International Food and Agribusiness Management Review
Volume 26, Issue 3, 2023; DOI: 10.22434/IFAMR2022.0090

Received: 2 August 2022 / Accepted: 21 December 2022

Special Issue: Agri-food systems transformation

Healthy diet and food system transformation in China

RESEARCH ARTICLE

Binjian Yan[ⓘa], Yiru Wang[b] and Yingheng Zhou[c]

[a]*Professor, College of Economics and Management, Nanjing Agricultural University, 1 Weigang, Nanjing, Jiangsu 210095, China P.R.*

[b]*Graduate student, Michigan State University Institute, Nanjing Agricultural University,1 Weigang, Nanjing, Jiangsu 210095, China P.R.*

[c]*Professor, School of Economics, Jiangxi University of Finance and Economics, 169 East Shuanggang Street, Nanjing, Qingshanhu 330044, China P.R.*

Abstract

The Chinese food system has expanded its focus from aiming to solve food problems to tackling current health and environmental issues. The Chinese diet has increased in quantity and improved in safety, but there is still room for improvement in terms of health and sustainability. This study used Chinese dietary data provided by the Global Diet Database to analyze the changes in China's dietary structure from 1990 to 2018 and highlight differences in urban and rural areas and across education levels. Findings show that the intake of food and beverage, macronutrients, and micronutrients in urban areas is higher than in rural areas. The difference in food and beverage intake between urban and rural areas is significant. The dietary gap between urban and rural areas has gradually widened. The difference in food and beverage and macronutrient intake across education levels is significant, but the difference in micronutrient intake is not significant. The gap in dietary structure across educational levels is relatively stable. These results indicate that the dietary structures of different groups in China are uncoordinated. We propose policies covering agricultural production, supply chain infrastructure, public institutions, education, and public awareness to build a sustainable food system with a healthy dietary pattern.

Keywords: food system, healthy diet, China
JEL code: I10

ⓘCorresponding author: yanbinjian@njau.edu.cn

1. Introduction

Food systems are critical for achieving healthy human nutrition and supporting environmental sustainability; however, current food systems pose challenges to both of these goals (Willett *et al.*, 2019). Diets are at the heart of food systems (GLOPAN, 2020). Brouwer (2021) points out the need to view food system transitions through the lens of healthy diets, ensures that food systems provide not only nutritious food, but also healthy, sustainable, and culturally compatible food that is affordable to consumers. Among food and land use system transitions, the return on investment from healthy diets is the highest, requiring a $30 billion investment by 2030, with $1.28 trillion in economic benefits and $2 trillion in business opportunities (The Food and Land Use Coalition, 2019). While healthy diets do not explicitly achieve sustainability, there is evidence that healthy diets do cause minimal environmental stress, while unhealthy diets based on processed foods and red meat have significant negative impacts on both health and the environment (Clark *et al.*, 2019). Therefore, the transition of dietary patterns to healthy diets is beneficial not only to health, but also to sustainable development.

Dietary patterns refer to the long-term dietary structure, eating habits, and consumption frequency of residents in a region, including the type, quantity, and proportion of food or the combination of different types of food and beverage. An unhealthy diet refers to a dietary structure with high consumption of processed meat, red meat, and sugary beverages, and low consumption of fruits, vegetables, whole grains, legumes, and nuts. There is no uniform standard for an ideal dietary structure, which is closely related to the natural environment, agricultural production characteristics, and social and cultural practices of the region. Dietary structures vary greatly by country. For example, the Mediterranean dietary structure has a low demand for red meat, the Nordic dietary structure values fresh food, and the dietary structure of West African countries has a high consumption of nuts.

Zhao *et al.* (2019) conclude that the dietary and nutritional status of Chinese residents has improved annually since the founding of China; in 1982, residents' cereal intake had reached the recommended standard and achieved the level of an energy-sufficient diet. From 1982 to 2012, the nutritional status of residents improved significantly. To investigate the changes in dietary structure and food system transformation of Chinese residents, this study used Chinese dietary data provided by the Global Dietary Database 2017 to analyze the changes in dietary structure in China from 1990 to 2018 and used *t*-test and one-way analysis of variance (ANOVA) to compare the differences in urban and rural areas and different education levels. The results of the analysis show that the changes in the Chinese dietary structure from 1990 to 2018 differed significantly between urban and rural areas and different education levels, with significant differences in the intake of food and beverage between urban and rural residents; there were also significant differences in the intake of food and beverage and macronutrients between residents with different education levels. The above research results tentatively indicate that there are problems of unbalanced overall structure and dietary structure among different groups of Chinese residents' diets, which requires the government and relevant departments to introduce policies to support healthy diets and educate and guide residents to choose healthy diets.

As a large country with a long history of traditional culture and food culture, China should choose a dietary structure that fits its own cultural tastes, so that Chinese consumers not only eat well, but also eat food that is healthy and tasty. To achieve this goal, this study proposes a Chinese food system policy support system oriented to a healthy diet. This food system policy support system covers four major areas, agricultural production, supply chain infrastructure development, public institutions, and education and public awareness, to alleviate the problem of unbalanced dietary structure of Chinese residents.

2. Literature review

2.1 Problems with current diets

The Food and Agriculture Organization of the United Nations states that three billion people worldwide cannot afford a healthy diet and that the cost of a healthy diet is, on average, five times higher than an energy-sufficient diet based on starchy staples, exceeding the international poverty line ($1.90/person/day) (FAO *et al.*, 2020). In 2019, a total of two billion people (25.9% of the total global population) faced hunger or lacked regular access to nutrition and adequate food. Globally, malnutrition, mortality, and morbidity from unhealthy diets have become the greatest challenges to global health (GBD 2017 Diet Collaborators, 2019). The 2021 Global Nutrition Report states that no continent has a diet that follows healthy dietary recommendations. In 2018, global consumption of fruits and vegetables was 48% below the recommended health standards, with Africa 59% below the recommended standard, Europe 41% below, and Asia 45% below. Global consumption of legumes was 74% below the recommended health standard, with Europe 86% lower, Latin America 52% lower, and Asia 74% lower. Global consumption of whole grains was 61% lower than the recommended health standard, of which, Latin America was 87% lower, Oceania was 41% lower, and Asia was 58% lower. Global fish consumption was 1% higher than the recommended health standard, with Europe 19% higher, North America 58% lower, and Asia 4% higher. Global dairy consumption was 20% lower than the recommended health standards, with Africa 62% lower, Asia 51% lower, and Europe 141% higher. Global red meat and processed meat consumption was 377% higher than the recommended standard, with Europe 790% higher, Africa 165% higher, and Asia 327% higher. The 2021 Global Nutrition Report shows that 29.9% (571 million) of women aged 15-49 are anemic and 22% (149 million) of children are stunted (Development Initiatives, 2021). At the same time, micronutrient deficiencies, overweight and obesity, and diet-related non-communicable diseases are increasing. Globally, 40% (2.2 billion people) of the adult population is overweight and, of these, 772 million are obese. Premature deaths caused by unhealthy diets have increased globally from just under 24% in 2010 to over 25% in 2018. The current food system puts enormous pressure on the Earth's environment (Rockstrom *et al.*, 2020). If current food consumption patterns continue, then there will be $1.3 trillion in health losses and $1.7 trillion in environmental losses per year (FAO *et al.*, 2020). Imamura *et al.* (2015) assessed dietary quality in 187 countries from 1990 to 2010 and found that dietary quality in high-income countries was improving and consumption of healthy foods was improving, while the quality of diets in some low-income countries in Asia and Africa was declining. In middle-income countries, the consumption of healthy and unhealthy foods was increasing simultaneously.

In China, high-calorie, low-nutrient foods are sought after due to the impact of Western and fast-food culture. Dietary imbalance is a major risk factor for the development of chronic diseases, and 3.1 million deaths among Chinese residents in 2017 can be attributed to a poor diet (Working Group of Scientific Report on Chinese Dietary Guidelines, 2021). High sodium intake, low fruit intake, and low aquatic intake are the top three causes of cardiovascular metabolic death. High oil and salt intake is still prevalent, and sugar-sweetened beverage consumption is increasing annually. Inadequate intake of whole grains, dark vegetables, fruits, dairy, fish, shrimp, and soybeans is the main reason for the high proportion of inadequate calcium intake among Chinese residents. Only one-fifth of adults consume 50 g of whole grains per day, only 30% of dark vegetables, less than 50% of the recommended intake, and only 55.7 g of fruit per capita in urban populations with higher incomes, far below the recommended level of 200 g, and 24.3 g fish and shrimp on average, with low consumption of soybeans (Development Initiatives, 2021). According to the 2021 Global Nutrition Report, China's consumption of whole grains, legumes, dairy products, nuts, and fruits is below the recommended health standards, by 95, 85, 75, 63 and 55%, respectively, while consumption of red meat and aquatic products is higher than the recommended health standards by 650 and 35%, respectively, and consumption of vegetables is generally consistent with the recommended health standards. China has anemia in 15.5% of women aged 15-49, which is lower than the global average, but still has room for decline. Five percent of infants are born at a low birth weight, 20.8% of infants aged 0-5 months are exclusively breastfed, and 8.5% of children under five years of age are obese. Eight percent of adult females and 7.7% of adult males are obese, with females below the East Asian average of 10.3% and males slightly above the

East Asian average of 7.5%. Approximately 8.6% of adult females and 12.4% of adult males have diabetes (FAO *et al*., 2020).

