

Intake and food sources of ascorbic acid in China

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Investigating differences in the intake of nutrients is of potential importance in characterizing diet-disease relationships and determining the level of intake necessary for optimal health. The intake and food sources of ascorbic acids were examined in an ecologic study of 64 rural counties in the People's Republic of China and compared with data reported for the United States. The mean (\pm SEM) and median individual intakes of ascorbic acid for all counties combined were 140 (\pm 88) and 128 mg/day, respectively (range 6-429 mg/day). This compares to a mean intake of 99 mg/day for adult men and 84 mg/day for adult women in the United States. The foods that contributed the most to ascorbic acid intake were sweet potatoes (37.2%), cabbages (23.9%), leafy green vegetables (10.6%), radishes (8.8%), and hot peppers (6.5%). In contrast to the US, where fruits supply 43% of ascorbic acid to the diet, fruits contributed a relatively small amount to overall ascorbic acid intake in rural China (1%). The wide range of ascorbic acid intake among counties resulted, in part, from differences in the availability of fresh produce which is grown and consumed locally. Despite this, the mean intake was still greater than the US because of the large contribution of plant products (approximately 90%), especially tubers and other vegetables, to the diet.

Introduction

Ascorbic acid (vitamin C) is an essential micronutrient involved in a wide variety of biochemical processes in the human body. Its antioxidant and free-radical scavenging properties, ability to enhance iron absorption, and function as a component in the synthesis of carnitine, norepinephrine, collagen and other compounds are well described¹⁻³. Less established but of potential benefit are its effects on serum cholesterol and cardiovascular disease^{4,5}, blood pressure^{4,6}, immune function¹, reduction in the toxicity of cancer chemotherapy and the prevention of cancer^{2,3}. In some cases, such as cancer prevention, it is difficult to determine whether the protective effect is due to ascorbic acid *per se* or other components of fruits and vegetables⁷.

Deficiency of ascorbic acid, usually associated with an intake of less than 10 mg/day, causes scurvy^{1,8}. Less clear is the amount necessary for optimum health^{2,3}. Due to this, in part, there has been controversy concerning the United States Recommended Dietary Allowance (RDA) which is currently 60 mg/day for adults⁸. While most have suggested this amount is adequate or should be raised^{9,10}, some have argued it may be unnecessarily high¹¹. The current mean daily intake of ascorbic acid in the US is estimated to be 99 mg for adult men and 84 mg for adult women¹². The predominant food sources are citrus fruits and juices, non-citrus fruits, potatoes and other vegetables¹³.

The food supply in the US is stable due to an advanced shipping system, and the diet is relatively homogeneous. Adequate amounts of nutrients, including ascorbic acid, are usually available although actual consumption may vary.

Less is known about the intake and food sources of ascorbic acid in other countries. In order to better characterize the relationships between ascorbic acid and specific health parameters, information on the intake and food sources of ascorbic acid in populations living under conditions other than those found in developed countries should be examined. Moreover, this may also help to expand the information base used to determine optimal intake.

China provides an opportunity to explore this area of research for a number of reasons. The diet consumed within each region has remained relatively unchanged over time¹⁴. In contrast, diet and local conditions vary widely among different areas. In addition, there has been little migration¹⁵. This combination of stable conditions within regions but variable conditions among regions may facilitate the examination of diet-disease relationships not easily demonstrated in more homogeneous populations. First, however, it is necessary to document dietary intake and sources of nutrients, which may lead to more detailed investigations later. The purpose of this paper is to report on the intake and food sources of ascorbic acid in the People's Republic of China and to compare them with data reported for the US.

Methods

A large ecologic study was undertaken in China in 1983 to

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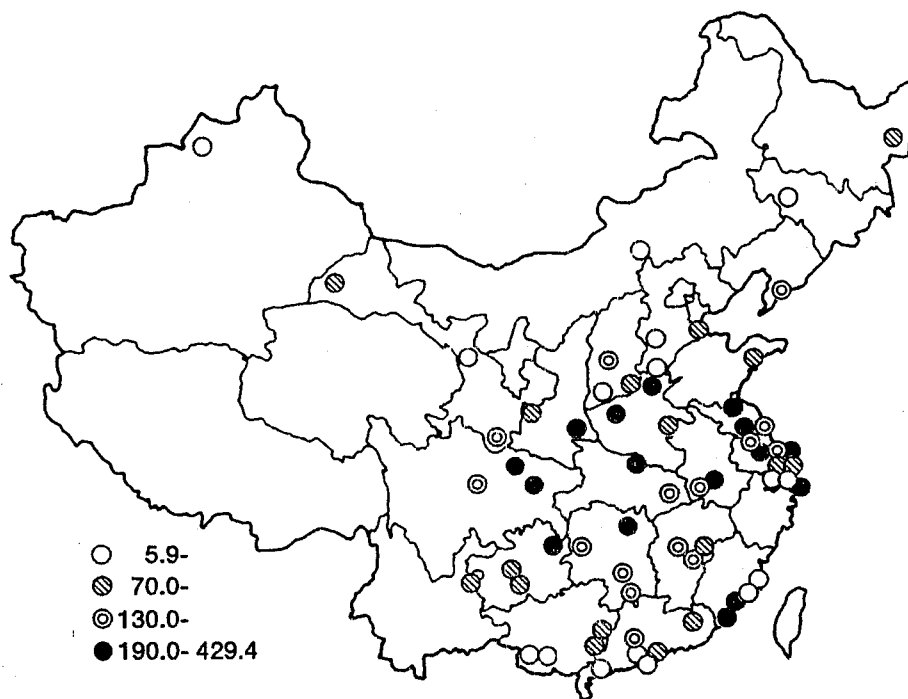


