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Analysis of Food Consumption and Its Characteristics in Uzbekistan based on the Emergy Method

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Abstract: Food resources play a great role in human livelihood, so it is meaningful to investigate their utilization and structural evolution, especially in developing countries. This study takes data from FAOSTAT and the World Bank, and applies the emergy method to analyze Uzbek food consumption changes and characteristics from 1992 to 2019. Two main results were obtained: (1) National food consumption showed a persistent increase and had a remarkable change in stages, with the first stage of low-level repetition, the second stage of speeding up and the third stage of high development. The increase of animal-based food consumption was more notable than that of plant-based food consumption. (2) Per capita annual food consumption had a tendency of change that was similar to that of national food consumption. The proportion of animal-based food in the total per capita annual food consumption usually remained about 2-fold higher than that of plant-based food consumption. The main food consumption pattern was the combination of crops such as wheat and rice with meat such as beef. The fruit and vegetable consumption also increased. With the growing population, various changes in food demand will inevitably happen, so it is necessary to take sustainable measures in time to satisfy the new demand and to protect resources and the environment.

Key words: food consumption; emergy method; Uzbekistan

1 Introduction

Food is the basis for human survival and plays the role of a link between human beings and nature. Food consumption plays a pivotal role in the development of a country or an area, and it reflects not only the food consumption level but also the standards of the local diets. However, as global challenges are becoming more serious, such as the rapidly expanding population, the raging worldwide pandemic, ecological destruction and threats to food security, it is urgent to address these issues to achieve sustainable development (Foley et al., 2011; Tilman et al., 2011; Rockström et al., 2017; Jain et al., 2020). At the same time, food consumption demand goes through new changes and this also reflects the demand for more food and more variety of foods from nature.

Choosing the correct method for evaluating a food consumption situation is an important foundation for policymakers. Current research is focused on either consumption or production and the factors influencing them (Rask and Rask, 2011; Lee et al., 2018; Yang and Zhen, 2020; Yang et al., 2020), and many researchers have developed and employed some useful evaluation methods to calculate the quantity of food production or consumption in order to reveal the tendencies or crucial change points. Some typical research methods include ecological footprint (Baabou et al., 2017; Deng et al., 2018; Li et al., 2019; Cao et al., 2020), modeling (Cardoso et al., 2017; Casella et al., 2019; Wang et al., 2020), and household survey (Desiere et al., 2018; Ntakyo and Berg, 2019; Yang et al., 2020). All these meth-

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ods still have shortcomings that make it difficult to overcome the unique standards when applying them to different situations, such as ecology, economy and society. Emergy analysis can solve the problem that different types of energy are difficult to directly compare and calculate, so it can measure the true value of products and services of natural ecosystems, social systems, and economic systems, and can analyze the results to realize the connections between theoretical researches and decision-making applications.

Emergy is the available energy of one kind (usually solar energy) that is required directly or indirectly to make a product or service (Odum and Peterson, 1996; Odum, 2000), and emergy is measured in emjoules (sej). In general, emergy is formulated as solar emergy because all of the biosphere originates from solar emergy directly or indirectly, and so emergy is measured in solar emergy (sej) (Ali et al., 2019). The emergy evaluation assigns a value to products and services by turning them into equivalents of solar energy joules, which can be used as a common denominator (Jorgensen et al., 2004). Therefore, different forms of resources with different units can be measured and directly compared to each other in this way (Zhao et al., 2019). In single product studies, such as wheat (Zhao et al., 2019), maize (Ghaley et al., 2018; Mwambo et al., 2020), and milk (Agostinho et al., 2019), researchers have used the emergy method to evaluate the sustainable production of wheat, maize and milk. Regarding agriculture systems, this method has been used to study the effective relationships between agriculture and other systems such as the environment, land-use, and agriculture's inner system (Shah et al., 2019; Skaf et al., 2019; Artuzo et al., 2021; dos Reis et al., 2021).