Although many countries have recognized the importance of healthy diets, their implementation varies widely. Wijesinha-Bettoni *et al.* (2021) analyzed the implementation of dietary guidelines in 27 countries and found that although many countries have an official body responsible for dietary guideline implementation, few have specific implementation plans and budget allocations, while even fewer collect monitoring and evaluation data.

2.2 Ideal healthy diet and food system

Since dietary structure varies greatly among countries around the world, many countries have issued targeted food and dietary guidelines based on the health status of their residents to guide them to eat properly. The food intake recommended by the dietary guidelines can be considered as the healthy dietary in line with the current reality of each country. The Dietary Guidelines for United States Residents (2020-2025) state that a healthy dietary pattern includes food and beverage with high nutrient density in each food group, with core elements including vegetables of all types, whole-fruit-based fruits, grains with at least half whole grains, fat-free or low-fat dairy products, lean meat, poultry, egg products, legumes, nut-based high-protein foods, vegetable oils, and oils from seafood and nuts. The scientific research report on dietary guidelines for Chinese residents (Chinese Nutrition Society, 2021) states that people who follow a balanced diet and maintain a botanical food-based diet with more vegetables and fruits, aquatic products, and dairy, moderate amounts of meat, poultry, and eggs, and a light and less oily dietary pattern can achieve better health benefits. This dietary pattern can reduce the incidence of diabetes, metabolic syndrome, breast cancer, coronary heart disease, and non-alcoholic fatty liver disease, as well as reducing all-cause mortality. The diet of the Jiangnan region in China, represented by Zhejiang, Shanghai, and Jiangsu, can be taken as a representative of the Eastern healthy dietary pattern, with rice as the main food, sufficient intake of fresh vegetables and fruits, animal food with pork, fish, and shrimp as the main food, and light cooking with less oil and salt. The dietary guidelines for Chinese residents (Chinese Nutrition Society, 2016) recommend a healthy dietary pattern suitable for Chinese people, proposing a variety of foods based on cereals, eating and moving in a balanced way, eating more vegetables, dairy and soybeans, fish, poultry, eggs, and lean meat in moderation, consuming less salt and oil, controlling sugar intake, limiting alcohol, shopping on demand, preparing meals on demand, sharing meals without waste, creating and supporting the social environment and conditions for a new style of diet, eating at home, and enjoying food. This will create and support the social environment and conditions for a new style of diet, eating at home, enjoying food, passing on a good food culture, and establishing a new style of healthy diet. The newly released Dietary guidelines for Chinese residents (Chinese Nutrition Society, 2022) based on the dietary pattern recommended by the Dietary guidelines for Chinese residents (Chinese Nutrition Society, 2016), proposes to reasonably match diverse foods, eat regularly, drink sufficient water, plan healthy meals in advance, learn to choose fresh and nutritious foods, and learn to reasonably choose pre-packaged foods through food labels. Herforth *et al.* (2019), through a comparative analysis of food dietary guidelines from 90 countries around the world, revealed both commonalities and differences between countries. Commonality is the encouragement of food consumption diversification, which encourages the consumption of starchy foods, fruits, vegetables, legumes, and animal foods and restricts the intake of sugar, fat, and salt; the difference is the large variation in the consumption of dairy products, red meat, fats, and nuts. This is also reflected in the recommended amounts of food intake for the world's major national and structurally healthy diets, as listed in Table 1.

A healthy dietary structure is crucial. It can be used to guide people to a rational diet, contribute to the design of policies to optimize diets, and help monitor the quality of individual or societal diets. However, it is difficult to determine a global healthy dietary structure. Different ages, sexes, health conditions, daily activity levels, and special conditions can affect nutrient requirements. A healthy dietary structure should contribute to health and be consistent with the dietary habits and social cultures of the local population.

Table 1. Dietary recommendations of major countries (Working Group of Scientific Report on Chinese Dietary Guidelines, 2021).

Food	China	Japan	India	United States	Britain	South Africa	Sweden
Whole grain	50-150 g	–	–	Not less than 48 g	–	–	Female: 70 g/d; Male: 90 g/d
Cereal and potato staples	250-400 g	200-280 g carbohydrate	–	170 g	–	–	–
Vegetables	300-500 g	350-420 g	>300 g	592 ml	>400 g	>400 g	500 g
Fruit	200-350 g	200g	100 g	473 ml			
Livestock and poultry	40-75 g	18-30 g protein	–	740 g/week	<70 g	<90 g	500 g/week
Eggs	40-50 g		3 /week		–	3-4 /week	–
Aquatic product	40-75 g		>100~200 g/week	226~283 g/week	280 g/week	160-270 g/week	2~3 times/ week
Soybeans and nuts	25-35 g		–	~142 g/week	–	–	A few tablespoons
Milk and products	300 g	200 ml	Not less than 250 ml	~710 ml	–	400~500 ml	–

2.3 The contribution of healthy diets to food system transformation

Franzo *et al.* (2020) summarized the drivers of food system transformation as globalization and trade, climate change, income increase and distribution, urbanization, demographic factors, political factors, and the sociocultural context. Recently, scholars and related institutions have increasingly focused on the contribution of healthy diets to food system transformation. Springmann *et al.* (2020) quantitatively compared food-based dietary guidelines (FBDGs) from 85 countries and found that most countries' FBDGs recommend that residents consume animal foods wisely, thereby improving their environmental sustainability. The Lancet Commission suggests that a healthy diet can lead to major transformations in the food system. The inclusion of healthy diets, consumer motivation, and food environment-related factors in food system transitions facilitates consumer access to sustainable, affordable, and culturally acceptable healthy diets (Brouwer *et al.*, 2021). Fanzo *et al.* (2020) constructed a food system framework that includes internal components and external drivers, stating that diets as a component of the food system, on the one hand, can directly influence nutritional and health outcomes and, on the other hand, can indirectly influence various parts of the food supply chain through social, economic, and environmental factors. The history of changes in the diet of the population, the growing body of research focused on human behavior, and the interactive collaboration of society, government, and business show the great feasibility of promoting food system transformation through healthy eating (Vermeulen *et al.*, 2020).

3. Changes in the dietary structure and food system transformation of the Chinese population

To explore the changes in the dietary structure of Chinese residents, this study used Chinese dietary data provided by the Global Dietary Database (GDD) to analyze the overall changes in the dietary structure of China from 1990 to 2018 and the differences between urban and rural areas, as well as among residents of different education levels. The GDD was constructed by the Global Nutrition and Policy Team of the Friedman School of Nutrition Science and Policy at Tufts University and is used to improve the health status of the global population by improving diets, measuring the dietary nutrient intake of different life course groups in different countries around the world, and assessing its impact on nutritional health. The GDD divides diets into three main categories: Food and beverage, micronutrients, and macronutrients. Table 2 shows the specific contents of the three dietary categories, while Table 3 distinguishes between healthy and unhealthy dietary elements.

Table 2. Specific classification of diets (Miller *et al.*, 2021).

	Food & Beverage	Macronutrients	Micronutrients
Categories	Fruits, non-starchy vegetables, potatoes, other starchy vegetables, beans, nuts and seeds, refined grains, whole grains, processed meat, fresh red meat, seafood, eggs, cheese, yogurt, sweetened beverages, fruit juices, coffee, tea, whole milk	Total carbohydrate, total protein, saturated fat, unsaturated fatty acids, total omega-6 fatty acids, seafood omega-3 fatty acids, plant omega-3 fatty acids, trans fatty acids, dietary cholesterol, dietary fiber, added sugar	Calcium, dietary sodium, iodine, iron, magnesium, potassium, selenium, vitamin A and supplements, vitamins B1, B2, B3, B6, B9, B12, C, D, E, zinc

Table 3. Healthy dietary elements and non-healthy dietary elements (Miller *et al.*, 2021).