Fig. 1. Geographic distribution of ascorbic acid intake in 64 survey counties in China. The values (eg 5.9 to 69.9) – see symbols above – are mg/day. One county was excluded because of an extraordinarily high intake of ascorbic acid from the consumption of fresh Chinese dates which was highly seasonal.

collect information regarding diet, lifestyle, and biochemical variables in order to examine the relationship between these characteristics and mortality from disease¹⁵. Data were gathered in each of 65 largely rural counties from various sources, including a three-day dietary survey and nutrient analysis of various plant food components. The 65 counties were selected from a total of over 2000 to represent the full range of mortality rates in China¹⁶. For the dietary survey, 30 households were randomly selected in each of the 65 counties. Individual foods were collected and weighed for the entire household before, during and after the three-day survey period. Children under two years of age were excluded from the survey. Because the food was collected by households, consumption was standardized by using a 'reference man' defined as an adult male, 19–59 years of age, 65 kg body weight, and undertaking very light physical work. Mean individual intake for each county was then determined by calculating the mean of the standardized individual intakes for the 30 households in each county. The ascorbic acid content of foods was obtained from the Chinese Food Composition Tables¹⁷. Further details concerning the study design, along with data on over 360 characteristics from the ecology survey and corresponding mortality rates of 49 of the survey counties, have been published in a monograph¹⁵.

Results

The mean intake of ascorbic acid for each county is shown geographically in Figure 1. The mean (\pm SEM) individual intake for all counties combined was 140 (\pm 88) mg/day while the median intake was 128 mg/day. Intake ranged from 6 mg/day to 429 mg/day. One county was excluded because of an extraordinarily high intake of ascorbic acid (1361 mg/day) from the seasonal consumption of fresh Chinese dates, which contain 540 mg ascorbic acid per 100 g.

The foods contributing the largest amounts of ascorbic acid to intake are rank-ordered in Table 1. Sweet potatoes

contributed the largest amount overall, 37.2%, and were consumed in 51 of the 65 counties surveyed. Cabbages contributed 23.9% and were the most widely consumed vegetable, eaten in 62 of the counties. Following these foods were other leafy green vegetables (10.9%), radishes (8.8%), and hot peppers (6.5%). The five foods contributing the largest amounts of ascorbic acid were determined for each of the 65 counties. A total of 45 foods comprised this list, reflecting the variability of food sources of ascorbic acid among the counties.

When categorized by major food groupings, vegetables (other than tubers) contributed 60% and tubers (predominantly sweet potatoes) 38%. Fruits contributed only about 1% to the total intake of ascorbic acid. Vegetables supplied the majority of ascorbic acid intake in all regions of the country. When broken down by quartile of intake among counties, vegetables supplied the majority of ascorbic acid intake in the top three quartiles. However, tubers contributed the most to ascorbic acid intake among counties in the bottom quartile of intake.

Food	Contribution to ascorbic acid intake, percent
Sweet potatoes	37.2
Cabbages	23.9
Leafy green vegetables other than cabbages*	10.6
Radishes	8.8
Hot peppers	6.5
Beans	2.3
Sweet peppers	1.8
Rutabagas	1.0
All others	7.9

*Primarily mustard greens, kale and spinach.

Although there was a large variety of foods consumed

among counties, within each county the diet was relatively homogeneous. An average of only 10 plant foods was consumed in each county, and usually five or less foods contributed at least 85% of ascorbic acid to the diet.

Discussion

Geographic and ethnic differences in food sources influence the macro- and micronutrient composition of the diets of individuals and populations^{18,19}. The food supply in the People's Republic of China is markedly different from that in the US and also varies widely among different regions within the country. The rural Chinese diet derives over 90% of its calories from predominantly unprocessed plant sources²⁰. China has in place a rationing policy for grains, oils and other staples, to help meet the minimal nutritional needs of the people²⁰. However, the major sources of ascorbic acid, ie vegetables and fruits, are not under government control. There is little refrigeration, foods are preserved by salting or fermenting and there is no efficient system for transporting them over long distances. Fruits and vegetables are grown and consumed locally. Consequently, the availability of fresh produce depends upon characteristics of the region in which it is grown. This explains the wide range of ascorbic acid intake among counties, and may explain the low intake among counties in the bottom quartile of intake where vegetables other than sweet potatoes may not be as readily available.