As one of the important countries of Asia, Uzbekistan is located in an arid plain and near the semi-arid foothill areas of the Aral Sea Basin (Kulmatov et al., 2020). The ecological environment is fragile and the increased population, low level of natural drainage and extensive areas of flood irrigation with poor-quality water, soil salinization and degradation are accelerating the destruction of its ecological environment (Kulmatov et al., 2020). The goals of this study are two points: 1) Evaluate the dynamics and characteristics of food consumption at the national scale and the per capita annual food consumption in Uzbekistan; and 2) Explore the reasons for the levels of the national-scale total and per capita food consumption. It is urgent to determine the tendency of change in food consumption and its characteristics, and this information can provide more scientific and efficient reference for achieving a more persistent and sustainable way to utilize various resources.

2 Materials and methods

2.1 Research area

Uzbekistan is the most populous country in Central Asia. It is located at 37°12′00″–45°33′36″N，55°59′24″–73°07′48″E with a continental climate, bordering Kazakhstan in the northwest, Kyrgyzstan and Tajikistan in the east, Turkmenistan in the south and the Aral Sea in the northwest. The overall terrain is high in the east and low in the west, and the plain lowlands account for 80% of the total area, most of which is located in the Kizilekum Desert in the northwest (Groll et al., 2015). The annual precipitation in the plain area is about 80–200 mm, while the annual precipitation in the mountainous areas can reach 1000 mm (Egamberdieva et al., 2008). Its population has grown to approximately 3.36×10^7, and the proportion of urban residents is 50.43%; the country area is 4.25×10^5 km^2, and agricultural land represents 9.20% of the total land area (World Bank, 2019). Agricultural cultivation has wheat in the first place, and animal husbandry mainly involves cows and sheep. The gross domestic product (GDP) came to 57.73 billion USD in 2019 and its ratio of increase was approximately 5.80%.

2.2 Data sources and analysis methods

In order to analyze food consumption more conveniently, it was divided into plant-based and animal-based foods. Plant-based food includes wheat, rice, barley, maize, nuts, vegetables, fruits, oilseeds and sugar; while animal-based food mainly includes beef, mutton, chicken, fish, pork, milk and eggs. The food consumption data were derived from the Food and Agriculture Organization of the United Nations (FAO, https://www.fao.org/faostat/en/#data, 2021.9). The data of some influencing factors such population, income, and agricultural land were obtained from the World Bank (WB, https://data.worldbank.org.cn/, 2021.9).

This research aimed to study the temporal changes of Uzbek food consumption and its characteristics after the country gained its independence in 1992. The calculation of different food consumption amounts mainly put all the food items into a unique standard using the appropriate conversion rates (Table 1). The equation expressing emergy comes from Li et al. (2019), and the specific calculation equations are:

$$C_i = G_i \times F_i \times R_i \tag{1}$$

$$C_P = \sum_{i=1}^{m} C_i \quad (m=1, 2, 3, \cdots, 9) \tag{2}$$

$$C_A = \sum_{i=10}^{n} C_i \quad (n=10, 11, 12, \cdots, 16) \tag{3}$$

where i is food item numbers from 1 to 16, G_i is the gravity of food consumption, F_i is the energy conversion rate, R_i is emergy transformity, C_i is the specific kind of food consumption emergy, C_P is total plant-based food consumption emergy, and C_A is total animal-based food consumption emergy.

Table 1 Conversion rates of different food items

Number	Food item	Energy conversion rate (J kg^{-1})	Emergy transformity (sej J^{-1})
1	Wheat	1.57×10^{7}	6.80×10^{4}
2	Rice	1.55×10^{7}	3.95×10^{4}
3	Barley	1.60×10^{7}	8.00×10^{4}
4	Maize	1.65×10^{7}	2.07×10^{4}
5	Oilseeds	2.55×10^{7}	6.90×10^{5}
6	Nuts	2.59×10^{7}	6.90×10^{5}
7	Fruits	3.30×10^{6}	5.30×10^{5}
8	Vegetables	2.51×10^{6}	2.70×10^{4}
9	Sugar	2.50×10^{6}	8.50×10^{4}
10	Egg	8.30×10^{6}	2.00×10^{6}
11	Chicken	5.40×10^{6}	2.00×10^{6}
12	Pork	2.00×10^{7}	1.70×10^{6}
13	Beef	8.76×10^{6}	3.17×10^{6}
14	Mutton	1.41×10^{7}	2.00×10^{6}
15	Milk	2.90×10^{6}	1.71×10^{6}
16	Fish	5.40×10^{9}	2.00×10^{6}

Note: Data from Li et al. (2019).