	Healthy dietary elements	Non-healthy dietary elements
Categories	Fruits, vegetables, legumes, nuts and seeds, whole grains, seafood, fruit juices, unsaturated fatty acids, seafood omega-3 fatty acids, plant omega-3 fatty acids, dietary fiber, calcium, whole milk	Processed meat, unprocessed red meat, sugar-sweetened beverages, saturated fat, trans fatty acids, dietary cholesterol, sodium

3.1 Changes in the dietary structure of Chinese residents from 1990 to 2018

Table 4 presents the changes in food and beverage intake of Chinese residents from 1990 to 2018. Chinese residents had the largest intake of refined grains and this was essentially stable at 396 g/day from 1990 to 2018. Whole grain intake is very small and declined in 2018 compared to 1990. Fruit intake increased from 79.9 g/day in 1990 to 89.4 g/day in 2018, an increase of 11.9%. Fresh red meat increased from 27.5 g/day in 1990 to 110.8 g/day in 2018, an increase of 302.6%, while processed meat decreased from 5.0 g/day in 1990 to 4.8 g/day in 2018, a decrease of 2.8%. Seafood intake increased from 13.1 g/day in 1990 to 37.9 g/day in 2018, an increase of 189.4%. Whole milk increased more, from 9.0 g/day in 1990 to 35.3 g/day in 2018, an increase of 293.7%, and eggs increased from 8.8 g/day in 1990 to 37.5 g/day in 2018, an increase of 302.6%. While yogurt and cheese intake remained largely unchanged, beans also showed a slight decline, from 16.5 g/day in 1990 to 15.2 g/day in 2018. The intake of non-starchy vegetables and nuts and seeds showed larger growth rates, increasing by 1,061.8 and 1,246.3%, respectively. Potatoes as a starchy vegetable increased from 3.8 g/day in 1990 to 19.0 g/day in 2018, while the intake of other starchy vegetables decreased.

Overall, the dietary intake of Chinese residents was getting closer to the healthy dietary recommended by the dietary guidelines. However, there are still some categories of foods whose intake deviates from the healthy diet. Compared with the recommended dietary intake in China listed in Table 1, the vegetable intake of Chinese residents in 2018 (306.085 g/day) has met 300-500 g per day as recommended by the guidelines. The intake of eggs (37.547/g), seafood (37.927/g), and soybeans and nuts (24.553/g) in 2018 has not reached the recommended intake, but they were very close to the minimum recommended intakes (40, 40 and 25 g/day, respectively). The intake of milk and its products, whole grains, cereal and potato staples, fruits and livestock meat deviated from the recommended values. In 2018, the intake of milk and its products was only 43.981 g/day, much lower than the recommended value of 300 g/day. The intake of whole grains was 6.789 g/day, much lower than the recommended value of 50-150 g/day. The intake of cereal and potato staples was 39.743 g/day, far below the recommended minimum intake of 250 g/day. The intake of fruits was 89.412 g/day, far below the recommended intake of 300-500 g/day. However, the intake of livestock meat (115.664

Table 4. Food and beverage intake of the Chinese population in 1990 and 2018.

Food and beverage	1990	2018	Growth rate
Whole milk (g/day)	8.965	35.294	293.69%
Tea (8 oz/day)	0.525	1.129	115.05%
Coffee (8 oz/day)	0.297	0.372	25.25%
Fruit juice (g/day)	0.842	0.489	-41.92%
Sugar-sweetened beverages (g/day)	14.460	9.800	-32.23%
Yogurt (g/day)	6.941	6.977	0.52%
Cheese (g/day)	1.657	1.710	3.20%
Eggs (g/day)	8.772	37.547	328.03%
Seafood (g/day)	13.104	37.927	189.43%
Fresh red meat (g/day)	27.530	110.837	302.60%
Processed meat (g/day)	4.964	4.827	-2.76%
Whole grains (g/day)	9.417	6.789	-27.91%
Refined grains (g/day)	396.086	395.842	-0.06%
Nuts and seeds (g/day)	0.696	9.370	1,246.26%
Beans (g/day)	16.546	15.183	-8.24%
Other starchy vegetables (g/day)	32.526	20.705	-36.34%
Potatoes (g/day)	3.786	19.038	402.85%
Non-starchy vegetables (g/day)	26.346	306.085	1,061.79%
Fruit (g/day)	79.908	89.412	11.89%

g/day) was much higher than the recommended intake and almost three times the recommended minimum intake. From the inadequate dietary intake of in 1990 to the increasing approach to healthy dietary today, this may be closely related to the increasing income of Chinese residents, the popularity of supermarkets, and the increasingly improved logistics facilities. While it is not certain whether this represents an increase in the health awareness of Chinese residents.

The macronutrient intake of Chinese residents in 1990 and 2018 is shown in Table 5. In the dietary structure of Chinese residents, total carbohydrates accounted for the highest proportion of daily calorie intake, essentially stable at approximately 60% of daily calorie intake, but its proportion decreased slightly from 61.1% in 1990 to 59.9% in 2018. Both saturated fats and unsaturated fatty acids increased as a proportion of the daily calorie intake of the population to 10% and 8.8%, respectively. The proportion of trans fatty acids in the daily calorie intake of the population decreased from 5.8% in 1990 to 2.2% in 2018, a reduction of 61.2%. The share of added sugars in the daily calorie intake of the population decreased from 1.5% in 1990 to 0.6% in 2018, a decrease of 59.4%. Dietary fiber intake increased from 4.1 g/day in 1990 to 21.4 g/day in 2018, an increase of 416%. The total protein and dietary cholesterol intake increased by approximately 100% from 1990 to 2018.

The micronutrient intake of Chinese residents from 1990 to 2018 is shown in Table 6. Except for the intake of iron and vitamin E, the intake of other micronutrients by Chinese residents increased to differing degrees. The intake of selenium and vitamin B12 was stable, with an increase of no more than 5%. The intake of vitamin B6, vitamin B3, potassium, and magnesium was increased by approximately 1.0-1.5 times. The two micronutrients with the largest increase in intake were calcium and vitamin C. The intake of calcium by Chinese residents increased from 134.2 mg/day in 1990 to 424.8 mg/day in 2018, an increase of 216.5%; the intake of vitamin C increased from 23.6 mg/day in 1990 to 84.7 mg/day in 2018, an increase of 259.5%.

Table 5. Intake of macronutrients by Chinese residents in 1990 and 2018.

Macronutrients	1990	2018	Growth rate
Total carbohydrates (% of daily calorie intake)	61.082	59.943	-1.86%
Total protein (g/day)	34.673	71.709	106.82%
Saturated fat (% of daily calorie intake)	7.839	10.042	28.10%
Unsaturated fatty acids (% of daily calorie intake)	7.632	8.821	15.58%
Total omega-6 fatty acids (% of daily calorie intake)	2.866	2.931	2.27%
Seafood omega-3 fatty acids (mg/day)	9.697	67.974	600.98%
Plant omega-3 fatty acids (mg/day)	1,846.8	2,812.125	52.27%
Trans fatty acids (% of daily calorie intake)	5.782	2.246	-61.16%
Dietary cholesterol (mg/day)	132.353	270.178	104.13%
Dietary fiber (g/day)	4.148	21.404	416.01%
Added sugar (% of daily calorie intake)	1.498	0.609	-59.35%

Table 6. Micronutrient intake of Chinese residents in 1990 and 2018.

Micronutrient	1990	2018	Growth rate
Zinc (mg/day)	7.490	12.202	62.91%
Vitamin E (mg/day)	9.517	8.764	-7.91%
Vitamin D (μg/day)	2.276	4.414	93.94%
Vitamin C (mg/day)	23.568	84.721	259.47%
Vitamin B9 (μg/day)	180.537	342.352	89.63%
Vitamin B6 (mg/day)	0.609	1.529	151.07%
Vitamin B3 (mg/day)	7.819	18.656	138.60%
Vitamin B2 (mg/day)	1.025	1.371	33.76%
Vitamin B1 (mg/day)	0.974	1.144	17.45%
Vitamin A (mg/day)	372.374	509.272	36.76%
Selenium (μg/day)	110.304	113.097	2.53%
Potassium (mg/day)	1,596.326	3,356.769	110.28%
Magnesium (mg/day)	114.439	269.387	135.40%
Iron (mg/day)	17.167	12.096	-29.54%
Iodine (μg/day)	104.305	133.439	27.93%
Dietary sodium (mg/day)	3,260.301	4,000.467	22.70%
Calcium (mg/day)	134.226	424.795	216.48%
Vitamin B12 (μg/day)	3.195	3.364	5.29%

3.2 Changes in dietary structure of urban and rural residents in China from 1990 to 2018

Figure 1 and 2 present the data on the consumption of food and beverage by urban and rural residents from 1990 to 2018. Overall, except for coffee and non-starchy vegetables, urban residents consumed more food and beverage in all categories than rural residents. Among them, urban residents' consumption of fruit juice, nuts and seeds, yogurt, and whole milk was nearly 20% higher than that of rural residents. From 1990 to 2018, the direction and degree of change in the consumption of each category of food and beverage by urban and rural residents were similar. The consumption of coffee by urban residents increased by 26.46%, while the consumption of coffee by rural residents increased by 25.42%, which is slightly lower than that of urban residents. The increase in the consumption of eggs by urban residents (324.14%) was also slightly higher than that of rural residents (322.23%).