Mean and median intakes among counties in this survey were relatively high, 140 and 128 mg/day, respectively. The 1987-88 US National Food Consumption Survey reported the mean daily intake in the US was 99 mg for adult men and 84 mg for adult women¹². Although these mean intakes exceed the RDA, 40% of adults surveyed consumed less than the RDA²¹. Because of the nature of the current study, ie an ecologic study with data reported as the mean individual intake in each county instead of actual individual intakes, it was not possible to determine the number of subjects with intakes below the Chinese RDA of 60 mg/day²². The RDAs are set high enough to meet or exceed the needs of practically all the population, so individuals below the RDA may not necessarily be deficient in ascorbic acid, but their likelihood of deficiency is increased.

Based on food availability data, fruits contribute 43% of ascorbic acid to the US food supply, including 28% from citrus fruits, while vegetables provide 48%¹³. This compares to the 1% contributed by fruits in rural China. Further comparisons between the US and China can be made by reclassifying data from the second US National Health and Nutrition Examination Survey (NHANES II) according to major food groups. While tubers contributed 38% to the total intake of ascorbic acid in China, they supply only 9% in the US. Similarly, other vegetables contributed 60% in China and only 21% in the US²³.

The specific foods that contribute most to ascorbic acid intake in the US are orange juice (27%); potatoes, including french fries (8%); grapefruit or grapefruit juice (7%); tomatoes or tomato juice (6%); and fortified fruit drinks (6%). An

average of 16 foods for blacks and 22 foods for whites contribute 85% of the ascorbic acid intake²⁴. This compares to five or less foods that contributed the same proportion among the Chinese counties in this study.

The US diet contains ascorbic acid from sources other than foods. Ascorbic acid supplements are consumed by 8% of the US population, while multi-vitamins containing ascorbic acid are consumed by 17%²⁵. In one survey of supplement users, ascorbic acid was the most commonly used supplement, consumed by 91% of vitamin users²⁶. Based on this, ascorbic acid supplements may contribute a significant amount of ascorbic acid to the total US intake. However, supplement users tend to have higher intakes of ascorbic acid from food sources compared to non-users, suggesting that those most likely to take supplements are less likely to need them²⁷.

In the US, ascorbic acid is widely used as a food additive, as is erythorbic acid, an epimer of ascorbic acid. Erythorbic acid has antioxidant activity but little or no antiscorbutic activity, although it may exert a slight sparing effect on ascorbic acid²⁸. Conventional analytical methods used to measure ascorbic acid in foods do not distinguish between ascorbic acid and erythorbic acid²⁹. Therefore, overestimation of the ascorbic acid content of processed foods containing erythorbic acid may occur, depending on the methodology used. This is important inasmuch as the amount of ascorbic acid supplied by processed fruits and vegetables in the US increased from 14% after the Second World War to 46% in 1985¹³. Unlike the US foods in rural China are usually consumed in their natural state. Supplements and processed foods containing additives contribute little ascorbic acid to the diet.

Losses during cooking may lower the actual intake of ascorbic acid in both China and the US. The effect of this on the data reported here cannot be estimated, since the Chinese Food Composition Tables used in this study are based on raw foods¹⁷. Regardless, the relative differences among counties, although slightly attenuated, should be preserved.

Although the intake values reported here for China are compared with values for the US, caution should be exercised when interpreting these data because of differences in survey methods used. In addition, seasonal conditions may contribute to variability in the amount and sources of ascorbic acid intake.

As demonstrated by this data, a dietary pattern composed of predominantly plant products can provide a large quantity of ascorbic acid when fresh produce is available. It is somewhat ironic that the diet in certain urban areas of China is becoming 'westernized', with the encouragement of the Chinese Government, through the introduction of more animal products and a corresponding decrease in plant sources of food²². It will be important to monitor trends in the intake of ascorbic acid and other nutrients if these changes occur, and to correlate them with changes in health status.

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抗壞血酸在中國的食物來源和攝取

摘要

研究不同營養素攝取和測定最佳健康的攝取水平在表示食物與疾病的關係可能是重要的，作者在中華人民共和國 64 個農村縣用生態的研究檢測了抗壞血酸的食物來源和攝取，並與美國報告的數據相比較。所有縣攝取抗壞血酸的平均數（±標準誤）和中數每日分別為 140（±88 毫克）和 128 毫克（範圍是 8-429 毫克/日）。美國成人男子平均每日為 99 毫克，而成人女子平均每日為 84 毫克。供應最多抗壞血酸的食物是甘薯（37.2%）、白菜（23.9%）、綠葉蔬菜（10.6%）、小蘿白（8.8%）和辣的胡椒（6.5%），與美國相反，他們從水果供應 43% 的抗壞血酸，而中國農村，水果僅供應少量的抗壞血酸（1%），由於食用蔬菜的新鮮程度不同，因而不同縣攝取抗壞血酸差異範圍很大。此外，中國飲食中有大量植物性食物（約 90%），特別是薯類和其它蔬菜，因而平均每人每日抗壞血酸攝入量也較美國多。