3 Results

3.1 Changes in annual food consumption

It is notable that total quantities of the plant-based (Fig. 1) and animal-based (Fig. 2) food consumption both showed significant increases during the research period from 1992 to 2019. The plant-based food consumption mainly focused on oilseeds, fruits and wheat, while the animal-based food consumption mainly focused on beef and milk. The 28 years period could be divided into three stages based on the quantitative change trend as the first stage of low-level repetition from 1992 to 1998, the second stage of speeding up from 1999 to 2013 and the third stage of high development from 2014 to 2019.

3.1.1 Changes in plant-based food consumption

In the change of plant-based food consumption quantity, the three kinds foods with the highest percentages were oil seeds, fruits and wheat (Fig. 1). Among the annual plant-based food consumption data, the consumption quantity of oil seeds, fruits and wheat had an average share of 91% in the total plant-based food consumption. The largest increase in quantity occurred in fruits, which was 50.09×10^{19} sej, and the increase rate came to 421.18%. The large and stable consumption of plant-based food mainly involved wheat and oilseeds. Their annual consumption levels remained at approximately 48.41×10^{19} sej and 53.07×10^{19} sej, respectively. In the first stage, the proportion of wheat and oilseeds consumption in the total plant-based food consumption always stayed above 80%. The consumption quantity of barley had a slight decrease by 36.15% (Fig. 1). The annual consumption of rice and maize showed slight increases by 6.71% and 28.16%, and these two kinds of food maintained an average annual consumption at 1.19×10^{19} sej and 0.55×10^{19} sej throughout the research period, respectively.

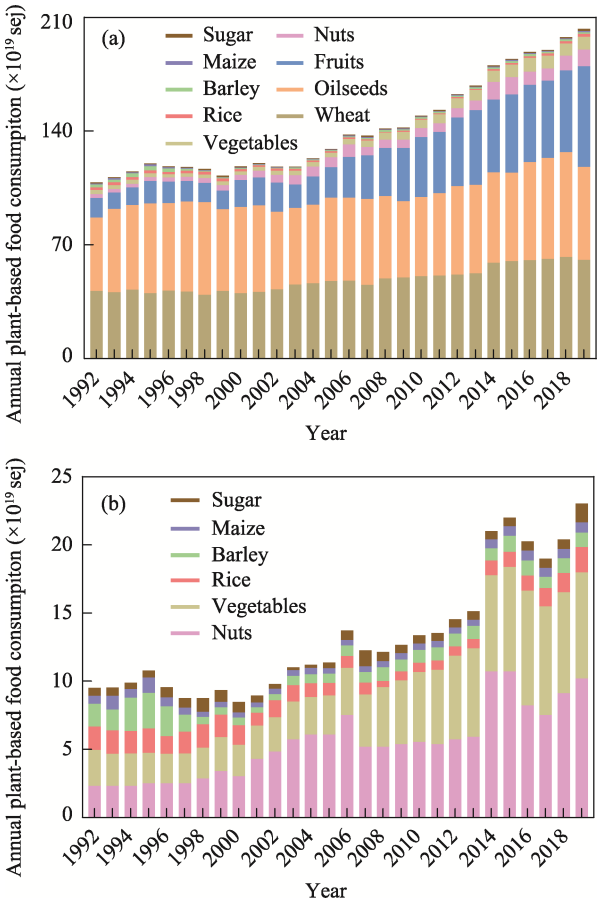

Fig. 1 Changes in the national annual plant-based food consumption from 1992 to 2019

Note: Fig. 1b is part of Fig 1a, and it shows the food types of less consumption in Fig. 1a.