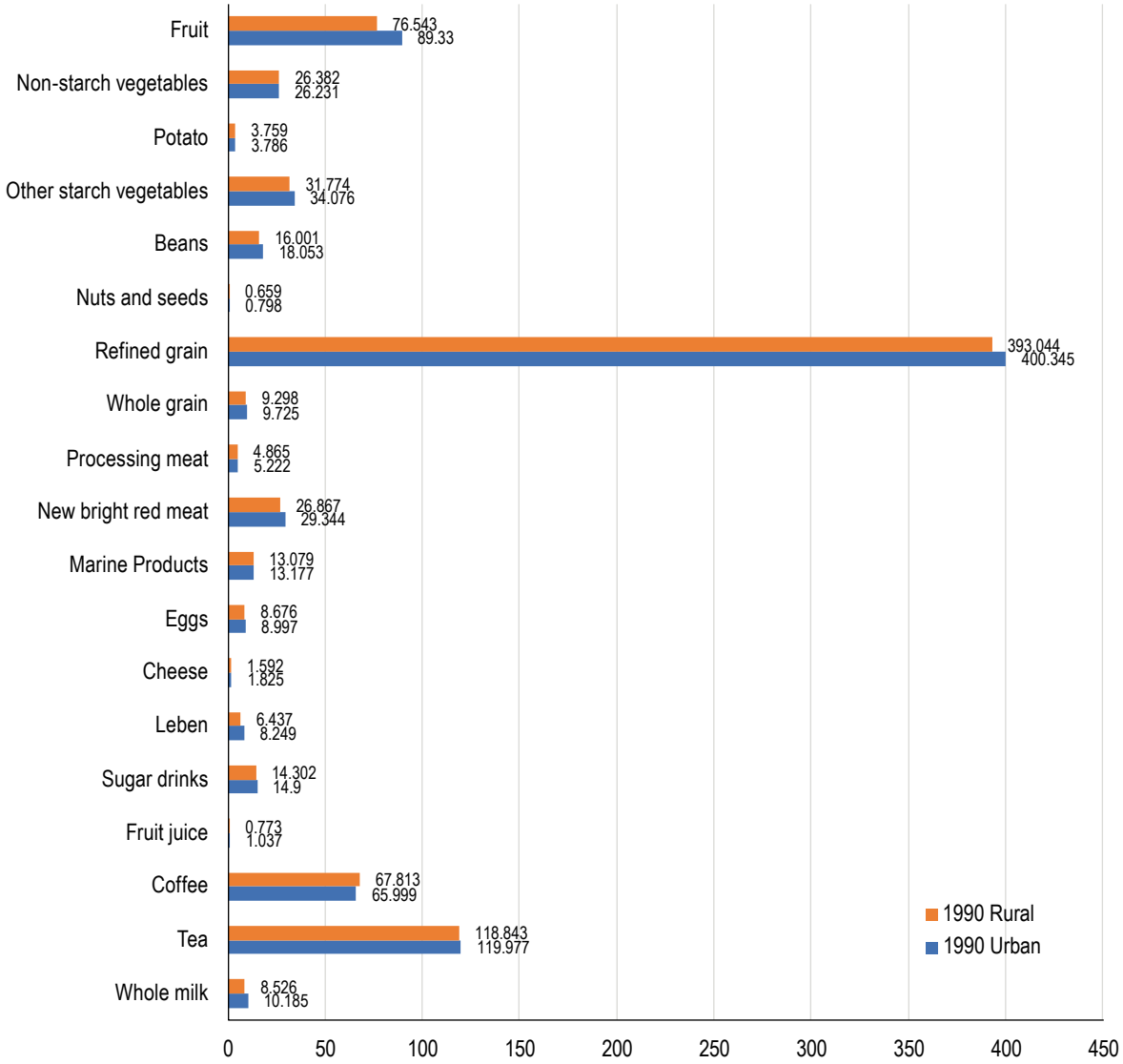

Figure 1. Comparison of the food and beverage intake of urban and rural residents in 1990.

By contrast, the consumption of nuts, seeds, and starchy vegetable potatoes by urban residents increased at a lower rate than that of rural residents. The decrease in the consumption of cheese and refined cereals was not entirely consistent between urban and rural residents. The consumption of cheese by urban residents decreased by 0.33%, while that of rural residents decreased by 1.89%; the consumption of refined cereals by urban residents decreased by 1.25%, while that of rural residents decreased by only 0.25%. From the ratio of urban and rural residents' consumption of various categories of food and beverage, it can be found that urban residents' intake of cheese, eggs, and other starchy vegetables further increased compared to rural residents. The ratio of urban and rural residents' cheese intake expanded from 1.146 in 1990 to 1.165 in 2018, the ratio of urban and rural residents' egg intake expanded from 1.037 in 1990 to 1.042 in 2018, and the ratio of urban and rural residents' intake of other starchy vegetables expanded from 1.072 in 1990 to 1.080 in 2018.

Comparing the dietary intakes of urban and rural residents in 2018 with the recommended dietary intakes of Chinese residents presented in Table 1, it was found that the dietary intakes of urban residents were more in line with the healthy diet. The daily intake of vegetables, soybeans and nuts for urban residents met the standards recommended by the dietary guidelines, but only the intake of vegetables for rural residents met the standards. For livestock meat, both urban and rural residents' intakes were higher than the recommended

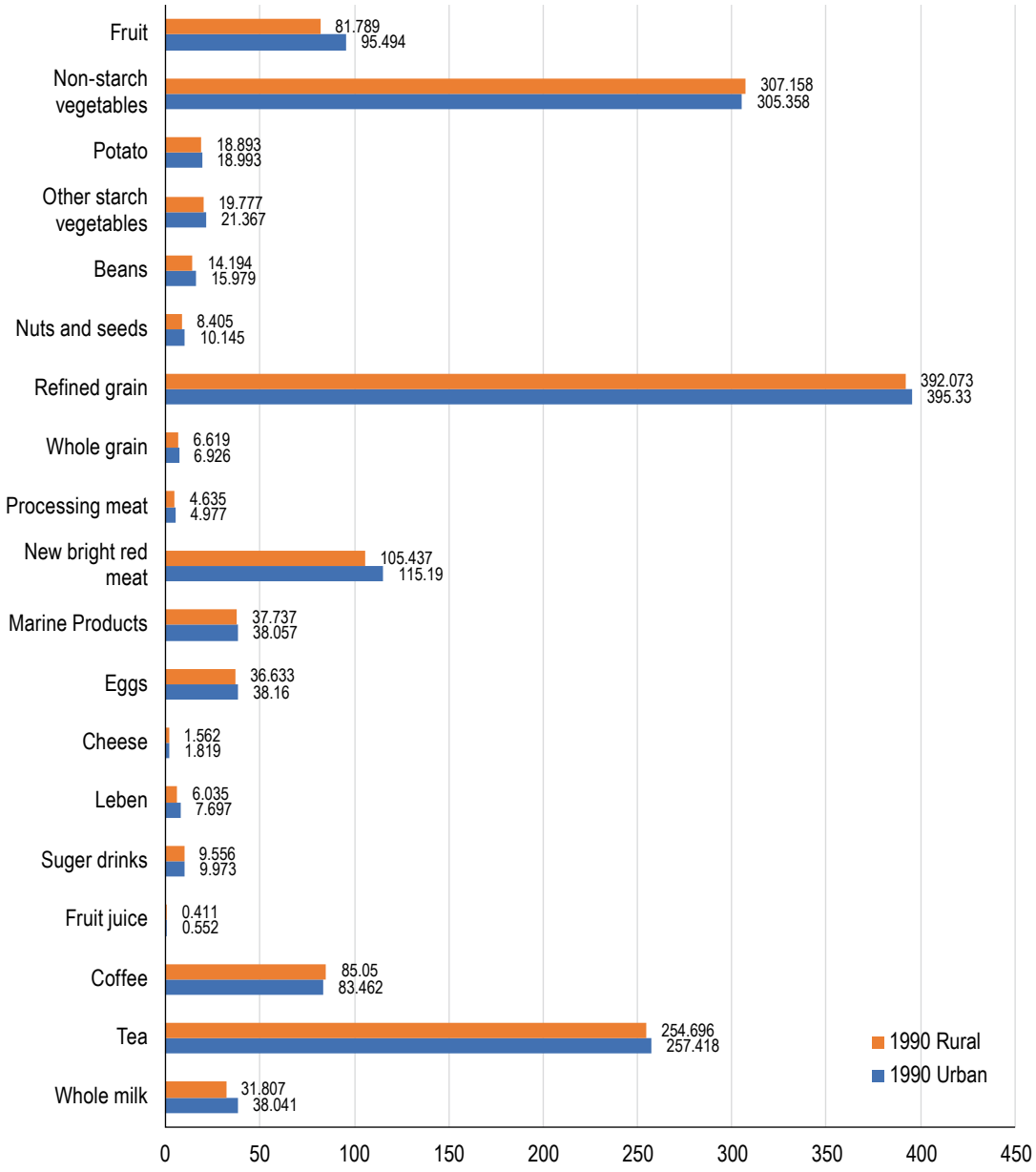

Figure 2. Comparison of the food and beverage intake of urban and rural residents in 2018.

intake range, and urban residents deviated more from the recommended intake. For whole grains, cereal and potato staples, fruits, eggs, seafoods, milk and milk products, the dietary intake of both urban and rural residents could not meet the minimum intake recommended by the dietary guidelines, but the gap between urban residents' intake and the recommended intake was smaller. The above comparisons show that urban residents' dietary intake is more in line with the healthy diet at this stage. This may be due to the higher income of urban residents, the greater variety of foods available in the local food systems and the greater convenience of food purchases. However, it is not reasonable to infer that this is due to urban residents being more health-conscious or aware of dietary health guidelines.

