enterprises is another constraint for farmers, preventing them from shifting from intensive agriculture toward green food production technology. Often, policymakers find it difficult to encourage the development of the green food industry. Considerably less funding has been put toward the research and development of the green food industry, and this has resulted in a lack of dearth knowledge regarding this industry.

5. Way Forward

In order to tackle the above challenges, we propose the following strategies to boost the development of the green food industry.

5.1. Optimize the Industry Structure

Better regulations in order to optimize the industry structure are conductive to green food development. This could be achieved by optimizing the industry structure through strengthening the provision of livestock, poultry, and value-added products so as to meet the demands of different customer populations in domestic and international markets. Furthermore, attention should be paid to insects and aquatic organisms as green food which provide quality products with low impact on environment. Insects have promising potential to provide sustainable alternative source of proteins for humans and livestock. They utilize water and food more efficiently, with higher feed conversion rates and better growth efficiencies, compared to conventional livestock [37–39]. Additionally, insect-based diets aid in maintaining diversity of habitats for other beneficial organisms by reducing pesticide use. Similarly, seafood such as jellyfish can be further developed as another alternative source of protein having less carbohydrates and fats with lower environmental impacts [40–43]. In brief, to develop a regional industry with specific products and an industrial structure and to exert the superiority of resources are key for regional green food development.

5.2. Update Standards and Strengthen Technological Innovation

The standard system and related techniques need to be updated by: fostering cooperation with universities and research institutions, training farmers for knowledge and technology transfer, such as through farmer field schools and communication technologies, integrating industry expansion with quality improvement and attaching more technology to the development of green food, supporting leading enterprises so as to enhance the formation of green food industry groups, green food industry and government should be clearer about understanding the international quality standards, and should improve the output quality and export competitiveness.

5.3. Optimize Supply Chain Management

Creative management of a supply chain can be achieved in the context of green food development, which not only increases farmer and industry profits, but also creates environmental benefits. This can help to explore demand-related information sharing among supply chain actors, including farmers, enterprises, suppliers, and consumers to strengthen both the forward and backward supply chains from the industry, to characterize the food supply chains in connection with sustainable consumption and production, to strengthen integration of a dominant industrial chain, balance the development of primary, secondary, and tertiary industries and to ensure the efficient use of byproducts and rural waste.

5.4. Exploit the Brand Effect

Green food brand advantage is a major element in marking strategies. In order to improve competitiveness in domestic and international markets, the green food industry should carry out a prominent brand strategy to further exploit the brand effect by incubating leading companies, improving food quality, increasing public awareness, and establishing the trace system so as to enhance the brand value in a favorable social environment; distinguish the products' value of being "green, safe, and environmentally friendly" so as to improve consumers' quality trust, establish more marketing channels in order to cut down customers' perceived costs and strengthen the control of advertisements through the media.

5.5. Make More Supportive Policies

The success of encouraging green food industry initiatives profoundly depends on governmental policies. The Chinese government should make more favorable supportive policies, i.e., subsidies, tax deductions, reduced certification costs, and low-interest loans, so as to encourage more farmers and companies to produce environmentally friendly organic fertilizers, pesticides, and processed green foods. Special ecological subsidies may apply to green crop production for a reduction in chemical fertilizers and for increases in carbon sequestration. Significant tax deductions would encourage livestock, poultry, and aquatic production, food processing, and the full provision of organic fertilizers. Other supportive policies may enhance farmers' motivation to shift from conventional intensive agriculture to green food mode.

6. Potential and Large-Scale Impact of Green Food Farming Scenario

The potential larger-scale impact of the green food industry in China has been projected through a scenario analysis. For instance, the large-scale adaptation of the "Green Food Fertilizer Application Guideline," namely, reducing chemical N fertilizers by 50% so that the proportion of green food in China increases to 20%, would determine the potential N fertilizer and emission reduction. In this simulation, the chemical N fertilizer (N fer) input of conventional farming was based on a previous study—a database constructed by Zhang et al. from a national survey of 6.6 million producers covering 54 crops in China, representing >95% of the cropland of China, which were categorized into cereals (133 kg N/ha), fruits (429 kg N/ha), vegetables (275 kg N/ha), and others (132 kg N/ha) [44]. The reduction of N consumption was estimated based on reducing chemical N fertilizers by 50%

compared with conventional farming on the same cultivated area. The emission factors/models of nitrate (NO_3^-–N) leaching, ammonia (NH_3–N) volatilization, and nitrous oxide (N_2O–N) emissions were calculated using exponential or linear models developed by Wang et al. for wheat and maize [45], by Cui et al. for rice [46], and by Wang et al. for vegetables [47]. For fruits, it was assumed that they have similar N losses as vegetables.

Based on the scenario analysis, with the green food standard, chemical N fertilizer use would be reduced by 2.2. MT (1.33 MT for cereals, 0.24 MT for vegetables, 0.25 MT for fruits, and 0.34 MT for other crops; Figure 7). The estimated NH_3 emissions would be reduced by 0.17 MT, the N_2O emissions would be reduced by 0.01 MT, and NO_3^-–N leaching would be reduced by 0.14 MT. If the proposition of the green food industry reached the predicted 20%, chemical N fertilizer use would be reduced by 5.53 MT; the emissions of NH_3 and N_2O would be reduced by 0.40 MT and 0.03 MT, respectively; NO_3^-–N leaching would be reduced by 0.33 MT. The green food industry has the ability of achieving remarkable reductions in terms of chemical N use, and developing green food is an effective way to reduce the fertilizer N input and to decrease environmental pollution. Nevertheless, because nitrogen loss is only calculated by chemical N reduction, it is currently quite difficult to obtain the organic fertilizer information, which is also a major source of emissions, and needs greater investigation in order to support further analysis. In addition, future research needs to recognize the effects across the full food system in order to investigate green food industry effects, such as health, environmental, social, and economic effects.