3.1.2 Changes in animal-based food consumption

The total annual animal-based food consumption showed an increase overall and had marked periodic change characteristics. In the first stage, the total animal-based food consumption was maintained at an average of 344.86×10^{19} sej (Fig. 2). In the second stage, although the consumption in the first year in this stage was slightly smaller than that in the first stage, this stage presented a continuous and rapid increase of 55.74% compared to the level in this stage's first year. Upon entering the third stage, it was found that animal-based food consumption of the first year in this stage was much higher than that in the last year of the second stage. The consumption changes in this stage were mainly increasing slowly at a higher level. The consumption of beef and milk took the first place in the total animal-based food, as the proportion of beef and milk consumption was consistently more than 85% of the total animal-based food

consumption throughout the whole research period.

Regarding the specific kinds of food consumption, all presented increasing tendencies to some extent. Beef consumption fluctuated frequently in the first stage, but upon entering the second stage, it showed a sustained increase until the third stage with an increase rate of 159.21%. Milk consumption mainly presented a slowly increasing situation with an average consumption of 203.04×10^{19} sej, while it achieved a significant increase of 47.29% in 2014 compared to the consumption level in the previous year and maintained a continuous and stable increase during the third stage. Pork, fish and chicken shared similar change trends that decreased at first and then increased continuously. Egg and mutton consumption showed a different change characteristic that increased and decreased repeatedly in the first stage but increased stably and persistently in the last two stages.

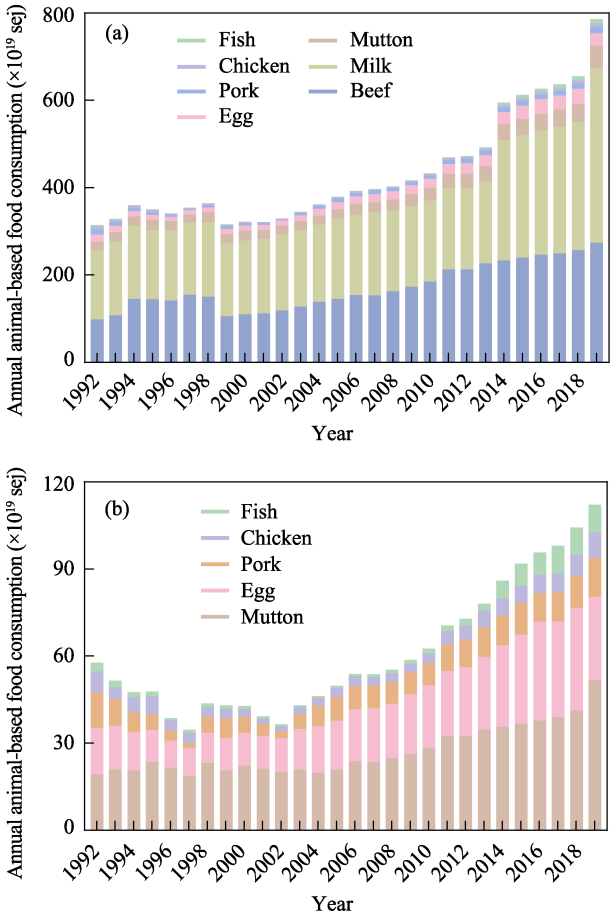

Fig. 2 Changes in the national annual animal-based food consumption from 1992 to 2019

Note: Fig. 2b is part of Fig 2a, and it shows the food types of less consumption in Fig. 2a.

3.2 Changes of per capita annual food consumption

The change in the per capita annual food consumption presented an apparent periodic characteristic when compared with the national annual food consumption (Fig. 3). The structure of per capita annual food consumption showed one notable feature that the proportion of animal-based food reached an average of 74.40% in the first two stages, and then achieved a new increase to more than 79% in the third stage (Fig. 4). This meant that the proportion of plant-based food consumption would decrease more and the food structure would represent a new change.