The intake of macronutrients by urban and rural residents from 1990 to 2018 is shown in Figure 3 and 4. Except for total carbohydrates and plant ω-3 fatty acids, urban residents had higher intake and intake ratios of other types of macronutrients than rural residents. The intake of seafood ω-3 fatty acids by urban residents was approximately 1.5 times higher than that of rural residents, and the proportion of added sugar in daily

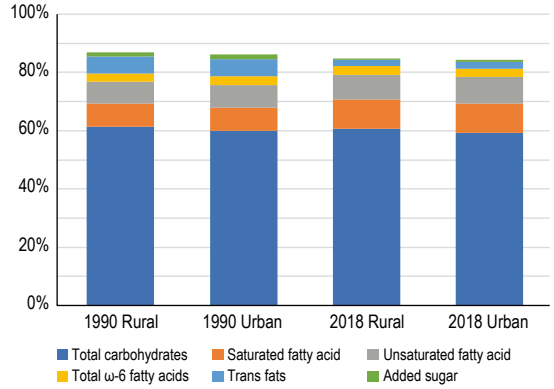

Figure 3. Proportion of constant elements intake of urban and rural residents from 1990 to 2018.

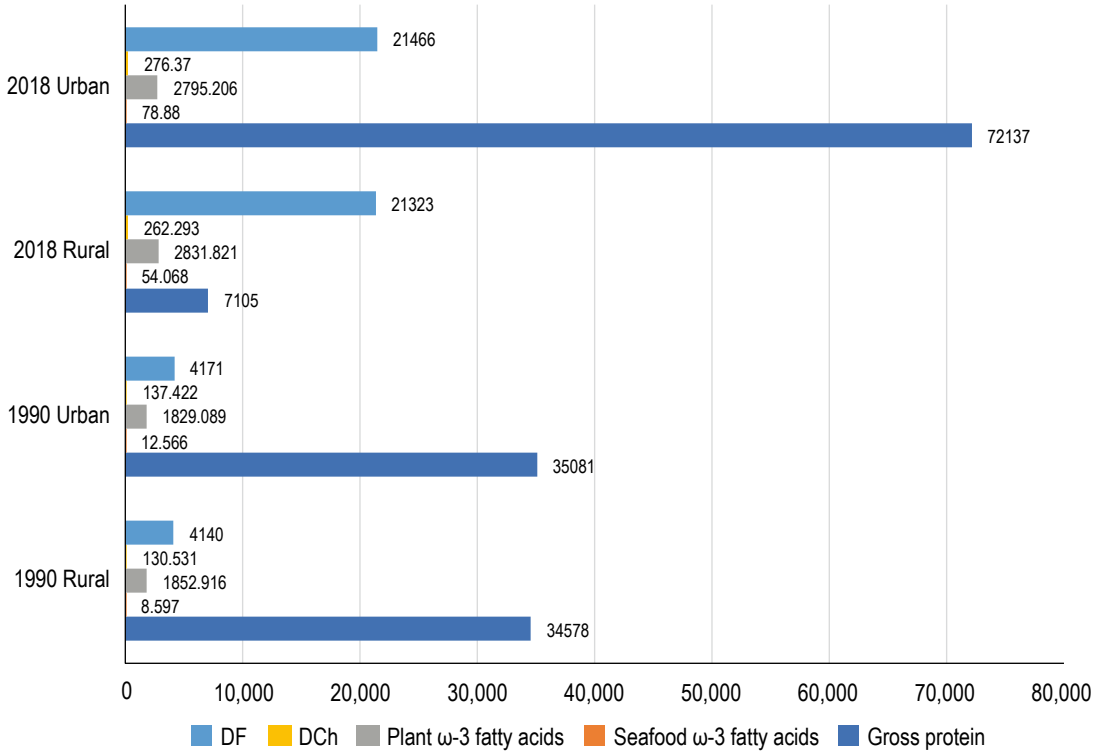

Figure 4. Constant elements intake of urban and rural residents in 1990 and 2018.

calorie intake was approximately 1.3 times higher than that of rural residents. From 1990 to 2018, the degree of change in the intake of various types of macronutrients by urban and rural residents was essentially the same; the proportion of total carbohydrates, trans fatty acids, and added sugar in the daily calorie intake structure of both types of residents decreased, while the proportion of other macronutrients increased. The proportion of trans fatty acids and added sugars decreased by more than 60%, and the proportion of total carbohydrates decreased by approximately 1.5%. From the ratios of various macronutrient intakes, it can be found that the gap between the daily calorie intake structure of urban and rural residents is further widened for unsaturated fatty acids, trans fatty acids, and added sugars. The urban-rural ratio of unsaturated fatty acid intake expanded from 1.032 in 1990 to 1.042 in 2018, the urban-rural ratio of trans fatty acid intake

expanded from 1.016 in 1990 to 1.051 in 2018, and the urban-rural ratio of added sugar intake expanded from 1.277 in 1990 to 1.307 in 2018.

Figure 5 shows the micronutrient intake of urban and rural residents from 1990 to 2018. Except for vitamin B6, dietary sodium, and selenium, urban residents' intake of other micronutrients was higher than that of rural residents. Among them, selenium intake of urban residents was slightly higher than that of rural residents in 1990 but slightly lower than that of rural residents in 2018, while that of urban residents was slightly lower than that of rural residents in 1990 but slightly higher than that of urban residents in 2018. Overall, from 1990 to 2018, the intake of all trace elements increased for both urban and rural residents, except for vitamin E and iron. Vitamin E intake decreased by nearly 10% and iron intake decreased by nearly 30%. The intake of vitamin C and calcium increased by nearly 2.5 times, and the intake of vitamin B6, vitamin B3, and magnesium increased by nearly 1.5 times. From the ratio of urban and rural residents of various types of micronutrient intake from 1990 to 2018, the ratio of micronutrient intake of urban and rural residents was found to not have changed much, except for vitamin B6 and calcium elements, and the gap between urban and rural residents on the intake of other trace elements shows a widening trend.

3.3 Changes in dietary structure of residents with different education levels in China from 1990 to 2018

Table 7 presents the intake of food and beverage among residents with different educational levels in China in 1990 and 2018. Overall, food consumption varied widely among residents with different education levels, with those with higher education levels consuming more food and beverage and less tea and refined grains. In terms of cereal consumption, the higher the level of education, the higher the consumption of whole grains, the lower the consumption of refined grains, and the healthier the food consumed. For processed red meat, consumption increased by approximately 20% for the higher level of education, while for fresh red meat, the medium level of education was 10% higher than the low level of education, and the high level of education was approximately the same as the medium level of education. In terms of beverage consumption, the higher the education level, the higher the consumption of coffee and fruit juice; the residents with high and medium education levels did not differ much in the consumption of sugar-sweetened beverages but consumed slightly higher amounts than residents with low education levels, and residents with high, medium, and low education levels did not differ much in the consumption of tea. The higher the education level, the higher the intake of whole milk, yogurt, and cheese. However, the difference in the consumption of cheese among residents with different education levels was not significant, and the difference in the consumption of whole milk and yogurt was greater. Residents with higher levels of education increased their consumption of whole milk by approximately 30% and their consumption of yogurt by about 40%. Comparing the ratio of food and beverage consumption among residents with different education levels in 1990 and 2018, we found that the ratios of food and beverage consumption of residents with high, middle, and low education levels remained essentially the same, but the ratio of refined cereals consumption of residents with high and middle education levels decreased from 1 to 0.95, indicating that the intake of refined cereals of residents with high education levels was less than that of residents with middle education levels.

