Changes in capacity of China's agriculture to feed its population

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In order to better understand whether China's agriculture can feed its population, and how much Chinese demand for food depends on the world, the changes in capacity of China's agriculture to feed the nation were explored. Moreover, the main food sources of energy and nutrients for the Chinese and the contribution of imported agricultural products were studied. The results show that for energy, self-sufficiency in cereals was achieved in 1970. Energy, protein, fat and superior protein provided by self-produced agricultural products could also meet the nation's demand since 1983, 1994, 1998 and 2002 respectively. Due to opening up, the supply of energy and nutrients increased and met the nation's demand ahead of time. Cereals have been the main source of energy and nutrients for the Chinese, but their importance has decreased. Energy and nutrients from vegetable products are substantial; however, the share of energy and nutrients from animal products has increased. The contribution rate of energy from imported products was low, but that of fat and superior protein increased rapidly and has been over the warning level of food security since 2000. Cereals, meats, eggs and vegetables, with a strong self-support capacity, are the most important food sources for the Chinese. It indicates that China has been depending on domestic production to meet its demand up to now. However, with growth in the population, optimization of nutritional structure and imbalance of the agriculture structure, the nation will have a great demand for the world's agricultural products.

Keywords: Demand, energy, food security, nutrients, supply.

THE foremost responsibility of China is to feed its more than one billion people. For this purpose, the Chinese Government has published a white paper on the food issue in China[1] and a national food security and long-term planning framework (2008–2020)[2] to highlight food safety issues. However, whether or not China's agriculture can feed its people has been a controversial issue for a long time, especially since Brown[3] putforth 'Who will feed China?' Many researchers have attempted to answer this question from different perspectives. For example, potential crop productivity and the influences of arable land loss on China's cereal security were studied from the perspective of agriculture production[4–7]. China's cereal demand was analysed from the perspective of food consumption as well as changes in nutrition and diet[8–11]. The nation's cereal demand and potential crop productivity were evaluated from the perspective of resource shortages and environmental damage due to population growth, economic development and urbanization[12–14]. Some researches discussed the self-sufficiency rate of a single agricultural product, such as corn, soybean, etc. from the perspective of trade[15,16]. However, such studies focused mainly on the single aspect of cereal security, not fully considering a substitution effect among different types of agricultural products. Furthermore, little information is available on the satisfaction level of the nation's demand for energy and nutrients provided by agricultural products and on the shares of energy and nutrients provided by various imported agricultural products.

The following points will help us to better understand China's conditions and to better answer Brown's question. First, cereal security does indeed relate to the national economy and livelihood of the people. However, according to the data of the Food and Agriculture Organization of the United Nations (FAO)[17], the trade amount of cereals in the international market is only half the cereal consumption in China; that is, cereal resources available for import to China are extremely limited. If China cannot depend on domestic production to guarantee basic self-sufficiency in cereals, it will affect not only its cereal security as well as national stability and development, but also the world's food security. It is worth mentioning that people need to consume a variety of agricultural products, and not only cereals, to keep healthy. In fact, the real need of people is the energy, protein, fat and other

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nutrients provided by food. As the basic function of agriculture is to feed people, to explore food security from the perspective of energy and nutrients is more in accordance with the requirements of agricultural production than simply from the perspective of specific agricultural products, such as cereals. Secondly, the main food sources of humans are agricultural products, due to their edibility. All kinds of agricultural products can provide energy and nutrients for the human body. Nevertheless, the quantity and quality of energy and nutrients contained in them are quite different. Therefore, when we explore the issue on food security, much attention should be paid to the supply of different kinds of agricultural products, not only cereals. Thirdly, whether food supply is sufficient depends not only on the ability of agricultural production, but also on population-based food consumption. Only by combining supply with population-based demand can it be correctly judged whether China's agriculture can feed its people. Therefore, food security should be measured by the capacity of agriculture to meet society's demand, which is measured by comparing the amount of energy and nutrients supplied from agricultural products with the demand of the total population for them in a certain period. Fourthly, in the era of economic globalization, it is no longer realistic to feed the nation depending solely on domestic agricultural production. International trade of agricultural products means use of resources worldwide, which should be considered in calculating the capacity of agriculture to feed a nation. It is equally important to understand the degree of dependence of agriculture of a country on foreign resources, which can use as a reference 'whether or not a country's agriculture is able to feed its nation depending solely on domestic resources'.

Based on the aforesaid points, this study aimed to (1) explore the capacity of China's agriculture supply to meet its demand and its change processes under self-sufficiency and open conditions from the perspective of combining supply with demand for energy and nutrients; (2) identify the main food sources from which energy and nutrients are obtained by the Chinese from the perspective of supply, and (3) measure the contribution rate of energy and nutrients provided by imported agricultural products from the perspective of supply.

Methodology and data preparation

Research framework

The question of whether or not China's agriculture can feed its people is studied from the perspective of combining the supply and demand for energy and nutrients. From the perspective of demand, the total population-based demand (D) for energy, protein and fat is calculated according to their dietary reference intakes. Meanwhile, from the perspective of supply, the total supply (Q) of energy, protein and fat is obtained by the sum of energy, protein and fat provided by various agricultural products. In order to understand the impacts of imports of agricultural products on the capacity of China's agriculture to feed its people, two scenarios, i.e. under self-sufficiency and open conditions, are assumed to calculate Q. By comparing D and Q, the capacity of China's agriculture to feed its people is investigated. By comparing open conditions with self-sufficiency conditions, the changes in capacity of China's agriculture to feed its people due to opening up are explored. By comparing the proportion of supply of specific agricultural products to the total supply, the main food sources of energy, protein and fat are inferred. To find out 'how much Chinese demand for food depends on the world's agricultural products', the contribution rate of energy and nutrients provide by imported various agricultural products (r) is measured. Figure 1 presents the research framework of this study.

Energy and nutrients demanded by the nation

The amount of energy and nutrients demanded by the nation was determined by population, gender and intake standards of various age groups. Figure 2 shows the Chinese dietary reference intakes recommended by the Chinese Nutrition Society[18]. It can be seen that demand for energy and nutrients differs in various age groups: adolescents aged 14–17 years have the greatest demand, followed by adults aged 18–59 years, the old aged 60 years and above, children aged 6–13 years and infants aged 0–5 years. Moreover, males demand more energy and nutrients than females in the same age group, and special populations, such as pregnant and lactating women, demand more energy and nutrients.