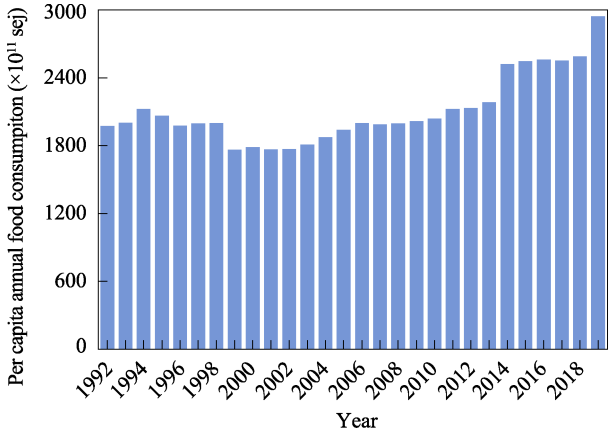

Fig. 3 Per capita annual food consumption

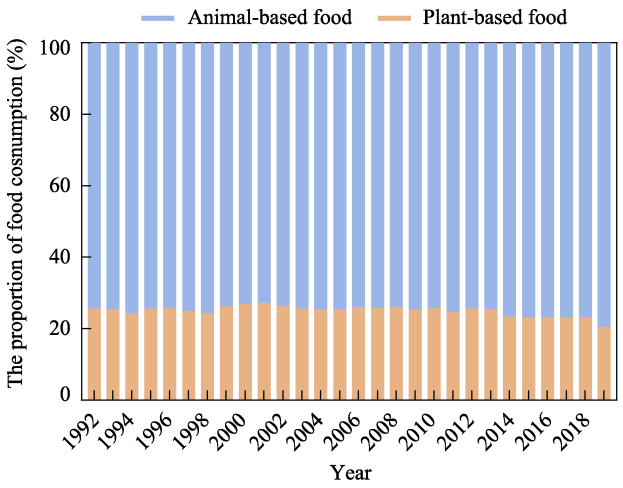

Fig. 4 Proportions of plant-based and animal-based food consumption

Overall per capita annual plant-based food consumption showed increases and decreases repeatedly. The consumption of fruits, nuts, and vegetables mainly presented a tendency of increasing, but the fluctuation in that increase was much stronger in nuts than that in fruits and vegetables. According to comparisons of the highest and lowest consumption quantities of these three kinds of food, they show different rates of increase, with the rates for nuts of 235.78%, vegetables of 185.56% and fruits of 309.14% (Fig. 5). Although wheat and oilseed consumption were much higher than other kinds of plant-based foods, both of them demonstrated decreases with slight fluctuations, with the average

consumption of wheat and oilseeds at 179.07×10^{11} sej and 198.94×10^{11} sej, respectively. Rice, barley, maize and sugar in the first stage showed marked and repeated increases and decreases and remained at low levels with small fluctuations. Maize and sugar consumption changes were much smaller than those of rice and barley, and maize and sugar consumption showed averages of 2.08×10^{11} sej and 2.44×10^{11} sej throughout the research period, respectively. Rice and barley had decreased from their highest quantities of 8.08×10^{11} sej and 11.40×10^{11} sej down to 1.68×10^{11} sej and 1.64×10^{11} sej by 79.21% and 85.61%, respectively.