Comparing the daily dietary intake of residents with the recommended intake, it can be found that the dietary intake of residents with high education level is the most consistent with the healthy diet, followed by residents with medium education level and the last is residents with low education level. The daily intake of vegetables, eggs, soybeans and nuts of the highly educated residents was within the recommended range. The gap between the dietary intakes of whole grains, cereals and potatoes, fruits and seafoods and the recommended value was the smallest, while the difference between the dietary intakes of livestock and meat and the recommended value was higher than that of the residents with medium and low education level. Residents with low education level, their daily dietary intake of all kinds of food deviates from the healthy diet, and the dietary structure is obviously unreasonable. The above comparison can reflect the influence of education on residents' dietary structure to a certain extent.

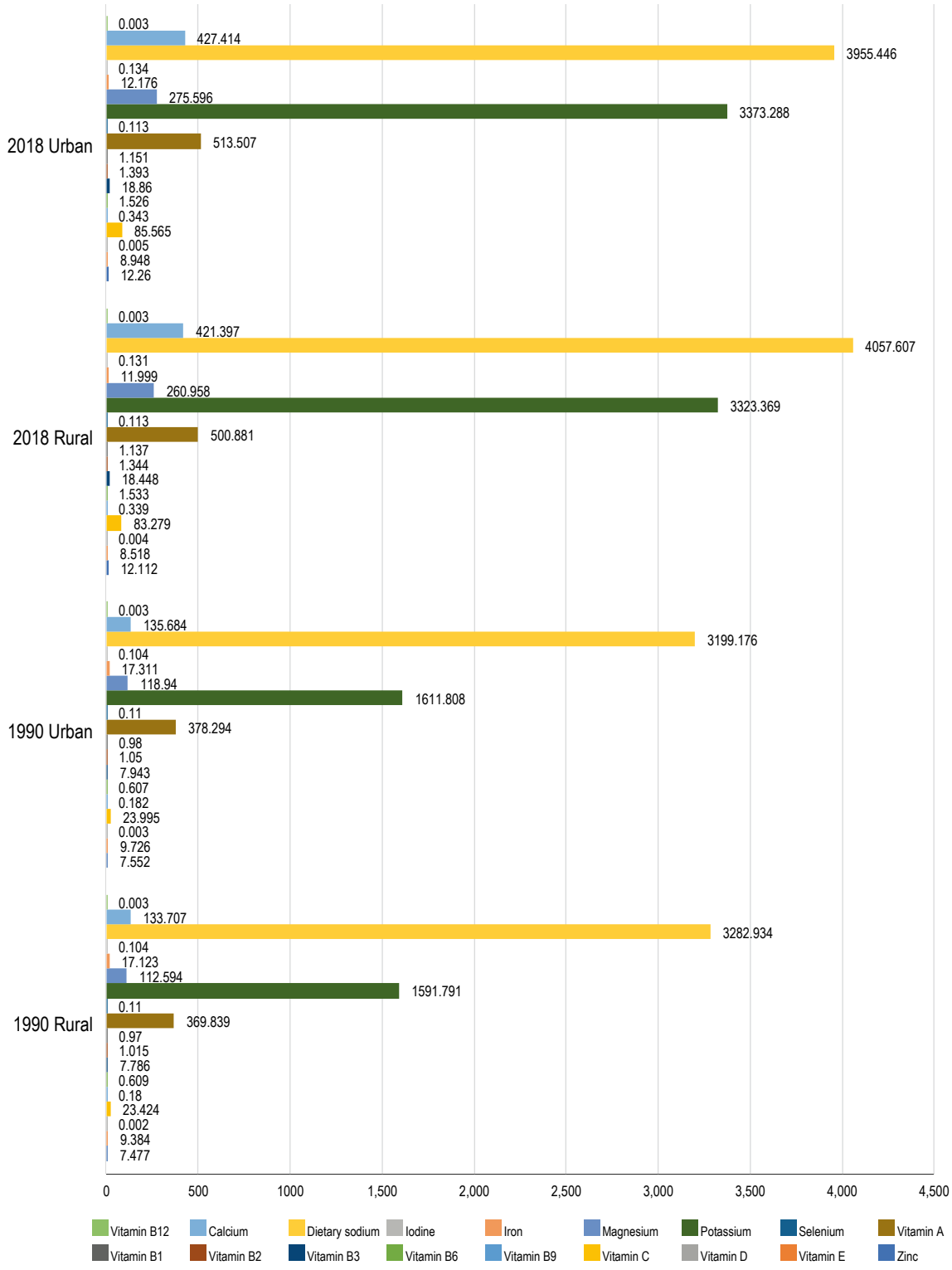

Figure 5. Intake of trace elements by urban and rural residents in 1990 and 2018.

Table 7. Food and beverage intake of residents with different education levels in China in 1990 and 2018.[1]

Food and beverage	1990 low	1990 medium	1990 high	2018 low	2018 medium	2018 high	1990 medium/ low	1990 high/ medium	2018 medium/ low	2018 high/ medium
Whole milk (g/day)	6.85	9.31	11.90	26.89	36.63	46.88	1.36	1.28	1.36	1.28
Tea (8 oz/day)	0.53	0.52	0.52	1.14	1.13	1.12	0.99	1.00	0.99	1.00
Coffee (8 oz/day)	0.26	0.31	0.32	0.33	0.39	0.41	1.17	1.05	1.17	1.05
Fruit juice (g/day)	0.60	0.87	1.20	0.35	0.50	0.70	1.44	1.39	1.45	1.39
Sugar-sweetened beverages (g/day)	12.86	15.41	15.31	8.71	10.43	10.37	1.20	0.99	1.20	0.99
Yogurt (g/day)	4.84	7.18	9.67	4.86	7.24	9.88	1.48	1.35	1.49	1.37
Cheese (g/day)	1.37	1.71	1.98	1.40	1.78	2.05	1.25	1.16	1.27	1.15
Eggs (g/day)	7.55	9.34	9.65	32.38	40.02	41.48	1.24	1.03	1.24	1.04
Seafood (g/day)	12.48	13.30	13.76	36.11	38.49	39.82	1.07	1.03	1.07	1.03
Fresh red meat (g/day)	25.80	28.40	28.76	103.81	114.36	115.89	1.10	1.01	1.10	1.01
Processed meat (g/day)	4.09	5.11	6.13	3.98	4.98	5.96	1.25	1.20	1.25	1.20
Whole grains (g/day)	8.78	9.66	10.02	6.33	6.97	7.22	1.10	1.04	1.10	1.04
Refined grains (g/day)	410.09	392.46	393.57	408.05	392.47	372.96	0.96	1.00	0.96	0.95
Nuts and seeds (g/day)	0.62	0.70	0.84	8.29	9.35	11.26	1.13	1.20	1.13	1.20
Beans (g/day)	16.18	16.62	16.97	14.83	15.26	15.58	1.03	1.02	1.03	1.02
Other starchy vegetables (g/day)	29.28	32.42	36.05	18.64	20.86	23.12	1.11	1.11	1.12	1.11
Potatoes (g/day)	3.34	3.91	4.15	16.89	19.66	20.80	1.17	1.06	1.16	1.06
Non-starchy vegetables (g/day)	25.10	26.73	27.74	291.74	310.61	322.38	1.06	1.04	1.06	1.04
Fruit (g/day)	64.14	82.94	100.87	71.78	92.75	112.94	1.29	1.22	1.29	1.22

[1] There are three types of education level: low (0-6 years of education), medium (6-12 years of education), and high (more than 12 years of education).

There was little difference in macronutrient intake among residents with different levels of education. As shown in Table 8, the higher the education level, the lower the proportion of total carbohydrates, and the higher the proportion of saturated and unsaturated fatty acids in the daily calorie intake of residents, the higher the daily intake of protein, seafood omega-3 fatty acids, and plant omega-3 fatty acids. From 1990 to 2018, the daily intake of protein and dietary cholesterol more than tripled and the daily intake of dietary fiber increased nearly five-fold among residents with high, medium, and low education levels, while the share of trans fatty acids and added sugars in daily calorie intake decreased by 50%, and the shares of saturated fat, unsaturated fatty acids, and total omega-6 fatty acids in residents' daily calorie intake increased slightly. The ratios of macronutrient intake among residents of different education levels showed that the gap between the intake of unsaturated fatty acids, trans fatty acids, and added sugars between residents of low and middle education levels tended to widen, while the ratios of other macronutrient intake remained the same. In particular, the share of total daily carbohydrates in daily calorie intake was lower among residents with low education levels than among residents with middle education levels in 1990, but higher than among residents with middle education levels by 2018. The gap in the intake of total carbohydrates, unsaturated fatty acids, and trans fatty acids between residents of middle and high education levels tended to widen, the gap in the intake of carbohydrates and seafood omega-3 fatty acids tended to narrow, and the intake ratio of other macronutrients remained unchanged. Overall, the carbohydrate intake ratios of the different groups showed large changes from 1990 to 2018, and the intake ratios of other macronutrients did not change significantly.