Cereals as a main source of energy cannot be completely substituted by vegetable oil, sugar and fruits. Therefore, there is a minimum requirement for the energy provided by cereals. To ensure a balanced nutrient level in diets, it is need to take into account of a reasonable collocation of animal foods and vegetable foods. In average daily per capita nutritional requirements, the General Office of the State Council of the People's Republic of China[19] suggested that the proportion of energy contributed by cereals should be not less than 50% and the percentage of superior protein from food higher than 45%. In this study superior protein is protein obtained from animal foods and some vegetable foods such as soybean, sesame, sunflower seeds, etc. Narrowing down the energy and protein in Figure 2 to 50% and 45% respectively, Chinese dietary reference intakes of energy from cereals and of superior protein were obtained.

Based on the data in Figure 2 and the Chinese census, the amount of energy and nutrients demanded by various age groups and genders can be calculated, and a demand structure of energy, protein and fat can be obtained in

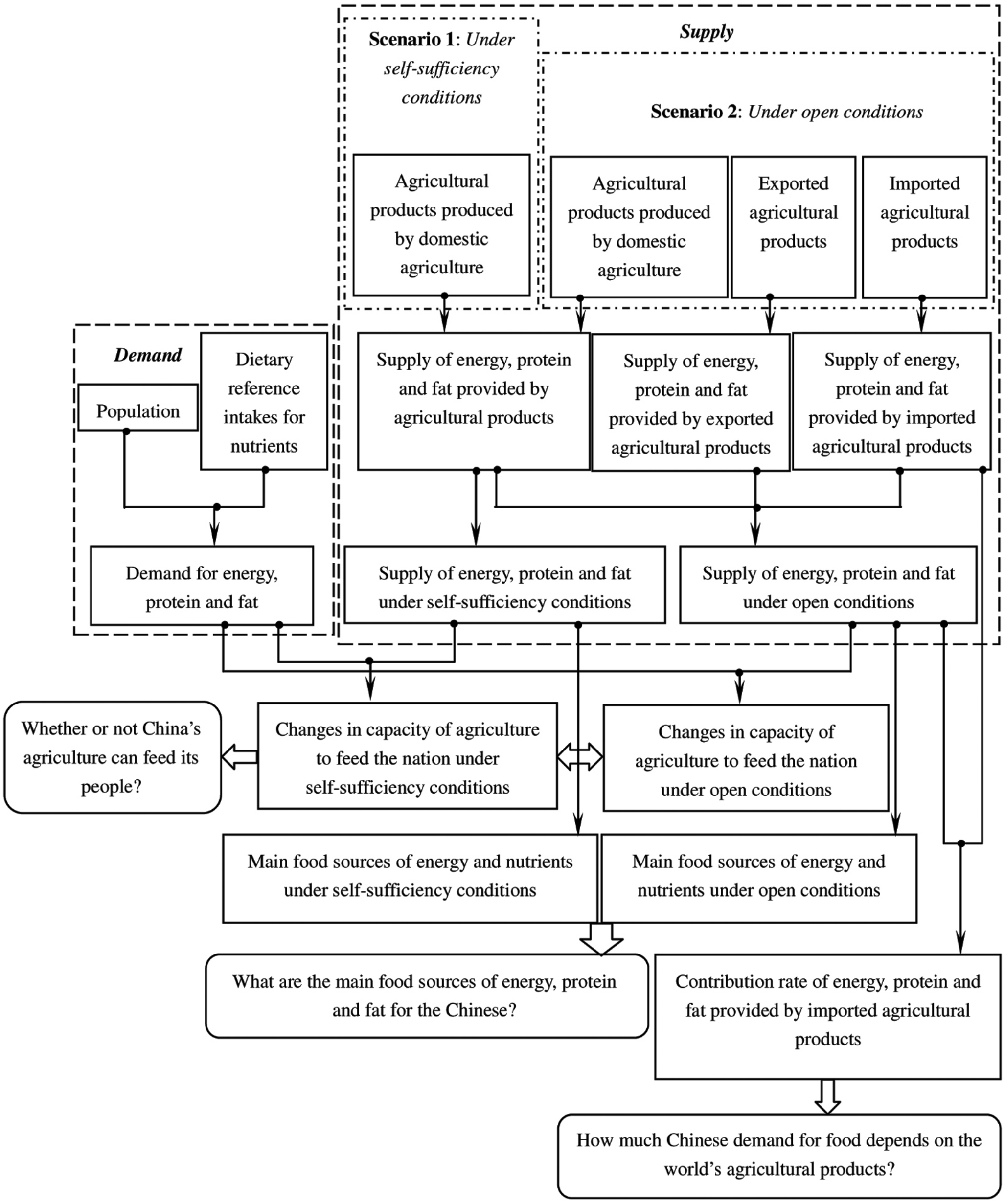

Figure 1. Research framework.

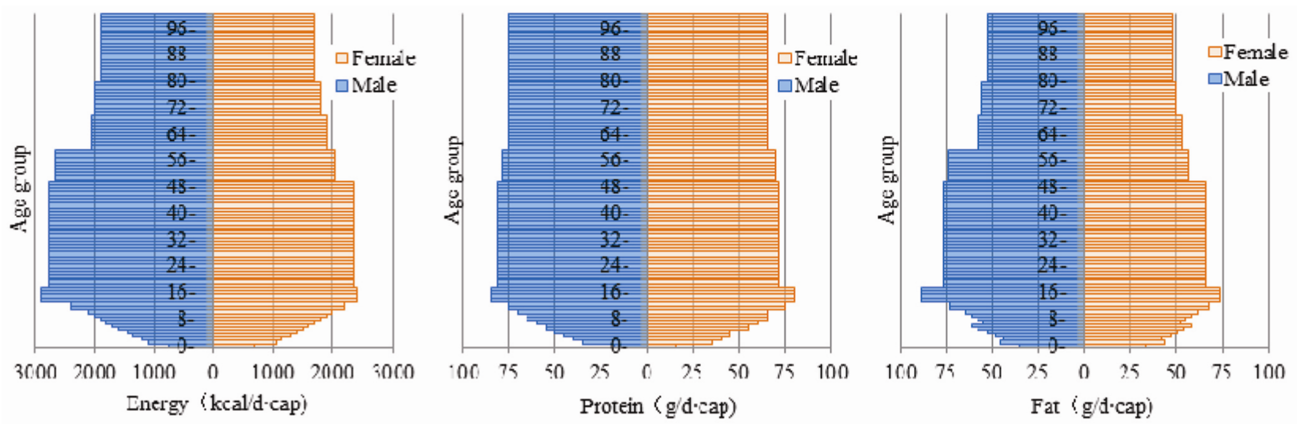

Figure 2. Dietary reference intakes recommended by the Chinese Nutrition Society.

several representative years. The total amount (D) of energy, protein and fat demanded by the nation in the corresponding year can be obtained by the sum of the demand of various age groups and genders.

Energy, protein and fat from agricultural products

Supply of agricultural products and amount used as food: Two scenarios are assumed to calculate supply of agricultural products.