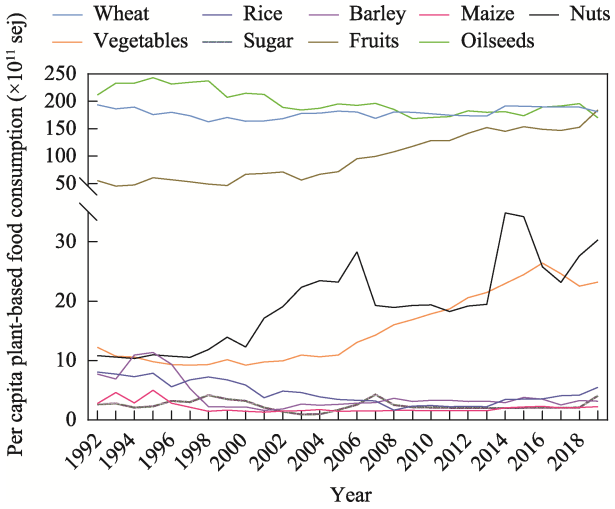

Fig. 5 Per capita plant-based food consumption

Compared with the changes in per capita plant-based food consumption, animal-based food consumption showed increases except for chicken and pork. The most remarkable consumption increases among animal-based foods were beef by 78.23% and fish by 101.84% across the whole period (Fig. 6). Their peak consumption quantities came to 814.54×10^{11} sej in 2019 and 29.50×10^{11} sej in 2017. Milk consumption presented periodic changes, and it showed a persistent decreasing level in the first two stages but remained stable with an average of 944.09×10^{11} sej in the third stage. Mutton and egg consumption also had significant increases, but they were smaller than those of beef and fish. The smallest consumption levels of mutton and eggs were 76.32×10^{11} sej and 40.68×10^{11} sej, respectively, and both of them showed the largest increases by 101.36% and 164.97%. For the per capita consumption of pork and chicken, both them achieved their highest consumption levels in 1992 and showed decreases by 29.03% and 24.86% in 2019, respectively.

4 Discussion

During the study period, different kinds of food consumption presented various trends. Food consumption quantity and patterns of evolution are affected by many different factors, including economic, social, and ecological factors. When searching for the causes of these trends, it was found that one of the most common reasons is population change, which has been previously mentioned (Supiyev et al., 2017; Hallström et al., 2018). As the country with the greatest population in Central Asia, the Uzbek population increased by 53.65% when compared with the population in the early years of the country's founding (Fig. A1). In general, a high urbanization level has much more resource demand and consumption, which includes food resources (Pandey et al., 2020; Putra et al., 2020; Zhong et al., 2021). Uzbek urbanization had exceeded 50% since 2009, and this was also the time in which the urban population exceeded the rural population, which meant that the food consumption in this country had undergone further expansion.

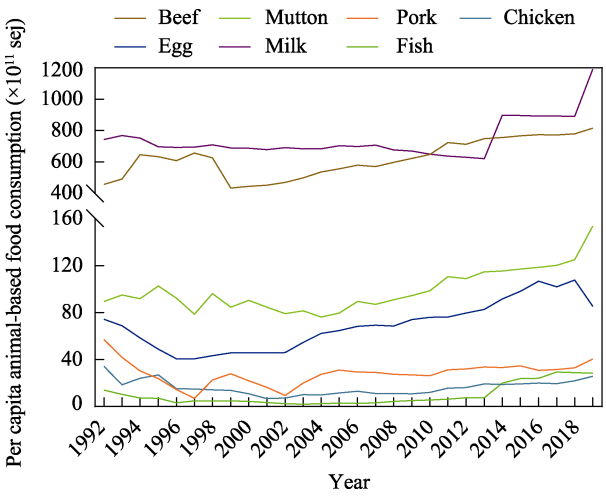

Fig. 6 Per capita animal-based food consumption

GDP represents the comprehensive economic ability of one country or one area (van Grinsven et al., 2015; Desiere et al., 2018; Mottaleb et al., 2018). This factor has a significant role in improving the residents' food consumption quantity and quality. The GDP in Uzbekistan presented a high and persistent growth by 2.80-fold during the research period (Fig. A2). GDP growth provides a strong foundation for people to purchase more food and more varied food. The per capita GDP also proves the point that this factor plays a major role in allowing residents to live a higher quality life to some extent, and related research has verified this result (Fróna et al., 2019).

