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Dietary changes to mitigate climate change and benefit public health in China

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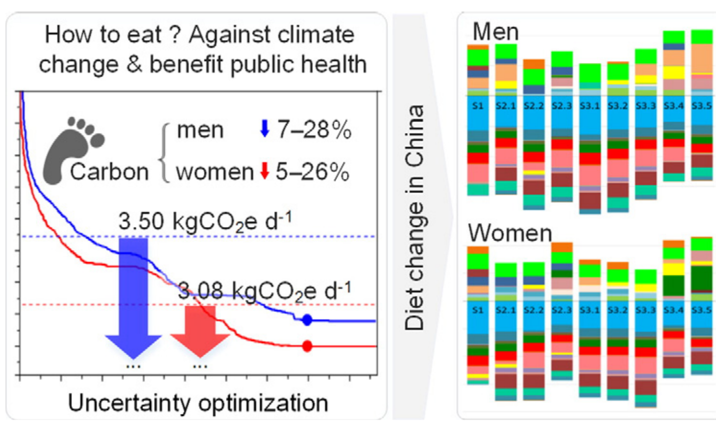
HIGHLIGHTS

- China faces dual challenges from climate change and a prevalence of non-communicable diseases.
- Nine diet scenarios from the latest National Program for Food and Nutrition were modeled.
- Diets lower the associated carbon footprint for women by 5–26% and for men by 7–28%.
- Diet change to benefit climate change mitigation and human health is possible in China.
- China's mitigation potential was compared with UK, France, Spain, Sweden, and New Zealand.

GRAPHICAL ABSTRACT



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ABSTRACT

Dietary change presents an opportunity to meet the dual challenges of non-communicable diseases and the effects of climate change in China. Based on a food survey and reviewed data sets, we linked nutrient composition and carbon footprint data by aggregating 1950 types of foods into 28 groups. Nine dietary scenarios for both men and women were modeled based on the current diet and latest National Program for Food and Nutrition. Linear uncertainty optimization was used to produce diets meeting the Chinese Dietary Reference Intakes for adults aged 18–50 years while minimizing carbon footprints. The theoretical optimal diet reduced daily footprints by 46%, but this diet was unrealistic due to limited food diversity. Constrained by acceptability, the optimal diet reduced the daily carbon footprints by 7–28%, from 3495 to 2517–3252 g CO_2e, for men and by 5–26%, from 3075 to 2280–2917 g CO_2e, for women. Dietary changes for adults are capable of benefiting China in terms of the considerable footprint reduction of 53–222 Mt. CO_2e year^{-1}, when magnified based on the Chinese population, which is the largest worldwide. Seven of eight scenarios showed that reductions in meat consumption resulted in greater reductions in greenhouse gas emissions. However, dramatic reductions in meat consumption may produce smaller reductions in emissions, as the consumption of other ingredients increases to compensate for the nutrients in meat. A trade-off between poultry and other meats (beef, pork, and lamb) is usually observed, and rice, which is a popular food in China, was the largest contributor to carbon footprint reductions. Our findings suggest

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that changing diets for climate change mitigation and human health is possible in China, though the per capital mitigation potential is slight lower than that in developed economies of France, Spain, Sweden, and New Zealand.

1. Introduction

Linking diet with human health and climate change has attracted considerable interest (Whitmee et al., 2015). The agricultural production of food to meet the requirements of human health is globally responsible for 19–35% of the anthropogenic emission of greenhouse gasses (GHGs) (Foley et al., 2011; Vermeulen et al., 2012). By summarizing strong empirical evidence, Tilman and Clark (2014) were the first to note that global agriculture, with changes in diets, could potentially reduce GHG emissions by 30–60% while lowering the rates of diabetes by 16–41%, cancer by 7–13%, and mortality from heart disease by 20–26%. Stehfest (2014) emphasized the profound significance of these findings due to the double benefits on health and the environment through dietary choices. Although the population only increased by 40% during 1979–2012, agricultural emissions in China doubled during the same period from 421 Mt. CO_2e to 835 Mt. CO_2e (FAO, 2012a), due to a large dietary shift to more animal-derived foods, which was driven by rapid urbanization and increased wealth (Lu et al., 2015). The consumption of pork, beef, poultry, and milk increased 3-, 10-, 11-, and 20-fold, respectively, between 1980 and 2009 (Huang et al., 2011), and the prevalence of diet-associated non-communicable diseases (NCDs) such as obesity, hypertension, and diabetes consequently placed an increasing burden on public health (Jaacks et al., 2015; Wang et al., 2014; Yang et al., 2008).