Scenario 1: Neither imports nor exports, namely under self-sufficiency conditions

In this scenario, production of agricultural products depends completely on a country's own resources, neither using foreign agricultural products nor exporting its own agricultural products. Therefore, the supply of agricultural products (S_{Domestic}) in a country depends solely on domestic agricultural yield ($S_{\text{Production}}$) and stock change (S_{Stock})

$$S_{\text{Domestic}} = S_{\text{Production}} - S_{\text{Stock}}. \quad (1)$$

Scenario 2: Both imports and exports, namely under open conditions.

In this scenario, because of using foreign agricultural products and exporting its own agricultural products, the supply of agricultural products (S_{Supply}) in a country depends not only on S_{Domestic} but also on the amount of import (S_{Import}) and export (S_{Export}) of agricultural products

$$S_{\text{Supply}} = S_{\text{Domestic}} + S_{\text{Import}} - S_{\text{Export}}. \quad (2)$$

The amount of agricultural products directly used as food is not simply equal to the supply of agricultural products S_{Domestic} or S_{Supply} in a country, because agricultural products can be used not only directly as food, but also indirectly for agricultural production. The latter includes providing feed for the breeding industry (S_{Feed}), providing seed for reproduction (S_{Seed}), providing raw materials for food and industry processing (S_{Process}), waste and loss (S_{Waste}) in storage, transportation, processing and use, as well as other uses (S_{Other}). Therefore, the amount of agricultural products finally used as food (S_{Food}) is

$$S_{\text{Food}} = S_{\text{Domestic}} - S_{\text{Feed}} - S_{\text{Seed}} - S_{\text{Process}} - S_{\text{Waste}} - S_{\text{Other}}$$

or

$$S_{\text{Food}} = S_{\text{Supply}} - S_{\text{Feed}} - S_{\text{Seed}} - S_{\text{Process}} - S_{\text{Waste}} - S_{\text{Other}}. \quad (3)$$

Energy, protein and fat from food: In terms of quantity, energy and nutrients from various foods are complementary and can be substituted mutually, so the total energy or total nutrients from food is the sum of the energy or nutrients from each specific food

$$Q_{\text{e}}(t) = \sum e_k \cdot S_{\text{Food}\,k};\; Q_{\text{p}}(t) = \sum p_k \cdot S_{\text{Food}\,k};$$

$$Q_{\text{f}}(t) = \sum f_{\text{k}} \cdot S_{\text{Food}\,k}, \quad (4)$$

where $Q_{\text{e}}(t)$, $Q_{\text{p}}(t)$ and $Q_{\text{f}}(t)$ are the amount of the total energy, total protein and total fat from various foods in t year under self-sufficiency or open conditions respectively; $S_{\text{Food k}}$ is the amount of kth kind of agricultural product used as food; e_{k}, p_{k} and f_{k} are per unit of the kth kind of food containing energy, protein and fat respectively; their values are derived from Food and Agriculture Organization (FAO) of the United Nations[20]. Based on the FAO classification[17], in eq. (4), $k = 1$–11 indicates cereals (wheat, rice, barley, maize, rye, oats, millet, sorghum, etc.), starch roots (cassava, potatoes, sweet potatoes, etc.), sugar and sweeteners, pulses (beans, peas, etc.), tree nuts, oil crops (soybean, groundnut, sunflower seed, rape and mustard seed, sesame seed, etc.), vegetable oil, vegetables, fruits, stimulants (coffee, cocoa beans, tea), spices, alcoholic beverages, which are all vegetable foods; $k = 12$–18 indicates meat (mutton and goat meat, pig meat, poultry meat, etc.), offals, animal fats, eggs, milk, fish and seafood (freshwater fish, demersal fish, pelagic fish, marine fish, crustaceans, cephalopods, molluscs, etc.), and other aquatic products, which are all animal foods.

Comparison of supply and demand for energy and nutrients as well as their main food sources

$Q < D$ indicates supply being insufficient and $Q > D$ indicates supply being surplus.

The main food sources of energy, protein and fat are inferred according to the proportion of energy, protein and fat from various agricultural products to total energy, protein and fat from all agricultural products.

Contribution rate of energy, protein and fat provided by imported agricultural products

In this study, contribution rate (r) of energy, protein and fat provided by imported agricultural products is defined as the ratio of the amount of energy, protein and fat from imported agricultural products ($\sum \beta_k \cdot S_{\text{Import}\,k}$) to the total amount of energy, protein and fat from all agricultural products under open conditions ($\sum \beta_k \cdot S_{\text{Supply}\,k}$) in a country. That is,

$$r = \left[\sum \beta_k \cdot S_{\text{Import}\,k} / \sum \beta_k \cdot S_{\text{Supply}\,k} \right] \times 100\%, \quad (5)$$

where S_{Import} and S_{Supply} are the same as in eq. (2). While calculating the contribution rate of energy (r_{e}), protein

(r_p) and fat (r_f) provided by imported agricultural products, the parameter β_k in eq. (5) is replaced by e_k, p_k and f_k in eq. (4) respectively.

From the perspective of supply, r can be used as an index to judge whether or not agricultural resources in a country are rich and also the open level of a country's agriculture. If $r \leq 10\%$, it indicates a stronger self-sufficiency capacity of a country's agriculture.

Equation (5) can also be used to calculate the contribution rate of energy, protein and fat provided by a specific-type of imported agricultural product, which is defined as the proportion of energy, protein and fat from a specific type of imported agricultural product to the total energy, protein and fat from the type of agricultural product in a country.

Data sources

Based on the census data for China in 1964, 1982, 1990, 2000, 2010 and the FAO data, total population, population by age and gender[21–24], the amount of various agricultural products, imports, exports, storage, etc. (i.e. e_k, p_k and f_k in eq. (4))[17], as well as the component contents of nutrients in foods[20] were obtained. The goals for nutritional intake were obtained from the China Food and Nutrition Development Outline (2014–20)[19] and dietary reference intakes for nutrients by age and gender recommended by the Chinese Nutrition Society[18].

Results and discussion

Chinese population and the amount of energy and nutrients demanded by the nation

Figure 3 shows the total population and natural population growth rate in China. In the past 50 years, total population in China had been increasing. In 1964, the birth rate and natural growth rate were 39.14‰ and 27.64‰ respectively; with the family planning policy in place, in 2010, they fell to 11.90‰ and 4.79‰ respectively. During 1964–82, 1983–90, 1991–2000 and 2001–10, the annual average natural population growth rates were 20.54‰, 15.01‰, 10.06‰ and 5.50‰ respectively.