In order to meet the domestic food demand and ensure a decrease in cost, many countries use food imports as a suitable way to transfer the production pressure to other countries (Sadler and Magnan, 2011; Ali et al., 2019; Beltran-Peña et al., 2020). Fruit imports had improved greatly to 9.50×10^{4} t in 2019, it got a great increase by 30.67-fold when compared that in 1992. But vegetables import was 3.13×10^{5} t in 2019 which got a little increase by 7.56% when compared that in 1992 (Fig. A3). Both of them had

large growth and showed that the dependence on fruit and vegetable imports increased. However, this option also represents a food security risk, especially during the anti-globalization trend and worldwide pandemic, which have prohibited world trade connections and produced more isolation (Sadler and Magnan, 2011; Welburn et al., 2016).

The ecological environment is the great foundation for human livelihood and provides many various foods (Hallström et al., 2018; Conrad et al., 2020). Different food yields and livestock quantities are guaranteed in the usual food supply. Uzbekistan is a traditional agricultural country, so the ecological environment plays a great role in its crop-planting and animal-breeding development (Veldwisch and Spoor, 2008; Abdullaev and Mollinga, 2010). Its plant-based food consumption mainly focuses on staple foods such as wheat, and its harvested area and yield both showed significant increases by 109.04% and 179.66% in 2019 when compared with those in the first year of the study period (Fig. A5). Compared with the first year of the country's founding, breeding quantities of the main animals such as cattle, goats, sheep and chickens achieved marked increases by 153.29%, 304.26%, 97.97% and 79.87%, respectively (Fig. A4). Persistent increases in yield and breeding have provided strong support for the improvement of the residents' food consumption.

The changes in food consumption at the national and personal levels were not only affected by the effects discussed above, but they were also affected by the non-quantitative influencing factors such as native customs and education level. More research is needed to understand the more comprehensive relationships among these different factors with the food consumption.

5 Conclusions

Through the analysis of national and personal levels of food consumption, this study found that Uzbek food consumption presented remarkable characteristics, and the main results are summarized here.

(1) National food consumption showed a persistent increase and had remarkable stages of change, with the first stage of low-level repetition, the second stage of speeding up and the third stage of high development. Animal-based food consumption increases were more notable than those of plant-based food consumption.

(2) Per capita annual food consumption had a similar tendency of change as national food consumption. The proportion of animal-based food in the total food consumption usually remained at an average of 74.44%, but in the third stage, this rate showed a new increase to more than 79%. The main food consumption pattern mostly represented the combination of crops such as wheat and rice with meat such as beef. Fruit and vegetable consumption also showed some increases.

Although some results were obtained through this analysis, there are still some shortcomings in the research. As the conversion rates of food items were based on Central Asia, not Uzbekistan, the accuracy of the calculations of food consumption might be affected. However, this research applied the emergy method to derive the unique evaluation standard to effectively reflect the food consumption characteristics in Uzbekistan.

Based on the results above, the food consumption changes revealed can provide some certification of the resource utilization and reflections of living standards. They can also provide some scientific and efficient support for the governors and managers in their search for more sustainable policies.

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基于能值法的乌兹别克斯坦食物消费及其特征分析

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摘　要：食物资源对人类生存至关重要，因此探究食物资源利用及其结构演变规律很有意义，对一些发展中国家尤其如此。本研究的基础数据主要来源于联合国粮食及农业组织和世界银行，采用能值法对乌兹别克斯坦自 1992 至 2019 年间的食物消费变化及其特征进行研究分析。主要得到以下两点结论：（1）国家食物消费呈现持续增加态势且具有明显的阶段性特征，主要包括低速反复阶段、快速提升阶段和高水平发展阶段。动物性食物消费变化较植物性食物更加显著；（2）人均食物年消费量变化同国家食物消费有相似的变化趋势。在人均食物年消费中，动物性食物消费占比一般比植物性食物占比高出 2 倍。当前乌兹别克斯坦居民食物消费主要是谷物和肉类相结合，其中谷物消费以小麦为主，肉类消费中以牛肉为主。此外，水果和蔬菜的消费需求进一步增多。随着人口进一步增加，食物多样性需求将更加强烈。当前，采取可持续性的措施以满足新的食物消费需求并保护资源和环境是非常必要的。