Obesity-associated NCDs have become common, but malnutrition ironically still occurs in China, as in most developed economies. Thus, the State Council of the Chinese government (2014), referring to the average per capita food consumption, issued the National Food-Nutrition Plan 2020 (NPFN 2020) to provide a rough sketch of health and food security by improving agricultural yield, but without mentioning the potential impact on GHG reduction from a sustainability perspective (Page A2 and Table A.1). As the largest emitter of GHGs, China has committed to lower its emissions per unit of gross domestic product by 40–45% by 2020 relative to the 2005 level and announced at the United Nations Climate Change Conference in Paris, 2015 (NDRC, 2015) that its emissions would peak before 2030. It also issued a national plan to combat climate change (NDRC, 2014). Diets higher in animal-derived foods generate larger carbon footprints along the entire food-provision chain, which will offset these ambitious mitigation efforts to some extent. Although Li et al. (2015) recently reported that both dietary and technological changes could alleviate GHG emissions from China's food chain based on scenario analysis, nutrient requirements for population health were not mentioned. Studies of dietary patterns in China are thus needed to find the double benefits for both GHG reduction and public health.

Achievement of these dual benefits is technically feasible. Methods such as environmentally extended input-output (IO) modelling (Hendrie et al., 2014), historical and scenario analyses (Meier and Christen, 2013), hybrid lifecycle assessment (LCA)-IO modelling (Hertwich, 2005; Pairotti et al., 2014), and linear and nonlinear optimization (Green et al., 2015; Macdiarmid et al., 2012; Thompson et al., 2013; Wilson et al., 2013) have illustrated that healthy diets can reduce GHG emissions. Although eating habits, dietary guidelines, food categorization, and data sources vary among countries, such as in the UK, France, Spain, Sweden, and New Zealand, healthy diets have common elements for mitigating climate change: all optimal diets have a tendency for lower meat consumption (by 12–60%), with a 59–60% reduction for a 36–40% reduction in GHG emissions in the UK (Green et al., 2015; Macdiarmid et al., 2012); most diets have a lower intake of dairy products, by 33% in Spain, 18% in Sweden, and 36–66% in the UK (Green et al., 2015; Milner et al., 2015; Thompson et al., 2013); and legume intake is usually higher, with a 50% increase in the UK and a 15-fold increase in France (Macdiarmid et al., 2012; Thompson et al., 2013).

Additionally, for the concept of a 'sustainable diet' as proposed by the Food and Agriculture Organization (FAO) of the United Nations (2012b), a series of recently released reviews demonstrate the key function of diet in linking human and planetary health (Auestad and Fulgoni, 2015; Hallström et al., 2015; Heller et al., 2013; Reynolds et al., 2014). China is experiencing large changes in its eating habits as well as rapid economic growth and has an opportunity to benefit both public health and GHG reduction. However, there is still a gap in awareness about the consequences of personal decisions regarding meeting personal nutrient requirements on overall GHG emissions and sustainability. Most people assume that their personal choices do not really matter, given the scope of the problem.

Our main objectives in this study were thus to quantify the carbon footprints embedded in food consumption for men and women aged 18–50 years based on data from a household survey and reviewed LCA studies; minimize GHG emissions (i.e., carbon footprints) using a method of uncertainty optimization while meeting health requirements, by developing dietary scenarios based on the NPFN 2020; and fill the knowledge gap in sustainable dietary changes, by comparing an optimal diet with current eating patterns.

2. Materials and methods

2.1. Food intake, nutrient, and carbon footprint data

Approximately 1.31 million records of food consumption were downloaded from the China Health and Nutrition Survey (CHNS, 2004, 2006, 2009, and 2011) database involving 11,160 respondents aged 18–50 years from 5253 households. Overall, 1950 kinds of foods are coded in the China Food Composition (CFC) tables (Yang, 2004; Yang et al., 2009), and the protein, fat, mineral, vitamin, saturated and unsaturated fatty acid, and energy contents are available to calculate nutrient intake. All food was aggregated into 28 groups based on the CFC (rice, wheat, maize, tubers and starch, biscuits, bread, sweets, other cereals, dumplings, legumes, beef, lamb, pork, poultry, other meats, eggs, milk, dairy products, yogurt, fish and shellfish, vegetables, fruits, vegetable oils, dried fruits, beverages, liquor, sugars, and others). The nutrient composition of each food group was averaged from the main uncooked or unprocessed food materials, and the minimum and maximum values were summarized from all food items in each food group to quantify the uncertainties. The detailed nutrient content of each food group is available in Table A.2 in the Appendix.

Carbon-footprint data for each food from an LCA perspective are unavailable in China. An innovative study by Tilman and Clark (2014) connected multi-source archives in which LCA studies of thousands of foods were unavailable, which was effective, although uncertainty remains (Stehfest, 2014). Thus, we accessed a global LCA literature database, the Double Food-Environmental Pyramid model supported by the Barilla Center for Food & Nutrition (BCFN, 2012), that contained 1237 reviewed LCA studies of food carbon footprints along with food supply chains including crop cultivation, breeding, industrial processes, transportation, and storage. The geographic distribution of this LCA-related literature varies considerably by continent (e.g., about 70% of studies estimated agricultural GHGs from Europe, 12% from America, 6% from Asia, 4% from Oceania, and 1% from Africa). All studies in the BCFN database were included to summarize the average, minimum, and maximum carbon footprints for each food group. A link was then created to