Figure 4 shows the population structure in China. For many years the proportion of population of the younger age group aged, i.e. 0–13 years, located in the bottom part of the population pyramid, decreased. At the same time, the proportion of population aged 14–59 years, located in the middle part of the population pyramid, increased. In 1964, 1982, 1990, 2000 and 2010, the proportion of population of the former was 38.26%, 31.15%, 25.88%, 21.03% and 15.41% respectively, and of latter 55.37%, 61.22%, 65.55%, 68.51% and 71.26% respectively.

Based on Figures 2 and 4, the amount of energy and nutrients demanded by various age groups and genders was calculated during several years for which census data were available. Thus the demand structure of energy, protein and fat and the total demand for them in the corresponding years were obtained (Figure 5).

As shown in Figure 5, in 1964 the bottom part of the demand structure of energy and nutrients was large; in 2010, the middle part was large and the top and bottom parts were small, which was consistent with the patterns of the population structure and their changes.

Energy and nutrients from China's agricultural products

Equations (1)–(4) were used to calculate the amount of energy, protein and fat from food in several representative years under self-sufficiency and open conditions. Table 1 shows the results.

Comparison of supply and demand of energy and nutrients

The capacity of China's agriculture supply to meet its demand was explored by comparing the data in Table 1 and Figure 5 as well as the continuous data for many years (Q and D). Under self-sufficiency conditions, $Q < D$ indicated that the nation had to survive at a lower nutrition level for a long time. With population growth and improvement in living standards, China's agriculture was not able to supply the energy and nutrients demanded by its people according to the related standards during this period. Until 1970, energy from cereals produced by China's domestic agriculture was able to meet domestic demand, i.e. $Q_{ec0} > D_{ec}$. Since 1983, the total energy from agricultural products produced by China's domestic agriculture was also able to meet domestic demand, i.e. $Q_{e0} > D_e$. Since 1994, 2002 and 1998, the protein, superior protein and fat produced by China's domestic agriculture have also been able to meet its demand according to the related standards, i.e. $Q_{p0} > D_p$, $Q_{ps0} > D_{ps}$ and $Q_{f0} > D_f$ and there was a surplus.

Under open conditions the supply of energy from cereals, total energy, protein, superior protein and fat from food had increased in most years. Table 2 lists the annual average growth rates of energy and nutrients in several representative periods. As shown in the table, the annual average growth rates of energy from cereals and food decreased continually, but those of protein and superior protein increased rapidly before 2000 and then decreased, while that of fat dropped after 1990.

Due to opening up to the outside world, the amount of energy, protein and fat from food in China obviously increased, especially since 1997, and because the main agricultural products were net exports during 1964–1996, the domestic supply of superior protein increased rapidly until 1997. Compared with those under self-sufficiency

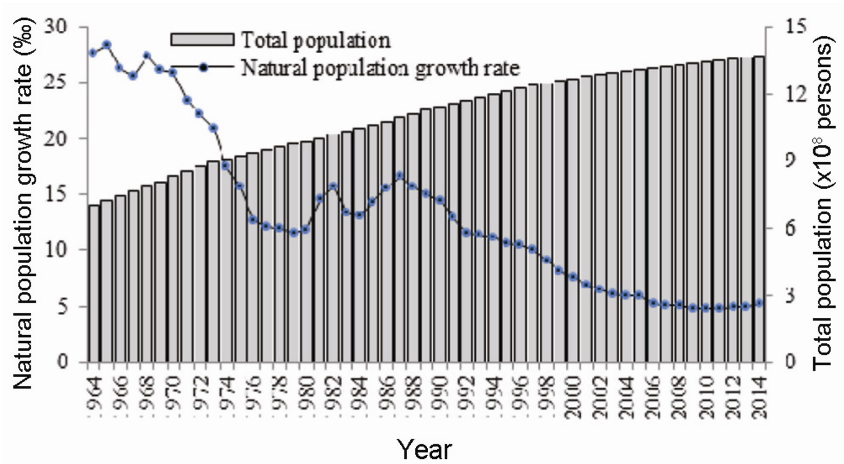

Figure 3. Total population and natural population growth rate in China.

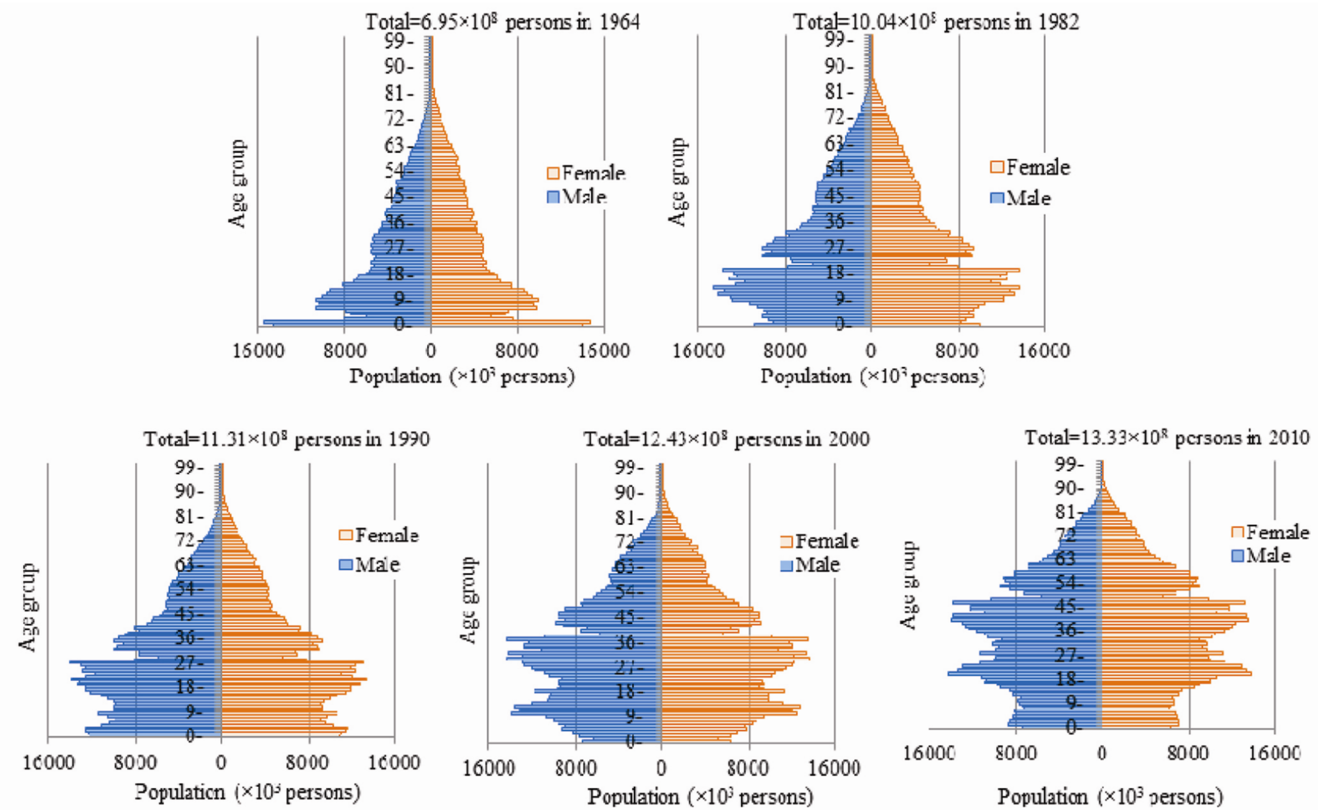

Figure 4. Population structure in China.

conditions, the growth rates of energy, protein, superior protein and fat under open conditions in 1997 were 1.83%, 0.88%, 1.14% and 5.68%, and in 2013 were 5.59%, 4.54%, 8.04% and 11.45% respectively. In contrast, the growth rates of energy from cereals continually decreased after opening up to the world.