关键词：食物消费；能值法；乌兹别克斯坦

Appendix

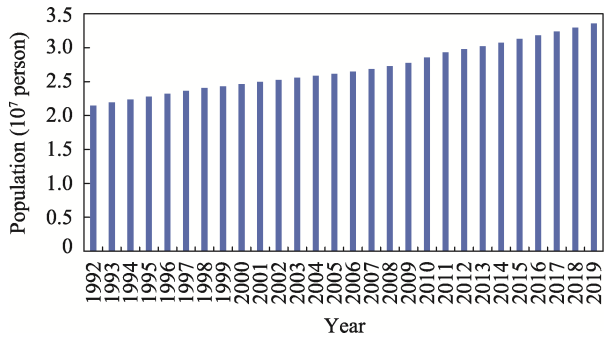

Fig. A1 Population of Uzbekistan from 1992 to 2019

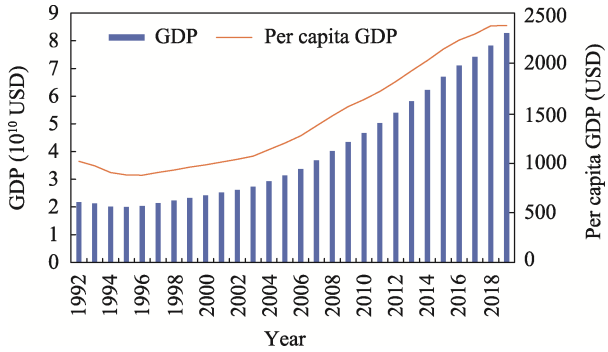

Fig. A2 GDP and per capita GDP of Uzbekistan from 1992 to 2019

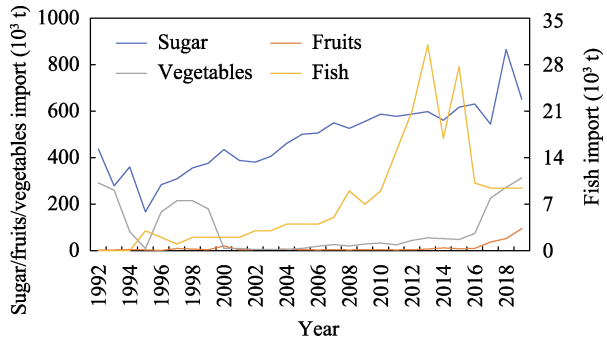

Fig. A3 Main types of food imports in Uzbekistan from 1992 to 2019

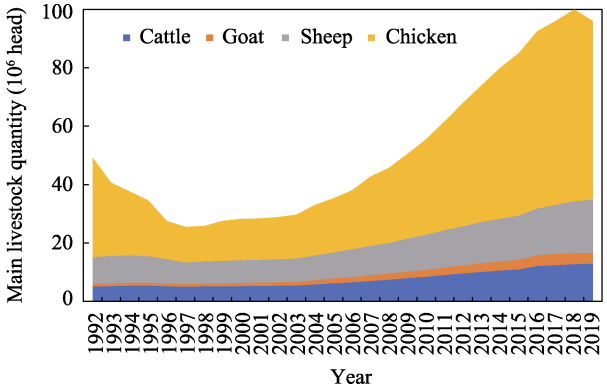

Fig. A4 Main livestock in Uzbekistan from 1992 to 2019

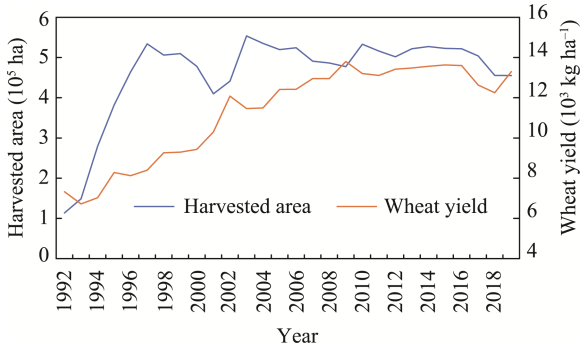

Fig. A5 Wheat yield and its harvested area in Uzbekistan from 1992 to 2019