Micronutrient intake varied little among residents with different levels of education. The micronutrient intake of residents with low and high school education levels in China from 1990 to 2018 is shown in Table 9. Among all micronutrients, residents with high school and low education levels had the highest intake of

Table 8. Intake of macronutrients for residents with different education levels in China in 1990 and 2018.

Macronutrients	1990 low	1990 medium	1990 high	2018 low	2018 medium	2018 high	1990 mid/ low	1990 high/ mid	2018 mid/ low	2018 high/ mid
Total carbohydrates (% of daily calorie intake)	62.849	60.483	59.218	61.759	63.804	58.061	0.96	0.98	1.03	0.91
Total protein (g/day)	33.826	34.988	35.666	69.829	72.166	73.703	1.03	1.02	1.03	1.02
Saturated fat (% of daily calorie intake)	7.605	7.781	8.349	9.763	9.973	10.622	1.02	1.07	1.02	1.07
Unsaturated fatty acids (% of daily calorie intake)	7.202	7.713	8.148	8.291	8.940	9.533	1.07	1.06	1.08	1.07
Total omega-6 fatty acids (% of daily calorie intake)	2.864	2.854	2.892	2.930	2.919	2.958	1.00	1.01	1.00	1.01
Seafood omega-3 fatty acids (mg/day)	9.145	9.089	11.409	64.177	63.804	80.030	0.99	1.26	0.99	1.25
Plant omega-3 fatty acids (mg/day)	1,756.424	1,862.541	1,968.066	2,672.341	2,832.619	2,997.135	1.06	1.06	1.06	1.06
Trans fatty acids (% of daily calorie intake)	5.755	5.838	5.834	2.161	2.301	2.273	1.01	1.00	1.06	0.99
Dietary cholesterol (mg/day)	125.042	133.103	143.279	255.285	271.624	292.206	1.06	1.08	1.06	1.08
Dietary fiber (g/day)	4.105	4.077	4.350	21.171	21.041	22.450	0.99	1.07	0.99	1.07
Added sugar (% of daily calorie intake)	1.384	1.575	1.509	0.554	0.642	0.614	1.14	0.96	1.16	0.96

potassium and dietary sodium, exceeding 1,500 mg/day and 3,100 mg/day, respectively. Except for dietary sodium, the higher the education level of the residents, the higher the daily intake of micronutrients. From 1990 to 2018, the intake of vitamin E and iron by residents with high, medium, and low educational levels decreased, and the intake of other micronutrients increased to varying degrees. There was a small increase in the intake of zinc, selenium, iodine, vitamin B1, vitamin B2, vitamin B2, vitamin A, and dietary sodium, an approximate two-fold increase in the intake of vitamin D, vitamin B9, vitamin B6, vitamin B3, potassium, and magnesium, and a more than three-fold increase in the intake of vitamin C and calcium. The gap in the intake of vitamin E, vitamin B3, and iron widened. The difference in intake of micronutrients between middle and high education level residents was smaller overall; only the intake ratio of vitamin D was around 1.10, the difference in intake of vitamin D and selenium elements between middle and high education level residents showed a decreasing trend, and the difference in intake of vitamin C and iodine elements showed a widening trend.

4. Problems arising in the transformation of China's food system

To explore whether dietary nutrient intake was significantly different among different groups in China, a *t*-test analysis was used to compare the dietary structure of urban and rural residents in 1990 and 2018, and the specific results are shown in Table 10. For residents with different education levels, a one-way ANOVA was applied to compare the dietary structure of residents with high, medium, and low education levels in China from 1990 to 2020. The results are listed in Table 11.

The results in Table 10 indicate that the difference in food and beverage intake between urban and rural residents in China is significant at the 5% level, but the overall intake of constant elements and trace elements is not significant. The intake of food and beverage varies significantly between urban and rural residents, and the average food and beverage intake is higher than that of rural residents, indicating that urban residents can obtain and consume more food and beverage through the urban area food system. The *t*-test for all kinds of food and drinks found that the intake of whole milk, water juice, yogurt, cheese, eggs, new bright red meat, processed meat, nuts and seeds, non-potato starchy vegetables, and fruits was significantly different. On the

Table 9. Micronutrient intake of residents with different education levels in China in 1990 and 2018.

Micro- nutrient	1990 low	1990 medium	1990 high	2018 low	2018 medium	2018 high	1990 mid/ low	1990 high/ mid	2018 medium/ low	2018 high/ mid
Zinc (mg/day)	7.442	7.495	7.564	12.154	12.174	12.326	1.01	1.01	1.00	1.01
Vitamin E (mg/day)	9.373	9.484	9.517	8.636	8.806	8.834	1.01	1.00	1.02	1.00
Vitamin D (μg/day)	2.049	2.317	2.543	3.994	4.496	4.913	1.13	1.10	1.13	1.09
Vitamin C (mg/day)	22.035	23.861	25.320	79.504	85.653	91.234	1.08	1.06	1.08	1.07
Vitamin B9 (μg/day)	173.273	182.411	187.976	329.234	344.465	355.932	1.05	1.03	1.05	1.03
Vitamin B6 (mg/day)	0.599	0.608	0.622	1.507	1.530	1.561	1.02	1.02	1.02	1.02
Vitamin B3 (mg/day)	7.511	7.924	8.131	17.934	18.924	19.408	1.05	1.03	1.06	1.03
Vitamin B2 (mg/day)	0.963	1.040	1.098	1.290	1.392	1.470	1.08	1.06	1.08	1.06
Vitamin B1 (mg/day)	0.940	0.986	1.004	1.104	1.158	1.183	1.05	1.02	1.05	1.02
Vitamin A (mg/day)	343.324	385.343	395.274	471.451	520.937	539.120	1.12	1.03	1.10	1.03
Selenium (μg/day)	108.708	109.590	110.388	112.705	112.551	112.975	1.01	1.01	1.00	1.00
Potassium (mg/day)	1,539.259	1,609.732	1,660.454	3,238.217	3,391.148	3,486.536	1.05	1.03	1.05	1.03
Magnesium (mg/day)	111.822	114.112	117.659	264.291	269.135	278.372	1.02	1.03	1.02	1.03
Iron (mg/day)	16.714	17.347	17.528	11.721	12.273	12.409	1.04	1.01	1.05	1.01
Iodine (μg/day)	93.034	106.179	110.502	120.196	135.452	142.787	1.14	1.04	1.13	1.05
Dietary sodium (mg/day)	3,240.975	3,317.226	3,188.036	3,976.144	4,072.692	3,911.347	1.02	0.96	1.02	0.96
Calcium (mg/day)	127.325	134.979	144.321	403.149	427.285	456.756	1.06	1.07	1.06	1.07
Vitamin B12 (μg/day)	2.943	3.339	3.323	3.109	3.516	3.509	1.13	1.00	1.13	1.00

Table 10. Results of the *t*-test of dietary nutrient intake of urban and rural residents.

Variable name	Mean of town samples	Mean of rural samples	*t*-statistics	Two-tailed *P*-value
Food & beverage (g/day)	55.83	54.06	-2.64	0.01
Macroelement	269.59	270.28	0.09	0.93
Microelement	405.51	406.57	0.14	0.88

one hand, because cold chain transportation and storage in rural areas are not as popular as those developed in urban areas, fresh and perishable foods, such as whole milk, fruit juice, yogurt, cheese, eggs, fresh red meat, and processed meat are sold in rural areas. On the other hand, because nuts and seeds (such as walnuts, Hawaiian nuts, and hazelnuts) and non-potato starch vegetables (such as sweet potato, lotus root, and broad beans), food requires higher geographical conditions for planting, and the sale price is more expensive, so the consumption of these foods in rural areas is significantly lower than that of urban residents. The intake of constant elements and trace elements is not very different between urban and rural residents, which shows that although urban residents can obtain more food and drink from the food system in urban areas, they are not significantly different from rural residents in the intake of constant elements and trace elements through food and drink. This shows that urban and rural residents still lack awareness of choosing a healthy diet through the food system, and they also need to popularize the concept and awareness of a healthy diet.

The results in Table 11 indicate that the intake of food and beverage and constant elements varies, but that of trace elements does not. The intake of food, beverages, and constant elements increased in high, medium, and low education levels, the intake of trace elements between high and medium education levels was modest, but all were higher than that of the low education level. A one-way ANOVA for each category of food and beverage found significant differences in the choice of food and beverage type among residents of different educational levels, except for tea and beans. This difference suggests that education can significantly influence the dietary choices of residents. Trace element intake was not significantly different between urban

Table 11. Results of one-way ANOVA on dietary nutrition intake of residents with low education level.