Comparing open conditions with self-sufficiency conditions, energy from cereals and energy, superior protein and fat from food met the nation's demand according to the related standards 4 years, 1 year, 2 years and 1 year ahead of time respectively. During 1964–1996, although the supply of protein increased due to opening up, it failed to meet the nation's demand ahead of time. The reason was that many agricultural products with rich protein, such as oil crops, meat, pulses, vegetables and eggs, were net exports with annual average value of 6.80×10^8, 2.54×10^8, 2.73×10^8, 7.40×10^8 and 0.49×10^8 kg respectively, from which 18.95×10^7, 3.15×10^7, 6.12×10^7, 1.00×10^7 and 0.57×10^7 kg of protein respectively, can be obtained. Net exports at that time also denote

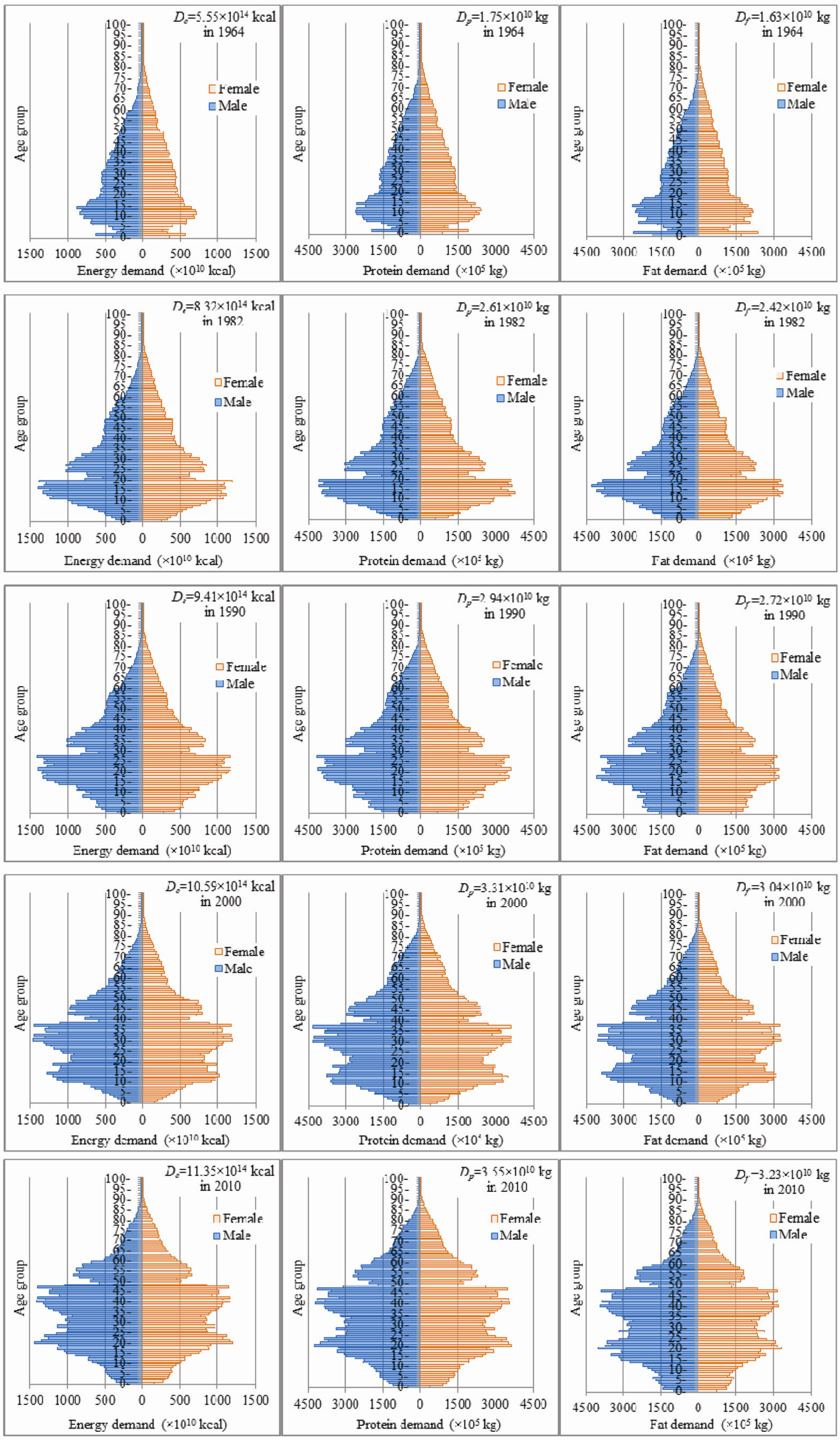

Figure 5. Demand structure of energy, protein and fat in 1964, 1982, 1990, 2000 and 2010. D_e, D_p and D_f are the amount of energy, protein and fat demanded by the nation respectively. The amount of energy from cereals (D_{ec}) and superior protein (D_{ps}) demanded by the nation was obtained by narrowing down energy (D_e) and protein (D_p) in the figure to 50% and 45% respectively.