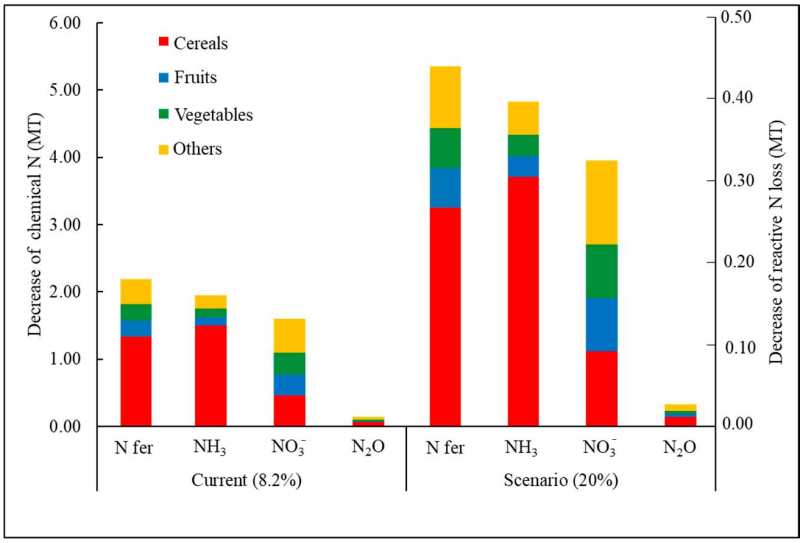


Figure 7. Achievable reduction in chemical N input (N fer), ammonia volatilization (NH_3), nitrate leaching (NO_3^-), and nitrous oxide emission (N_2O) if the proportion of green food in China increases to 20%.

While N fertilizer is excessively overused in China, sustainable agriculture has become a priority for China. China released the "action to achieve zero growth of chemical fertilizer use by 2020" policy in order to achieve zero growth for chemical fertilizer use for principal crops by 2020 [44]. By 2019, 83% of the provinces reached a negative three-year average annual growth of fertilizer use, showing the potential for successfully achieving this policy [48]. Nevertheless, China's agriculture still has a long way to go in facing the challenges of further enhancing agricultural productivity while minimizing environmental impacts. Green food is a sustainable and environmentally friendly approach, as its limited use of chemical inputs can considerably reduce environment-related concerns. Therefore, shifting from intensive conventional agriculture toward green food farming at a large scale is an effective way to realize sustainable development in China.

In addition to mitigation of environmental pollution, shifting from conventional to green food-like farming system has the potential to improve soil health by improving its physical, chemical and

biological properties [49–52]. Sustainable soil health depends on the application of carbon-rich amendments that support the biological processes, which are the central foundations of healthy soil. Additionally, systemic reduction of chemical nitrogen, according to the green food rule, prevents its overuse by small-hold farmers and better balances crop nutrition, improving the quality of agricultural commodities, i.e., increasing the sugar/acid ratio of apple and grape [23,53]. It helps prepare farms and people to be more resilient to climate change; primarily, the addition of organic fertilizers improves water use efficiency, consequently, resistance to risky weather, and ultimately lowers the chances of crop failure. Pesticides and heavy metals are also critical substances under regulation of green food, however, more data and field experiments are required for in-depth quantitative analysis in the future. In brief, large-scale expansion of green food farming has promising potential to produce safe and nutritious food, improve soil fertility and quality, and eventually uplift the living standard of people on a sustainable basis.

7. Conclusions

In sharp contrast to long-standing yield-centered production systems, green food, as a national program, has historically put a high priority on environment and food quality since early 1990s by stringent selection of arable land, dramatic cuts in chemical inputs, and a wide array of gradually-established detailed regulations of postharvest processes. After nearly 30 years' steady and rapid development, green food accounts for 8.2% of the total farmland area and 9.7% of the GDP from agriculture in China, signifying high efficiencies of existing regulations and broader practical applicability of current standards in the future. Here, for the first time, we systematically summarized its regulation, standards, achievements, environmental benefits, challenges, and future strategies.

Economic growth in China has averaged 9.5% over the past two decades and the country is currently experiencing rapid urbanization. More and more attention is being focused on environment- and health-related problems, and a healthy diet has become a new consumption trend, which conditions a much more favorable socioeconomic environment for green food. Increasingly strict environment protection policies further favors the implementation of green food standards. To meet the environment requirements and increase the food value, more non-green food farmers are willing to reduce chemical nitrogen fertilizers by 50% and properly utilize 131 kinds of pesticides out of 527 market available products. In the long run, green food represents a sustainable agricultural developmental model that can drastically reduce environmental costs, while increasing product value and producer profit. Optimizing the industry structure, upgrading standards and technologies, strengthening brand impact, and establishing supportive policies will boost green food growth in the future.

Supplementary Materials: The following are available online at http://www.mdpi.com/2077-0472/10/12/614/s1, Table S1: The complete list of green food certified by the China Green Food Development Center (CGFDC), Table S2: Comprehensive impacts of organic amendments with 50% reduction in chemical nitrogen fertilizers.

Author Contributions: Conceptualization, J.X. and X.L.; writing—original draft preparation, J.X.; writing—reviewing and editing, J.X., Z.Z., X.Z., M.I., J.Z., W.L., F.Z., and X.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: This work was supported by the China Green Food Development Center (GXTC-C-19050052).

Conflicts of Interest: The authors declare no conflict of interest.

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