Variable name	Mean			Source of variance	Quadratic sum	Free degree	Mean square	F	Prob>F
	low	middle	high						
Food & beverage (g/day)	52.52	55.25	56.93	interblock	207,433.56	2	103,716.78	14.21	0.0000
Macroelement	251.82	265.78	281.57	interblock	6,399,420.13	2	3,199,710.06	6.27	0.0019
Microelement	394.42	409.51	409.47	interblock	4,093,702.32	2	2,046,851.16	2.11	0.1206

and rural residents and residents with different levels of education, which may be due to the low resident intake of trace elements themselves; therefore, their intake did not differ significantly between the groups.

5. Policies for building a health-oriented Chinese food system

The food system should be oriented towards the transformation and upgrading of residents' food consumption structure and dietary pattern. However, there are some problems in China's food system such as unbalanced diet structure of urban and rural residents and unbalanced diet structure of residents among different education levels. On the one hand, these problems may be since the knowledge reserve and health awareness of the residents themselves are not enough to support them to choose a healthy and balanced diet. On the other hand, they may be since the production and processing of the food system in the area where the residents live have not been effectively connected with the healthy dietary patterns of the residents, and the residents lack of access to a healthy diet. To alleviate these problems and promote the transformation of China's food system from a dietary perspective, this paper proposes the following policy recommendations.

5.1 Policies in the field of agricultural production

Farmers should be supported to grow and sell nutritious food through agricultural extension programs, breeding programs, infrastructure provision, and technical training. The real income of agricultural producers who grow and sell nutritious food should be increased and production risks should be reduced by providing production subsidies, land titling, agricultural insurance, and regulatory protection, with special attention paid to women and low-income families. This would also encourage local processing and marketing of locally produced nutritious food to increase the availability of fresh and nutritious food to residents.

5.2 Policy in the field of supply chain infrastructure

Distribution networks, cold chain transportation, and warehousing should be expanded throughout the country to ensure that rural and urban residents can purchase nutritious food, especially non-refined foods, such as fresh food, with equal convenience. Digitalization should be strengthened, producers and consumers should be closely connected, a bridge should be built to connect dietary and food production structures, and customized production should be carried out to reduce waste and losses. A shared, whole-process database should be built to systematically monitor consumers' preferences and choices of nutritious foods and their nutritional status and targeted incentive policies should be formulated for nutritious food purchases.

5.3 Policy for public institutions

The increase in the number of young and middle-aged people working outside the home has stimulated demand for convenience foods, which has had a certain degree of impact on their health status. Simultaneously, school-age children and college students have had to obtain their three daily meals outside the home. Both

situations place demands on the supply of healthy food in public institutions, such as schools, company cafeterias, and supermarkets. Therefore, a comprehensive school food program should be implemented to ensure balanced nutrition in the daily meals of students in school. Simultaneously, subsidies for nutritious meals should be provided to public institutions to improve the supply of nutritious and fresh meals.

5.4 Education and public awareness

On the one hand, the government and related agencies should issue dietary guidelines on a regular basis, corresponding all food system policies and programs to the dietary guidelines, and communicating widely with the public. On the other hand, they should increase the promotion and guidance of healthy diets on social media and provide corresponding instructional courses in schools to ensure that residents of low, medium, and high education levels have the opportunity to be educated about healthy diets. It is recommended that whole life cycle food education is carried out, calling on all people to abandon unhealthy eating habits and to establish healthy diets.

Funding statement

Supported by the National Natural Science Foundation of China (71974097); Jiangsu Qinglan Project, Jiangsu the Priority Academic Program Development of Jiangsu Higher Education Institute (PAPD), Jin Shanbao Institute for Agriculture & Rural Development, Jiangsu Reserach Center for Agricultural Modernization.

References

Brouwer, I.D., M.J. van Liere, A. de Brauw, P. Dominguez-Salas, A. Herforth, G. Kennedy, C. Lachat, E.B. Omosa, E.F. Talsma, S. Vandevijvere, J. Fanzo, and M. Riel. 2021. Reverse thinking: taking a healthy diet perspective towards food systems transformations. *Food Security* 13(6): 1497-1523.

Chinese Nutrition Society. 2016. The dietary guidelines for Chinese residents. People's medical publishing house, BJ, China. (in Chinese)

Chinese Nutrition Society. 2022. The dietary guidelines for Chinese residents. People's medical publishing house, BJ, China. (in Chinese)

Chinese Nutrition Society. 2021. The scientific research report on dietary guidelines for Chinese residents. People's medical publishing house, BJ, China. (in Chinese)

Clark, M., M. Springmann, J. Hill, and D. Tilman. 2019. Multiple health and environmental impacts of foods. *Proceedings of the National Academy of Sciences of the USA* 116(46): 23357-23362.

Development Initiatives. 2021. 2021 Global Nutrition Report: the state of global nutrition. Available at: https://globalnutritionreport.org/reports/2021-global-nutrition-report.

Fanzo, J., L. Haddad, R. McLaren, Q. Marshall, C. Davis, A. Herforth, A. Jones, T. Beal, D. Tschirley, A. Bellows, L. Miachon, Y.X. Gu, M. Bloem, and A. Kapuria. 2020. The food systems dashboard is a new tool to inform better food policy. *Nature Food* 1(5): 243-246.

FAO, IFAD, UNICEF, WFP, WHO. 2020. The state of food security and nutrition in the world 2020. Transforming food systems for affordable health diets. Available at: https://doi.org/10.4060/ca9692en

GBD 2017 Diet Collaborators. 2019. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet* 393(10184): 1958-1972.

Global Dietary Database 2017: data availability and gaps on 54 major foods, beverages and nutrients among 5.6 million children and adults from 1220 surveys worldwide. *BMJ Global Health* 6(2): e003585.

GLOPAN. 2020. Future food system: for people, our planet, and prosperity. Global Panel on Agriculture and Food Systems for Nutrition.

Herforth, A., M. Arimond, C. Alvarez-Sanchez, J. Coates, K. Christianson, and E. Muehlhoff. 2019. A global review of food-based dietary guidelines. *Advances in Nutrition* 10(4): 590-606.

Imamura, F., R. Micha, S. Khatibzadeh, S. Fahimi, P.L. Shi, J. Powles, and D. Mozaffarian. 2015. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. *Lancet Global Health* 3(3): E132-E142.

Miller, V., G.M. Singh, J. Onopa, J. Reedy, P.L. Shi, J.Y. Zhang, A. Tahira, M.L.S. Morris, D.P. Marsden, S. Kranz, S. Stoyell, P. Webb, R. Micha, and D. Mozaffarian. 2021. Global Dietary Database 2017: data availability and gaps on 54 major foods, beverages and nutrients among 5.6 million children and adults from 1220 surveys worldwide. *BMJ Global Health* 6(2): e003585.

Springmann, M., L. Spajic, M.A. Clark, J. Poore, A. Herforth, P. Webb, M. Rayner, and P. Scarborough. 2020. The healthiness and sustainability of national and global food based dietary guidelines: modelling study. *BMJ* 370: m2322.

The Food and Land Use Coalition. 2019. Growing better: ten critical transitions to transform food use and land use. The global consultation report of the food and land use coalition. Available at: https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf.

Vermeulen, S., T. Park, C.K. Khoury, and C. Bene. 2020. Changing diets and the transformation of the global food system. *Annals of the New York Academy of Sciences* 1478(1): 3-17.

Wijesinha-Bettoni, R., A. Khosravi, A.I. Ramos, J. Sherman, Y. Hernandez-Garbanzo, V. Molina, M. Vargas, and F. Hachem. 2021. A snapshot of food-based dietary guidelines implementation in selected countries. *Global Food Security* 29 (Suppl. 2): 100533.

Willett, W., J. Rockstrom, B. Loken, M. Springmann, T. Lang, S. Vermeulen, T. Garnett, D. Tilman, F. DeClerck, A. Wood, M. Jonell, M. Clark, L.J. Gordon, J. Fanzo, C. Hawkes, R. Zurayk, J.A. Rivera, W. De Vries, L.M. Sibanda, A. Afshin, A. Chaudhary, M. Herrero, R. Agustina, F. Branca, A. Lartey, S.G. Fan, B. Crona, E. Fox, V. Bignet, M. Troell, T. Lindahl, S. Singh, S.E. Cornell, K.S. Reddy, S. Narain, S. Nishtar, and C.J.L. Murray. 2019. Food in the Anthropocene: the EAT-Lancet Commission on health diets from sustainable food systems. *The Lancet* 393(10170): 447-492.

Working Group of Scientific Report on Chinese Dietary Guidelines. 2021. Scientific research report on Chinese dietary guidelines, Chinese Nutrition Society. (in Chinese)

Zhao, L., Q. Guo, S. Li, W. Zhao, and G. Ding. 2019. Improving nutrition and health status of Chinese residents by strengthening nutrition survey and surveillance. *Health Research* 48(4): 517-520. (in Chinese)