Table 1. Amount of energy, protein and fat from food under self-sufficiency and open conditions

	1964	1982	1990	2000	2010
Q_{e0} (× 10^{14} kcal)[a]	4.13	8.13	10.13	12.82	14.42
Q_e (× 10^{14} kcal)[b]	4.27 (3.37)	8.58 (5.51)	10.62 (4.88)	13.06 (1.94)	15.02 (4.17)
Q_{ec0} (× 10^{14} kcal)[a]	2.60	5.51	6.54	7.10	7.01
Q_{ec} (× 10^{14} kcal)[b]	2.75 (5.56)	5.90 (7.13)	6.89 (5.42)	7.13 (0.49)	7.06 (0.68)
Q_{p0} (× 10^{10} kg)[a]	1.13	2.00	2.65	3.80	4.51
Q_p (× 10^{10} kg)[b]	1.16 (2.82)	2.11 (6.06)	2.73 (2.82)	3.87 (1.81)	4.66 (3.39)
Q_{ps0} (× 10^{10} kg)[a]	0.43	0.53	0.82	1.47	1.97
Q_{ps} (× 10^{10} kg)[b]	0.42 (–2.9)	0.52 (–0.25)	0.79 (–4.21)	1.53 (4.46)	2.12 (7.73)
Q_{f0} (× 10^{10} kg)[a]	0.55	1.33	1.99	3.24	4.10
Q_f (× 10^{10} kg)[b]	0.55 (0.24)	1.34 (0.99)	2.19 (10.15)	3.44 (6.12)	4.57 (11.51)

[a]Q_{e0}, Q_{ec0}, Q_{p0}, Q_{ps0} and Q_{f0} are respectively, energy from food, energy from cereals, protein, superior protein and fat from food under self-sufficiency conditions. [b]Q_e, Q_{ec}, Q_p, Q_{ps} and Q_f are respectively, energy from food, energy from cereals, protein, superior protein and fat from food under open conditions. [c]Values in brackets are the results of $[(Q - Q_0)/Q_0] \times 100\%$ and indicate increase in the rate of supply amount under open conditions compared to self-sufficiency conditions.

Table 2. Annual average growth rates (%) of energy and nutrients from food in China under open conditions

Period	Energy from food	Energy from cereals	Protein	Superior protein	Fat
1964–1982	3.95	4.34	3.37	1.23	5.05
1983–1990	2.44	1.43	3.05	5.96	6.69
1991–2000	2.51	0.88	4.06	7.35	4.78
2001–2010	1.46	–0.06	2.04	3.66	3.15

a contribution of China's agriculture to the world's food supply.

Main food sources of energy and nutrients

During 1964–2013, the proportion of energy, protein and fat from main agricultural products to total energy, protein and fat from all agricultural products was calculated under self-sufficiency and open conditions respectively. The results are shown in Figure 6; the main food sources of energy, protein and nutrients for the nation can be inferred from the figure.

Main food sources of energy: During 1964–2013 and under self-sufficiency conditions, about 74–91% of energy in China was provided by cereals, starch roots, meat, vegetable oils and vegetables, with annual average shares of energy from them being 60.3%, 9.7%, 9.0%, 3.6% and 2.6% respectively. Among these, the share of energy from cereals from 1984 and that from starch roots from 1970 decreased continually, especially that from cereals, which has been less than 50% since 2008. However, the share of energy from meat increased rapidly at an annual average growth rate of 2.75% during 1964–2013, with only 4.3% in 1964, for the first time more than 10% in 1993 and then increased continually up to 16.1% in 2013. The share of energy from vegetable oils increased slowly and that from vegetables changed a little.

During the same period and under open conditions, the main sources of energy obtained by the Chinese were still provided by cereals, starch roots, meat, vegetable oils and vegetables, with annual average shares of energy from them being 60.4%, 9.5%, 8.6%, 4.3% and 3.7% respectively. Among these, the share of energy from cereals and starch roots decreased at annual average rates of 0.69% and 1.97% respectively, but those from meat and vegetable oils increased at annual average rates of 2.78% and 1.86% respectively.

Main food sources of protein: During 1964–2013 and under self-sufficiency conditions, about 75–88% of protein in China was provided by cereals, meat, vegetables, oil crops and eggs, with annual average share of protein from them being 52.5%, 12.2%, 7.4%, 7.2% and 3.6% respectively. Among these, since 1984 the share of protein from cereals has decreased continually at an annual average rate of 2.09% during 1984–2013, especially since 1995, when it has been less than 50%. The share of protein from oil crops also decreased continually at an annual average rate of 2.62% during 1964–2013 and since 2000, has been less than 5%. In contrast, the share of protein from meat increased continually at an annual average rate of 2.70% during 1964–2013, with less than 10% before 1987, for the first time more than 15% in 1995, and up to 20.6% in 2013. Moreover, as one of the main food sources of superior protein, the rising share of meat means optimizing the nutrition structure of the nation.

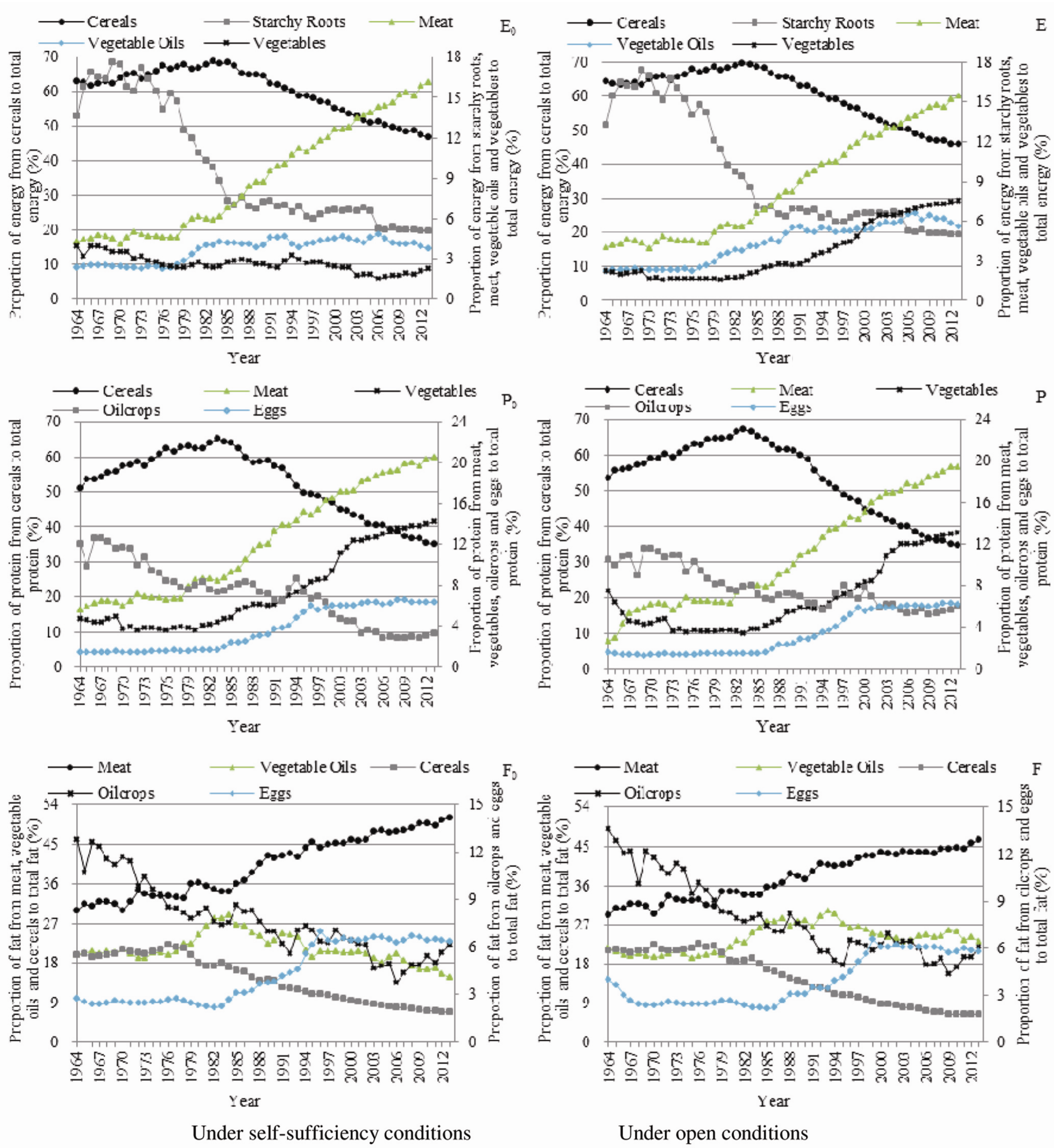

Figure 6. Proportion of energy, protein and fat from main agricultural products during 1964–2013.

During the same period, the share of protein from vegetables and eggs also increased at annual average rates of 2.29% and 3.05% respectively.

During the same period and under open conditions, the main food sources of protein were also provided by cereals, meat, oil crops, vegetables and eggs, with annual average shares of protein from them being 53.6%, 10.8%, 7.8%, 6.7% and 3.2% respectively. In particular, cereals were still the primary source of protein, but since 1984 their share has decreased continually at an annual average rate of 2.22% during 1984–2013. In contrast, the share of protein from meat, vegetables and eggs greatly increased at annual average rates of 3.09%, 4.35% and 5.01% respectively, during the same period.

Compared to self-sufficiency conditions, when imports and exports were counted, annual average share of protein from meat, vegetables and eggs decreased by 1.38%, 1.51% and 0.41% respectively. In contrast, the annual average share of protein from oil crops increased by 2.18% during 1996–2013, which led to oil crops replacing vegetables as the third largest protein source.

Main food sources of fat: During 1964–2013 and under self-sufficiency conditions, about 80–91% of fat in China was provided by meat, vegetable oils, cereals, oil crops and eggs, with annual average share of fat from them being 40.1%, 21.2%, 14.3%, 7.7% and 4.3% respectively. Among these, the share of fat from meat increased continually at an annual average rate of 1.09%, with 30% in 1964, more than 40% since 1988 and up to 51.1% in 2013. The share of fat from vegetable oils, cereals and oil crops decreased at annual average rates of 0.60%, 2.17% and 1.48% respectively, but the share of fat from eggs increased at an annual average rate of 1.74%.

During the same period, the main sources of fat and their change trends under open conditions were similar to those under self-sufficiency conditions, with annual average share of fat from meat, vegetable oils, cereals, oil crops and eggs being 37.8%, 23.8%, 14.5%, 7.9% and 3.9% respectively.

Compared to self-sufficiency conditions, when imports and exports were counted, the share of fat from meat decreased at an annual average rate of 2.3% during 1964–2013. In contrast, the share of fat from vegetable oils increased greatly at an annual average rate of 5.32% during 1985–2013, in particular, increasing at a rate above 8% after 2009. The share of fat from cereals increased slightly at an annual average rate of 0.71% during 1964–93, but decreased slightly at an annual average rate of 0.53% during 1994–2013, while that from eggs decreased at an annual average rate of 0.75% during 1983–2013.

In conclusion, under open conditions, cereals were still the largest food source of energy and nutrients, but their importance decreased. During 1964–2013, the annual average share of energy, protein and fat from vegetable products was larger, at 87.3%, 77.4% and 50.4% respectively. However, the share of energy, protein and fat from animal products increased rapidly, with the share of energy only 3.6% in 1964, 11.4% in 1990 and up to 23.2% in 2013. In the corresponding years, the share of protein was 8.5%, 20.7% and 40.2% and that of fat 26.3%, 47.8% and 61.8% respectively.

Contribution rate of energy, protein and fat provided by imported agricultural products

Contribution rate provided by all imported agricultural products: The contribution rate of energy, protein and fat provided by all imported agricultural products in China was calculated using eq. (5). Figure 7 shows the results.

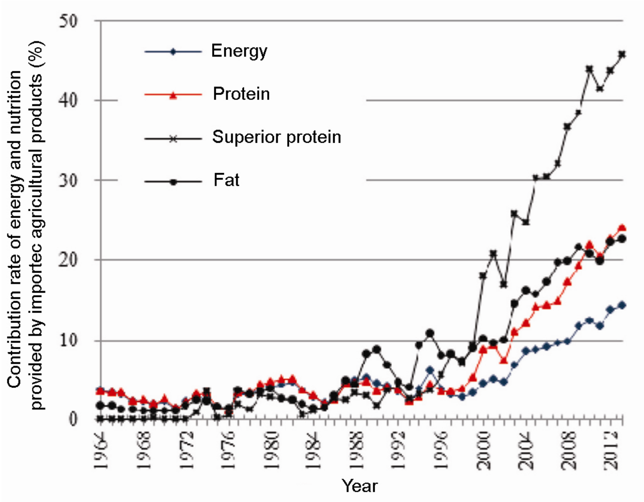

Figure 7. Contribution rate of energy, protein and fat provided by all imported agricultural products.

In China, the contribution rate of energy, protein and fat provided by all imported agricultural products was very low and changed little before 1993, but it increased rapidly during 1994–2002. In order to meet the nation's demand, a large amount of agricultural products was imported, which led to the rapid increase in the contribution rate of energy and nutrients from imported products, especially those of superior protein and fats 2003–2013. Specifically, the change in contribution rate of energy from imported products was relatively low, with an annual average contribution rate of 3.12% during 1964–1993, 4.14% during 1994–2002, and 10.58% during 2003–2013. Note that the contribution rate of energy from imported products grew rapidly during 2003–2013, at an annual average rate of 7.66%. The change in contribution rate of protein from imported products was similar to that of energy, at an annual average of 3.18% during 1964–1993, 5.34% during 1994–2002, and 17.42% during 2003–2013. Similarly, the contribution rate of protein from imported products also grew rapidly during 2003–2013, at an annual average rate of 8.14%. The change in contribution rate of superior protein from imported products was largest, with an annual average of only 0.02% during 1964–1972, 2.17% during 1973–1993, 10.26% during 1994–2002, 35.81% during 2003–2013, more than 30% since 2005, and more than 40% since 2010. The contribution rate of superior protein from imported products went through three important stages: slowly growing at an annual average rate of 6.13% during 1973–1993, rapidly growing at an annual average rate of 23.19% during 1994–2002, and slowly growing at an annual average rate of 5.89% during 2003–2013. The annual average contribution rate of fat from imported products was low before 1985, at 1.98% during 1964–1985, grew rapidly at an annual average rate of 7.76% with an annual average of 7.43% during 1986–2002, then grew slowly at an annual average rate of 4.56% with an annual average of 19.12% during 2003–2013, in particular, an annual average of more than 20% since 2009. When the contribution rate of nutrients provided by imported agricultural products (r) is less than 10%, it indicates a stronger self-sufficiency capacity of the country's agriculture. Therefore, the contribution rate of protein, superior protein and fat provided by all imported agricultural products was very high and has been above the level of national food security since 2000.

Contribution rate of energy and nutrients provided by specific types of imported agricultural products: Using eq. (5), the contribution rate of energy, protein and fat provided by several specific types of imported agriculture products was calculated. By comparing supply and demand for energy from cereals, China achieved self-sufficiency in cereals in 1970; that is, cereals from domestic production were basically able to meet the nation's demand for energy from cereals according to the standards of energy from cereals. Therefore, the contribution rate of energy from imported cereals was relatively low and the annual average contribution rate was 2.77%, with a low of 0.35% and a high of 5.55% during 1964–2013. The contribution rate of energy, protein and fat from imported cereals decreased continually from 1989 at annual average rates of 2.48%, 3.16% and 3.10% respectively, during 1989–2013.

During 1994–2013, the annual average contribution rates of energy, protein and fat provided by imported meat was rather low at 0.95%, 1.27% and 0.89% respectively, and the changes were small.

During the same period, the annual average contribution rates of energy, protein and fat from imported starch root was 7.72%, 4.62% and 5.66% respectively. Whereas those of protein and fat from eggs, and of energy and protein from vegetables were also rather low, with the former all less than 0.001% and the latter all less than 0.04%.

During 1994–2013, the contribution rate of imported vegetable oils and oil crops was high. The annual average contribution rates of energy and fat provided by the former were already above 29% with a low of 15.6% and a high of 37.9%, and those of protein and fat provided by the latter were 32.45% and 18.27% respectively. In particular, the contribution rates of energy, protein and fat provided by imported soybean in oil crops were very high and grew rapidly at an annual average rate of 26.87%, with only 0.326% in 1994, 42.38% in 2000 and up to 84.35% in 2010. The higher contribution rates of protein and fat provided by imported oil crops, especially soybean, indicate that the supply of protein and fat in China has been over-reliant on world resources.

During 1994–2013, aquatic products were not the main food source of energy and nutrients for the Chinese, but the contribution rates of energy, protein and fat provided by them were very high with annual average values of 25.19%, 19.64% and 24.65% respectively. Moreover, the annual average contribution rate of imported animal fats was up to 95%.

Conclusion

For energy provided by agricultural products, China achieved self-sufficiency in cereals in 1970. The total energy, protein, fat and superior protein provided by self-produced agricultural products in China have met its demand according to nutrition standards since 1983, 1994, 1998 and 2002 respectively. Due to opening up to the world, the supply of energy, protein and fat has increased, especially significantly since 1997. Comparing open conditions with self-sufficiency conditions, energy from cereals, energy, superior protein and fat from food met the nation's demand according to the related standards 4 years, 1 year, 2 years and 1 year ahead of time respectively. However, before 1994, although the supply of protein increased due to opening up, it failed to meet the nation's demand ahead of time.

Under open conditions, i.e. considering both imports and exports, the food sources of energy and nutrients obtained by the Chinese were similar to those under self-sufficiency conditions. Energy was mainly provided by cereals, starch roots, meat, vegetable oils and vegetables, protein by cereals, meats, vegetables and eggs, and fat by meats, vegetable oils, cereals and eggs. These provide more than 80% of the energy, protein and fat obtained by the Chinese. In the main food sources of energy and nutrients, cereals were still the most important, but their importance decreased. Although the share of vegetable products has been large, the share of animal products increased rapidly with changes in the dietary habits of the Chinese, i.e. more animal and less vegetable foods.

For a long time, protein, superior protein and fat provided by China's agriculture did not meet its demand when depending solely on domestic resources. Therefore, China's agricultural products trade was in a state of excess of imports over exports; in particular, the contribution rate of superior protein from imported products was high and has been above the warning level of national food security since 2000. From the perspective of specific products, cereals, meat, eggs and vegetables with a low dependence degree were the most important sources of energy and nutrients obtained by the Chinese. Except for vegetable oils and oil crops, agricultural products with a high-dependence degree did not become the main source of energy and nutrients obtained by the Chinese. This suggests that China has depended mainly on domestic production to meet its demand for most agricultural products up to now. However, the higher contribution rate of protein and fat provided by imported oil crops, especially soybean, indicates that the supply of protein and fat in China has been over-reliant on world resources.

Using foreign resources could significantly improve the status of national health and nutrition, due to not only enhancing the capacity of China's agriculture to feed its population, helping the nation to achieve a balance between supply and demand for energy and nutrients ahead of time, but also enhancing the ability to optimize the Chinese nutrition structure, helping the nation to get dietary nutrients according to high nutrition standards. However, the existing structure of agricultural production in China is still unable to meet its demand and improve the nation's nutritional structure. First, the nation's demand for food will be greater, especially after implementation of the family planning policy. Cereal yields in China are not abundant with respect to the continually growing population; so that the solution in the long term would be to further increase cereal yields in China. However, China's agriculture is limited by resource endowment and ecological environment, such as a shortage of arable land and freshwater, as well as the impact of urbanization and industrialization. Therefore, agricultural products need to be imported to make up for the insufficient supply when domestic agricultural output is not enough to meet the demand. Secondly, except for meat some animal products such as fish and seafood, have still not become main food sources of energy and nutrients obtained by the Chinese. However, in order to optimize the nation's nutritional structure, Chinese dietary habits should be changed to reduce excess fat intake and get more reasonable energy and nutrients from the diet. This change will lead to adjustment of the agricultural structure, increased consumption of meat, eggs, milk and further increased demand for cereals. Therefore, in order to increase the supply of superior protein, it is necessary for China to increase the yield of eggs, milk and aquatic products due to their high contents of superior protein and their high dependence degree. In addition, the imbalance of the agricultural production structure will cause some agricultural products, such as soybean, animal fat, etc. to depend on imports. Therefore, China will have a great demand for the world's agricultural products over a fairly long period.

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